ABUNDANCE AND SURVIVAL OF JUVENILE CHINOOK SALMON IN THE SACRAMENTO-SAN JOAQUIN ESTUARY

2001-2005 ANNUAL PROGRESS REPORT
STOCKTON FISH AND WILDLIFE OFFICE
U.S. FISH AND WILDLIFE SERVICE
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Interagency Ecological Program

Cooperative Ecological Investigations Since 1970

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Cover photo: DJFMP field staff conduct a Kodiak trawl at Mossdale on the San Joaquin River (Credit: Heather Webb).

Acknowledgments

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We extend particular gratitude to the many biological science field technicians and boat operators that spent countless hours under all environmental conditions to collect data.

Table of Acronyms
The following acronyms have been used in the following text:

AFRP – Anadromous Fish Restoration Program
CDEC – California Data Exchange
CDFG – California Department of Fish & Game
cfs – Cubic feet per second
CNFH – Coleman National Fish Hatchery
CPUE – Catch per unit effort
CVP – Central Valley Project
CVPIA – Central Valley Project Improvement Act
CWT – Coded wire tag
DJFMP – Delta Juvenile Fish Monitoring Program
DWR – California Department of Water Resources
FL – Fork length
HORB – Head of Old River Barrier
IEP – Interagency Ecological Program
KDTR – Kodiak trawl
MWTR – Midwater trawl
NMFS – National Marine Fisheries Service
NRSI – Natural Resource Scientists, Inc.
PSMFC – Pacific States Marine Fisheries Commission
RBDD – Red Bluff Diversion Dam
rm – River mile
RMPC – Regional Mark Processing Center
SE – Standard error
SLNWR - Stone Lakes National Wildlife Refuge
STFWO – Stockton Fish & Wildlife Office
SWP – State Water Project
USFWS – United States Fish & Wildlife Office
VAMP – Vernalis Adaptive Management Program
WQCP – Water Quality Control Plan

Introduction

The Delta Juvenile Fish Monitoring Program (DJFMP) at the Stockton Fish and Wildlife Office (STFWO) has been monitoring populations of juvenile Chinook salmon *(Oncorhynchus tshawytscha)* in the lower Sacramento River and Delta since the 1970s. The program and its goals have evolved since then based on water management actions and endangered species listings. Prior to 1982, the program focused on monitoring juvenile salmon relative abundance and determining how reduced river flows would affect the survival of young salmon. After 1982 (the defeat of the Peripheral Canal proposal), part of the focus was changed to evaluate the impact of through-Delta water conveyance on juvenile salmon survival. The greatest change in the program occurred in 1992-1993 in response to the Federal Endangered Species listing of winter-run salmon. The Sacramento River winter-run race was listed by the state as "endangered" in May 1989 (California Code of Regulations, Title XIV, section 670.5, Filed 22 September 1989), and federally listed as "endangered" by the National Marine Fisheries Service (NMFS) in February 1994 (59 FR 440). The listing encouraged the Bureau of Reclamation to fund salmon monitoring in the lower Sacramento River and Delta between September 1 and May 31 of each year. Other listings of salmonids in the Central Valley followed. In 1998, the Central Valley steelhead was federally listed as threatened. Spring-run Chinook salmon was listed as threatened by the State of California in February 1999 and federally listed in November 1999. The DJFMP program responded by creating a sampling program that operates throughout the year at the entry (Sacramento and Mossdale) and exit (Chipps Island) points of the Delta and in areas where the fish reside (lower Sacramento and San Joaquin Rivers, Delta, and Bay).

Annual reports have been written for each year to document sampling effort and summarize findings and are available from the STFWO.

The DJFMP historically monitored populations of juveniles from all fish species. This report will focus on Chinook salmon, and includes a section on a special study conducted at Liberty Island that focused on the life stages of all fish species utilizing the flooded island habitat.

Work in 2001-2005 was conducted to update and refine our knowledge of the factors influencing juvenile salmon relative abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. Field sampling and special studies for each "field season" were conducted between August 1 of the previous year and July 31 of the following year, as juveniles reared and migrated through the lower Sacramento and San Joaquin Rivers, Delta, and Bay.

Two objectives of the 2001-2005 field seasons were:

1. Monitor relative abundance, distribution, and timing of juvenile Chinook salmon rearing and migrating through the lower Sacramento and San Joaquin Rivers, the Delta, and portions of San Pablo and San Francisco Bays; and

2. Determine relative survival (using fall and late-fall hatchery smolts) of juvenile salmon released in the upper river and Delta, and identify potential factors influencing survival.

Midwater trawling, Kodiak trawling, and beach seining were employed at varying times and locations in the Delta, lower Sacramento and San Joaquin Rivers, and parts of San Pablo and San Francisco Bays. Different sized juveniles of Chinook salmon presumably have distinct spatial and temporal distributions making them vulnerable to different gear types.

Race Delineation

The STFWO conducts one of several salmon monitoring programs within the Central Valley that use size and date of capture to estimate race of juvenile Chinook salmon in the lower Sacramento River and Delta. The size criterion was developed by Frank Fisher (Fisher 1992), of CDFG in 1992 as a weekly model of Chinook salmon growth and later modified to a daily criterion by Sheila Greene of California Department of Water Resources. At this time, it is the only tool used to by DJFMP determine race of juvenile salmon in the field. However, several problems exist regarding the validity of the size at date criterion and these problems have been discussed in past reports (United States Fish and Wildlife Service 1995). For these reasons, the race designations used in this report should be used only as a rough approximation and not interpreted as definitive. Research on various markers for genetic differentiation of races is ongoing and may help determine true race of Central Valley salmon juveniles sampled in the future (e.g., Hedgecock et al. 2001, Greig et al. 2003).

In this report, spring- and fall-run races were combined into a “spring/fall-run” group due to the close overlap in size and emigration timing of these two races. The exception to this is during the Sacramento area beach seines when the goal is to target less common races, the spring-run sized salmon are separated from the fall-run size salmon, and only spring-run salmon are reported. Spring-run yearlings originating from Deer or Mill Creeks are likely categorized as late fall- or winter-run based on size criteria.

Late fall-run salmon enter the Delta on their way to the Pacific Ocean either as fry in spring and summer or as smolts/yearlings in fall and winter. These different life history characteristics within a brood year cause catches from multiple brood years to occur in one field year (August-July). As a result, in addition to total late fall-run catch, we report individuals from each brood year class for late fall-run fish.

Life Stage Delineation

Salmon are classified in the field as sac fry, fry, parr, silvery parr, smolt, and adult life stages based on external characteristics, including the presence or absence of an external yolk sac, visible parr marks, or deciduous scales. However, for this report, we used fork length as a rough estimate of life stage as a simplified classification scheme. We defined fry as ≤70 mm fork length (FL). Juveniles that were >70 mm (FL) were defined as smolts because this is the approximate length at which they begin undergoing behavioral and physiological changes in preparation for transition to salt

water. However, because designation of life stages of juvenile Chinook depends primarily on the physiological state of a fish, fork length does not always define life stage. Therefore, life stage designation in this report should be interpreted only as a rough approximation.

Escapement

To help understand patterns in abundance of juvenile salmon populations in the Delta, it is useful to view patterns in adults returning upstream to spawn for each race. These data were obtained by referencing Grand Tab, a Microsoft Excel spreadsheet that contains estimates of all races of Chinook salmon returning to a variety of locations within the Delta, commonly referred to as "escapement." Grand Tab is regularly maintained and updated annually by CDFG, Inland Fisheries Division, Red Bluff. In particular, we focused on fish passing the Red Bluff Diversion Dam (RBDD) in the upper Sacramento River, returning to the Coleman National Fish Hatchery (CNFH), and other notable locations (Feather River, American River, and the combination of Stanislaus, Tuolumne, and Merced Rivers). The Feather and American Rivers were chosen because they empty into the Sacramento River downstream of the RBDD and generally support large spawning populations of fall-run Chinook salmon. The Stanislaus, Tuolumne, and Merced Rivers were chosen because, when combined, they represent the major tributaries of the lower San Joaquin River.

In order to obtain accurate escapement estimates at the RBDD, the gates must be in the closed position. Since 1993, this has not occurred during the late fall upstream migration (Oct. – Apr.). Gates are used to maximize RBDD diversion capabilities. Regulations established by NMFS in 1993 order that gates can be closed only between May 15 and September 15. To account for the lack of closure during upstream migration, returns to CNFH were used as late fall escapement estimates between 1993 and 1998. Since 1998, carcass surveys have been used to estimate late fall escapement.

Estimates of winter-run salmon returns for each year during 2001-2005 were greater than the previous 19 years (Figure 1a). In 2001, an estimated 8120 fish returned. In 2002, estimated returns decreased slightly to 7360 fish but increased in 2003 to 8133 fish. Although the estimated winter-run returns for 2004 (n = 7784) were slightly less than 2003, the 2005 return estimates (n = 15,730 fish) rose to the third highest since 1978.

Spring-/fall-run salmon estimated returns declined from 2001 to 2005. In 2001, 58,528 fish returned (Figure 1b). In 2002, an estimate of 45,796 fish returned. Estimated returns in 2003 (n = 66,485 fish) were the highest of the reporting period. Estimated returns in 2004 and 2005 were 34,445 and 44,980 fish, respectively, the two lowest estimates since 1998.

Late fall-run salmon estimated returns for 2001 (n = 18,351 fish) and 2002 (n = 36,004 fish) were the third and second highest, respectively, since sampling began in 1978 (Figure 1c). In 2003, the estimates dropped by 85% to 5346 fish. Estimated returns for

late fall-run increased from 2003 to 2004 (n = 8824 fish) and 2005 (n=9565 fish), but were still much lower than those in 2002.

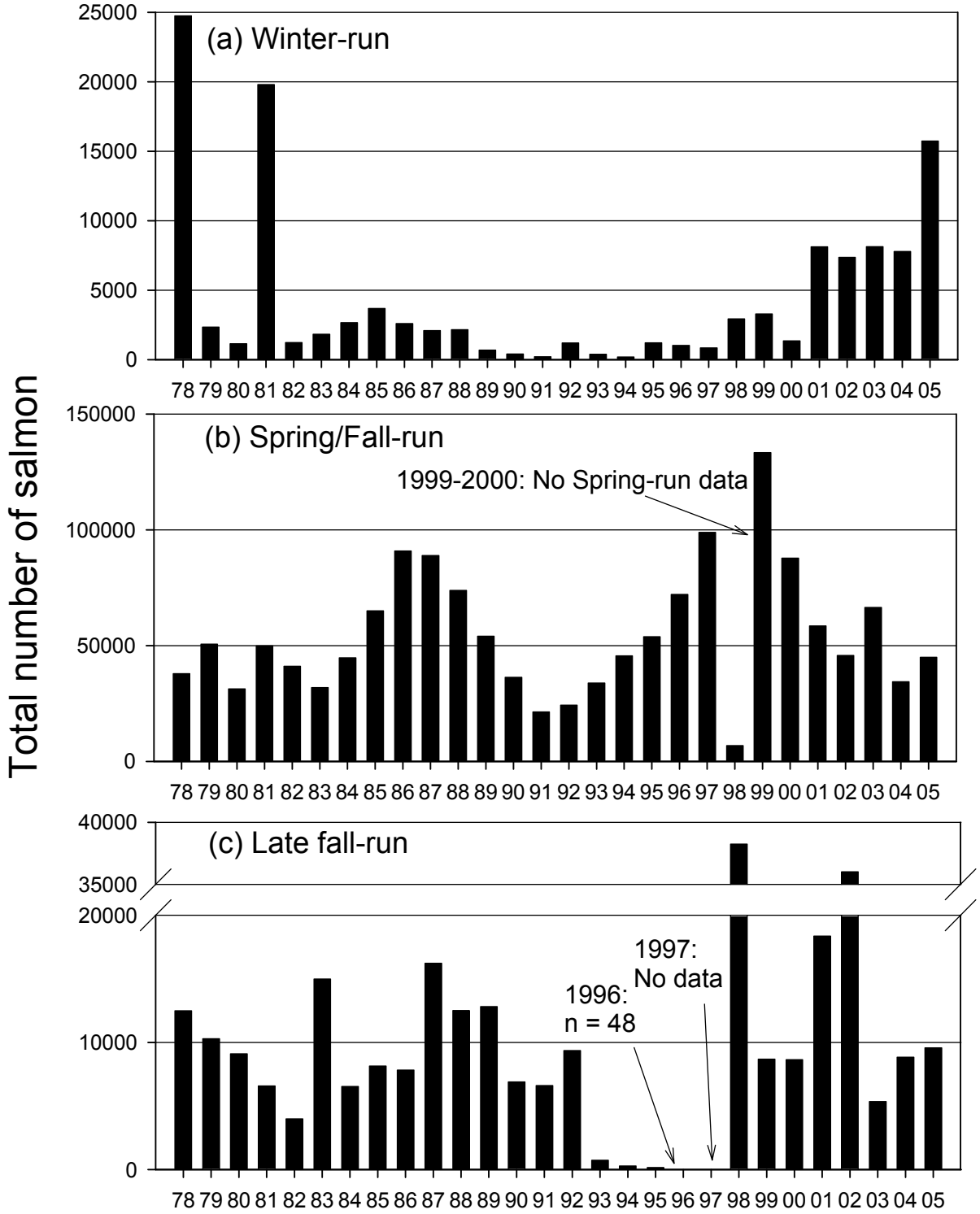

Figure 1. Yearly escapement estimates of adult (a) winter, (b) fall-/spring-, and (c) late fall-run Chinook salmon at the RBDD. Values are the sum of both in-river and hatchery totals. Note change in scale among panels. Source: Grand Tab, CDFG, Inland Fisheries Division, Red Bluff.

Fall-run escapements for 2001 in the Feather and American Rivers were the highest on record (Figure 2). Both escapement estimates exceeded 114,000 fish. Combined spawner population estimates from the Stanislaus, Tuolumne, and Merced Rivers increased since the early 1990's and estimates in 2001 were the second highest since 1985. However, spawner estimates have decreased each of the past four years (2002-2005) at all sites, with the exception of 2003 in the American River.

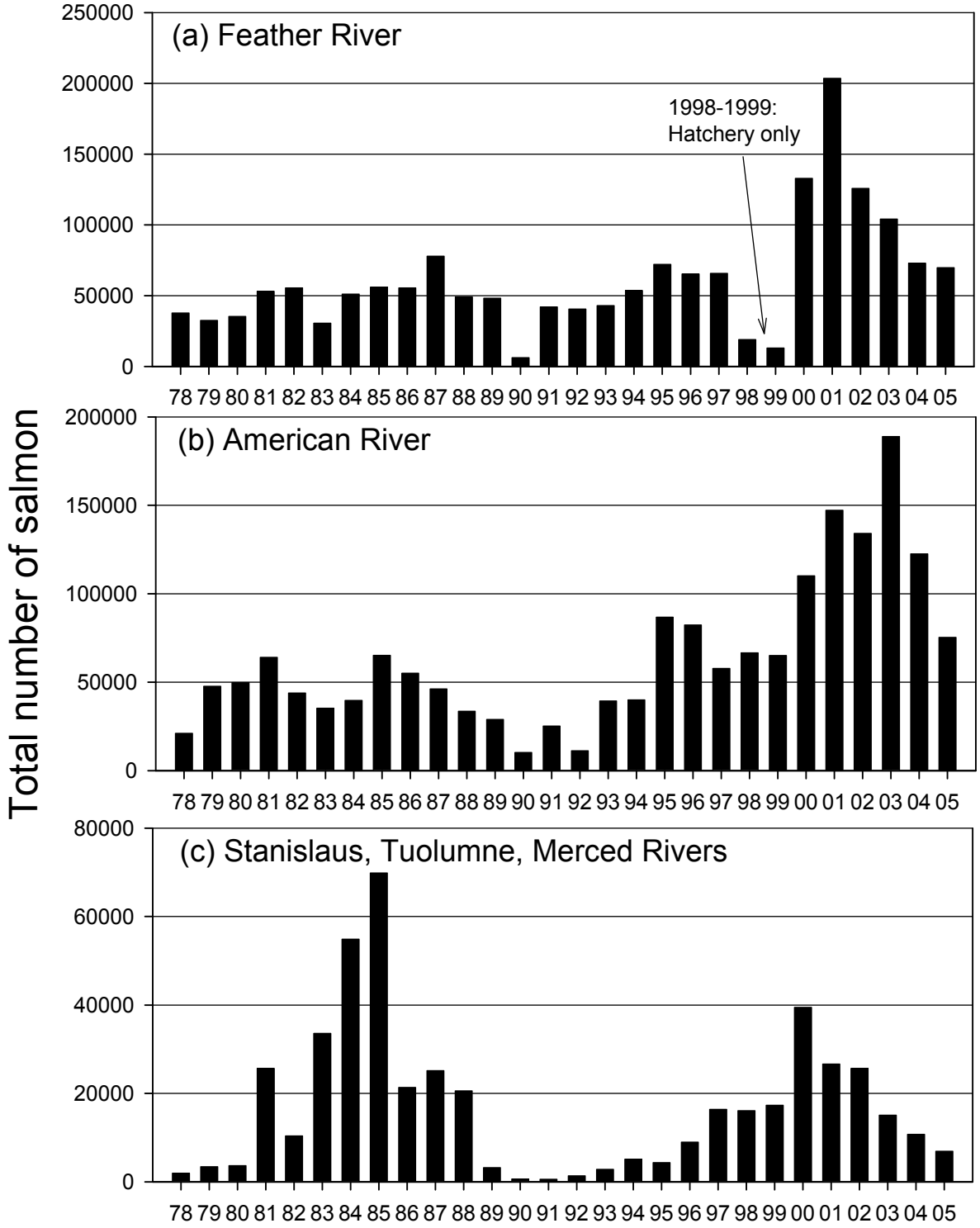

Figure 2. Population estimates of fall-run Chinook salmon spawners between 1978 and 2005 on the (a) Feather and (b) American Rivers, and (c) a combination of the Stanislaus, Tuolumne, and Merced Rivers. Values are the sum of both in-river and hatchery totals. Note change in scale among panels. Source: Grand Tab, CDFG, Inland Fisheries Division, Red Bluff.

Water Conditions

Data for water flow rates were obtained from CDEC (California Department of Water Resources, 2006 http://cdec.water.ca.gov/) and Dayflow (Interagency Ecological Program, 2006 http://www.iep.ca.gov/dayflow/index.html) websites. We calculated mean daily flow rates by month at Colusa, river mile (rm) 144 and Freeport (rm 48) for the lower Sacramento River and at Vernalis (rm 114) for the San Joaquin River (Figure 3). Further, we obtained net Delta outflow estimates as calculated by Dayflow to estimate flow past Chipps Island towards San Francisco Bay (Figure 3).

The 2001 and 2002 water years were classified as dry in both Sacramento and San Joaquin Valleys (CDEC, 2006). In 2003, the Sacramento Valley was classified as above normal, whereas the San Joaquin Valley was classified as below normal. The 2004 water year in the Sacramento Valley was below normal, whereas the San Joaquin Valley was dry. The 2005 water year was classified as above normal in the Sacramento Valley and classified as wet in the San Joaquin Valley.

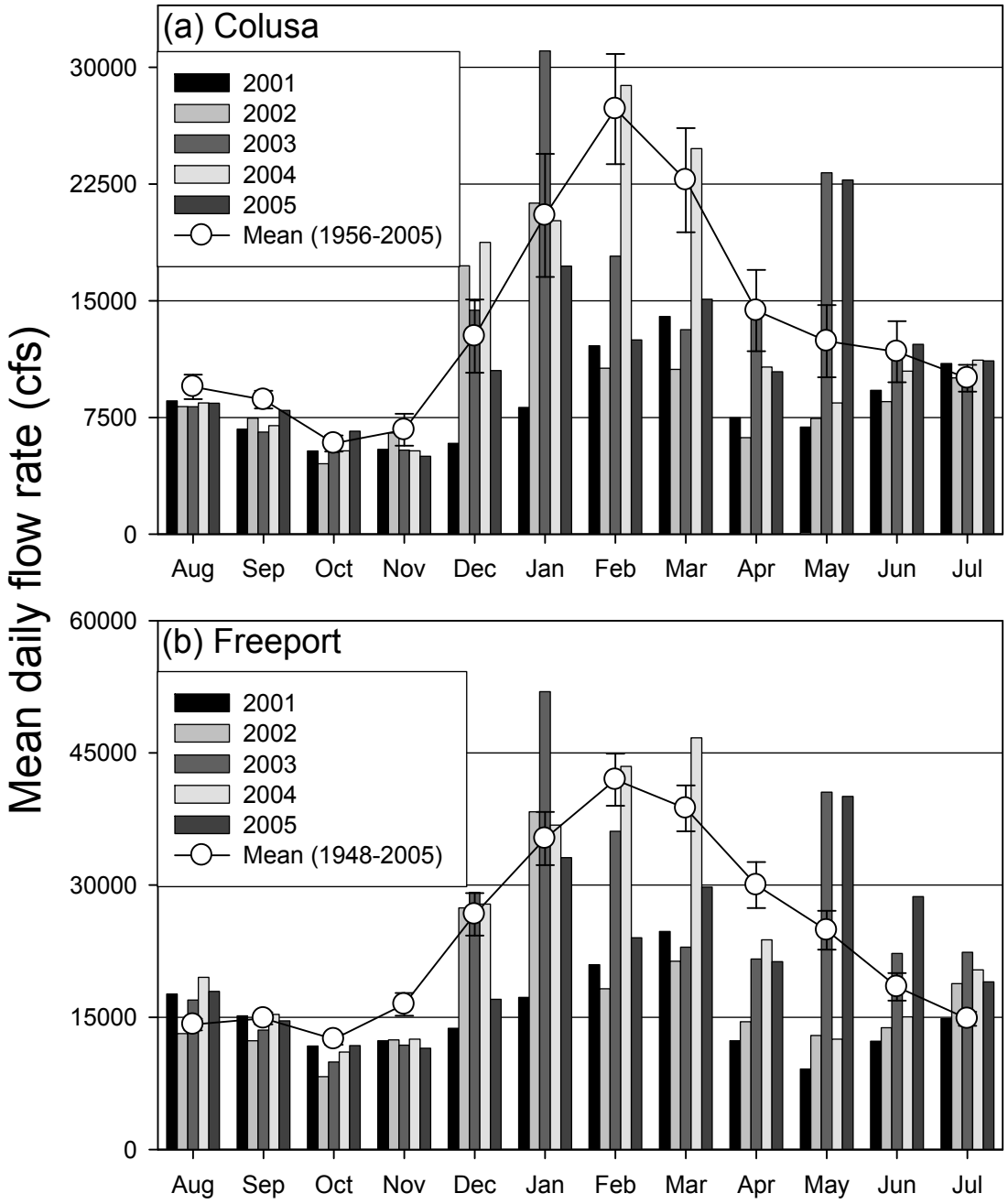

Figure 3. Mean daily flow rate (in cubic feet per second [cfs]) by month for the 2001-2005 field seasons on the lower Sacramento River at (a) Colusa and (b) Freeport, (c) on the San Joaquin River at Vernalis, and (d) total calculated Delta outflow near Chipps Island. Historical means for each site are included for comparative purposes. Error bars are ±1 SE.

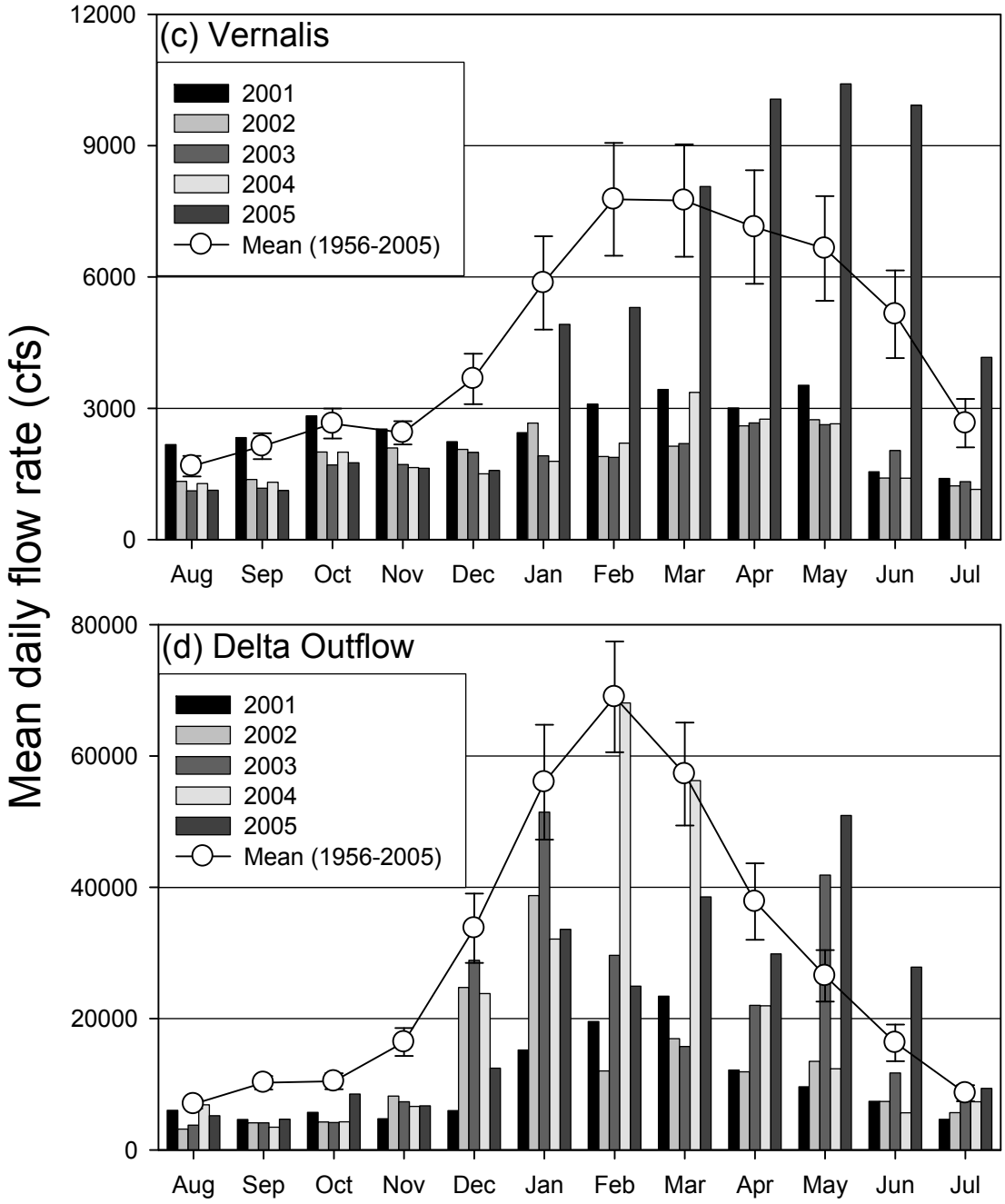
(c) Vernalis
2001
2002
2003
2004
2005
Mean (1956-2005)
12000
9000
6000
3000
0
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Mean daily flow rate (cfs)
(d) Delta Outflow
2001
2002
2003
2004
2005
Mean (1956-2005)
80000
60000
40000
20000
0
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul

Fig. 3 (cont)

General Methods

Monitoring Locations

The majority of sites on the Sacramento River and Delta have been sampled since the mid-1970s by the DJFMP to document the relative abundance of juvenile Chinook salmon among and within years (Table 1; Figure 4). Sites have been added through time as more information has been needed. The sampling area is currently divided into six regions to facilitate data analysis and our understanding of fish abundance and movement throughout the system: (1) Lower Sacramento River (between Colusa and Elkhorn), (2) North Delta (Discovery Park to Antioch on the Sacramento River), (3) Central Delta (between the San Joaquin River and Sacramento River), (4) South Delta (adjacent to and south of the San Joaquin River), (5) San Joaquin River (between Mossdale and the Tuolumne River) and (6) San Francisco/San Pablo Bays (downstream of Pittsburg to Tiburon in San Francisco Bay). Regions were originally established in 1976 as areas where fish movement patterns should be similar and are delineated by locations of canals or water by-passes, where fish may be diverted from historical migration routes.

Additional beach seining is conducted on the Sacramento River in the Sacramento region between October and February to increase our sampling effort for less abundant races of salmon. This region includes sites from Regions 1 and 2 plus three additional sites (Miller Park, Sand Cove, and Sherwood Harbor) and is sampled three times per week. During the remainder of the year, sites at Verona and Elkhorn are grouped with Region 1 and Discovery Park, American River, and Garcia Bend are grouped with Region 2 sampling.

The DJFMP monitors sites that are influenced by water exiting from either the Sacramento or San Joaquin Valleys via the Sacramento and San Joaquin Rivers, respectively. The influence of these two watersheds may cause entirely different water conditions for different sites. Therefore, it is necessary to define the appropriate water year conditions. For ease of interpretation, we consider all sites in the San Joaquin River region to experience San Joaquin Valley water year conditions and all other sites to experience Sacramento Valley water year conditions. In addition, we attempt to relate each region to the closest water flow monitoring site available on CDEC and Dayflow web sites.

Table 1. Sites sampled by the DJFMP during 2001-2005 field seasons organized by region. Station codes refer to body of water (first 2 letters; AR = American River, DS = Disappointment Slough, GS = Georgiana Slough, LP = Little Potato Slough, MK = Mokelumne River, MR = Middle River, MS = Mayberry Slough, OR = Old River, SA = San Francisco Bay, SB = Suisun Bay, SF = South Fork of Mokelumne River, SJ = San Joaquin River, SP=San Pablo Bay, SR = Sacramento River, SS = Steamboat Slough, TM = Three Mile Slough, WD = Werner Dredger Cut, or XC = Delta Cross Channel), river mile (3 digits), and location within site (last letter; N = north, S = south, W = west, E = east, or M = middle). For example, Colusa State Park is on the Sacramento River (SR) at river mile 144 on the west bank (W).

Site	Station Code
Region 1. Lower Sacramento River	
Colusa State Park	SR144W
Elkhorn*	SR071E
Knight's Landing	SR090W
Reels Beach	SR094E
South Meridian	SR130E
Verona*	SR080E
Ward's Landing	SR138E
Region 2. North Delta	
American River*	AM001S
Clarksburg	SR043W
Discovery Park*	SR060E
Garcia Bend*	SR049E
Isleton	SR017E
Koket	SR024E
Rio Vista	SR014W
Sherman Island	MS001N
Steamboat Slough (mouth)	SS011N
Stump Beach	SR012E
Region 3. Central Delta	
Antioch Dunes	SJ001S
B&W Marina	MK004W
Brannan Island	TM001N
Delta Cross Channel	XC001N
Eddo's	SJ005N
Georgiana Slough	GS010E
King's Island	DS002S
Terminous	LP003E
Wimpy's	SF014E
Sacramento Seine (additional sites)	
Sherwood Harbor	SR055E
Sand Cove	SR062E
Miller Park	SR057E

Site	Station Code
Region 4. South Delta	
Cruiser Haven	OR014W
Dad's Point	SJ041N
Dos Reis	SJ051E
Frank's Tract	OR003W
Lost Isle	SJ032S
Old River	OR019E
Union Island	OR023E
Veale Tract	WD002W
Venice Island	SJ026N
Woodward Island	MR010W
Region 5. San Joaquin River	
Big Beach	SJ063W
Durham Site	SJ068W
Mossdale	SJ056E
N. of Tuolumne River	SJ083W
Route 132	SJ077E
Sturgeon Bend	SJ074W
Wetherbee	SJ058W
Region 6. Bay	
Berkeley Frontage Rd	SA007E
China Camp	SP001W
Keller Beach	SA009E
McNear's Beach	SP000W
Paradise Beach	SA008W
Point Molate	SP000E
Point Pinole East	SP003E
San Quentin Beach	SA010W
Tiburon Beach	SA004W
Treasure Island	SA001M
Trawls	
Chipps Island	SB018M,N,& S
Mossdale	SJ054M
Sacramento	SR055M

*Indicates site switched to Sacramento Seine region during periods with more intense sampling (3 days per week, Oct – Jan.).

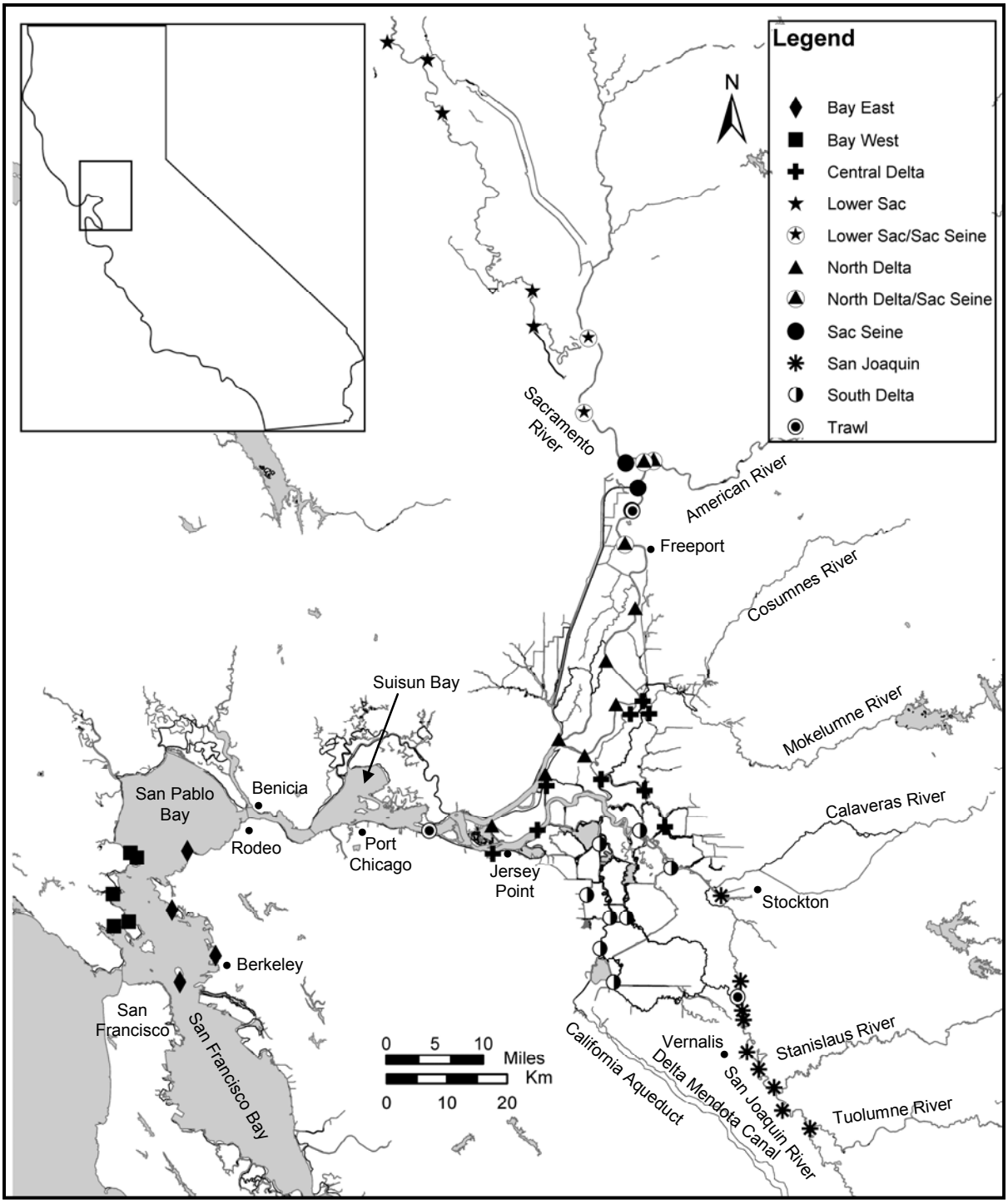

Figure 4. Trawl and beach seine sites for the 2001-2005 field seasons. Regions are designated as: (1) lower Sacramento, (2) North Delta, (3) Central Delta, (4) South Delta, (5) lower San Joaquin River, and (6) San Francisco/San Pablo Bay.

Monitoring Methods
We employed three field sampling methodologies for fish collection depending on site, purpose, and time of year: beach seine, midwater trawl, and Kodiak trawl.

Beach Seine
The purpose of conducting beach seining is to estimate the relative abundance of shallow, near shore benthic and pelagic juvenile fish populations. All seining is conducted using a 15 m x 1.2 m (50' x 4') beach seine with 3 mm (1/8") delta square mesh and a 1.2 m (4') bag. One seine haul is conducted at each site. Seine site substrata include pavement, sand, mud, or vegetation. Substrate at a given site may change throughout the year depending on river flow, river stage, and tide. Sites are accessed by either vehicle or small vessel.

To retain validity of year to year comparisons, our goal is to seine established historical sites. In this dynamic system, occasional changes in flow, habitat, or environmental conditions prevent sampling or make it necessary to temporarily relocate sites. If new sites are needed, we attempt to relocate to an area within 100 yards of the original location containing similar habitat characteristics (i.e., substrate, vegetation). In rare cases, sites have been permanently relocated or removed completely because of more permanent issues (i.e., thick vegetation inundated the site). More information on sample site relocations or other sampling modifications can be found at www.iep.ca.gov/metedata/dbms/trawls/usfws.pdf.

Before comparisons in fish abundance and timing within and among years can be made, catches are corrected for effort by standardizing to catch per unit effort (CPUE; in m^3) using the following equation:

$$Seine\ \ CPUE = \frac{Catch}{\frac{1}{2} Depth \times Width \times Length} \qquad (1)$$

Effort is measured by volume of water sampled. Our measure of depth is the mean value of depth measured at the two deep corners (Fig. 5). By assuming a constant slope from shore to the corners where depth measurements were taken, we calculate the volume of the wedge of water sampled and, thus, use ½ x depth in calculations.

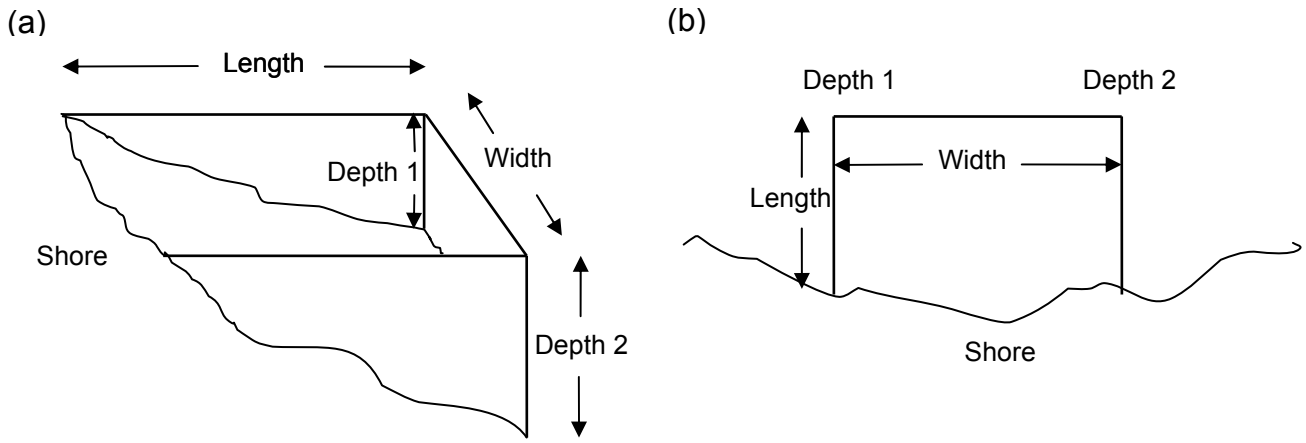

Figure 5. Schematic diagram of beach seine measurements: (a) three-dimensional view, (b) top view.

Mean CPUE calculations for beach seines
In all calculations, races of salmon (Winter, Late Fall, and Fall/Spring) and regions were treated separately. Data from North, Central, and South Delta regions were combined into a single "Delta" region.

Because the number and location of sites sampled within a region varied within and among years, it is difficult to compare CPUE of a region through time. However, we attempted to ameliorate this issue through a variety of methods.

First, because sampling at each site was attempted once per week (defined here as Sunday-Saturday), we used weekly means as replicates. We first calculated mean weekly CPUE for each site within a region. If a site was sampled only once in a given week, mean CPUE is identical to actual CPUE for that week. Therefore, this technique eliminates overweighting sites that were sampled more than once a week.

Next, we calculated the mean of mean weekly CPUE of all sites within a region for each week. This value represents mean CPUE for all sites combined within each region in weekly intervals. In this calculation, weekly mean CPUE for each site is treated as a sub-sample and regional weekly mean CPUE is treated as the replicate. We plotted these values through time and compared them to previous years.

We also calculated mean CPUE by month for table presentation. In this case, we first calculated mean CPUE by month of each site separately, as we did for mean daily CPUE by week above. Next, we calculated the mean of mean monthly CPUE of all sites within a region for each month separately. These monthly mean CPUE values were then compared to historical monthly mean CPUE for each region separately.

Midwater trawl

Midwater trawls (MWTR) are conducted to estimate the relative abundance of fish in the top of the water column. Different sized MWTR nets are used depending on the site. Although called a “midwater trawl,” the net is actually towed in the top few meters of the water column.

The MWTR net used at Sacramento is composed of six panels, each decreasing in mesh size towards the cod end (Figure 7). Mesh size ranges from 20.3 cm (8”) stretch at the mouth to 1.3 cm (½”) stretch just before the cod end. The cod end is composed of 0.7 cm (1/8”) weave mesh. Fully extended mouth size is 1.83 x 4.57 m (6' x 15'). Depressors are made of 0.7 cm (¼”) stainless steel (one on each side of the net lead line) and are attached to the net with shackles to spread the bottom line of the mouth of the net. Hydrofoils are made of 0.7 cm (¼”) aluminum plate with split seine floats and spread the top of the net at the surface and are attached to the float line of the net with shackles. On each side, the depressor and hydrofoil are connected to the boat using two 30.5 m (100’) Amsteel rope bridles (0.6 cm diameter). Bridles are attached to 61 m (200’) Amsteel rope backing (1 cm diameter) using 0.8 cm (5/16”) stainless steel quick links. The net is fished 33 m (108’) behind the boat. Actual fishing dimensions of the net vary with environmental conditions, as described previously (USFWS 1993).

A larger MWTR net is used at Chipps Island (Figure 7). It is similar in construction to the MWTR net used at Sacramento and has a mouth dimension of 3 x 9 m (10 x 30'). There are six panels, each with decreasing mesh size towards the cod end. Mesh size ranges from 10.2 cm (4”) stretch at the mouth to 1.3 cm (½”) stretch just before the cod end. The cod end is composed of 0.8 cm (5/16“) knotless material. The 0.8 cm cod end was used for the entire five year period except when a net was repaired unknowingly with a 0.6 cm cod end size. This net was used from Jan 18, 2001 to Jun 17, 2001. This change in cod end mesh size was not analyzed in this report. Depressors and hydrofoils are appropriately larger and were connected identically to those on the Sacramento MWTR. The net is fished 46 m (150’) behind the boat (100’ bridle and 50’ backing).

Catch per unit effort (CPUE; in m^3) of the MWTR was calculated as:

$$CPUE = \frac{catch\ per\ tow}{net\ mouth\ area\ x\ distance\ traveled} \qquad (2)$$

Because MWTR nets do not open completely while under tow and net mouth dimensions vary within and among tows, we used previously quantified estimates of mean net mouth area (Sacramento: 5.08 m^2, Chipps Island: 18.58 m^2; USFWS 1993). Distance traveled in the water was recorded with a General Oceanics mechanical flow meter (Model #2030). This measure of distance is not related to distance traveled relative to land, which can be affected by river flow rate and direction.

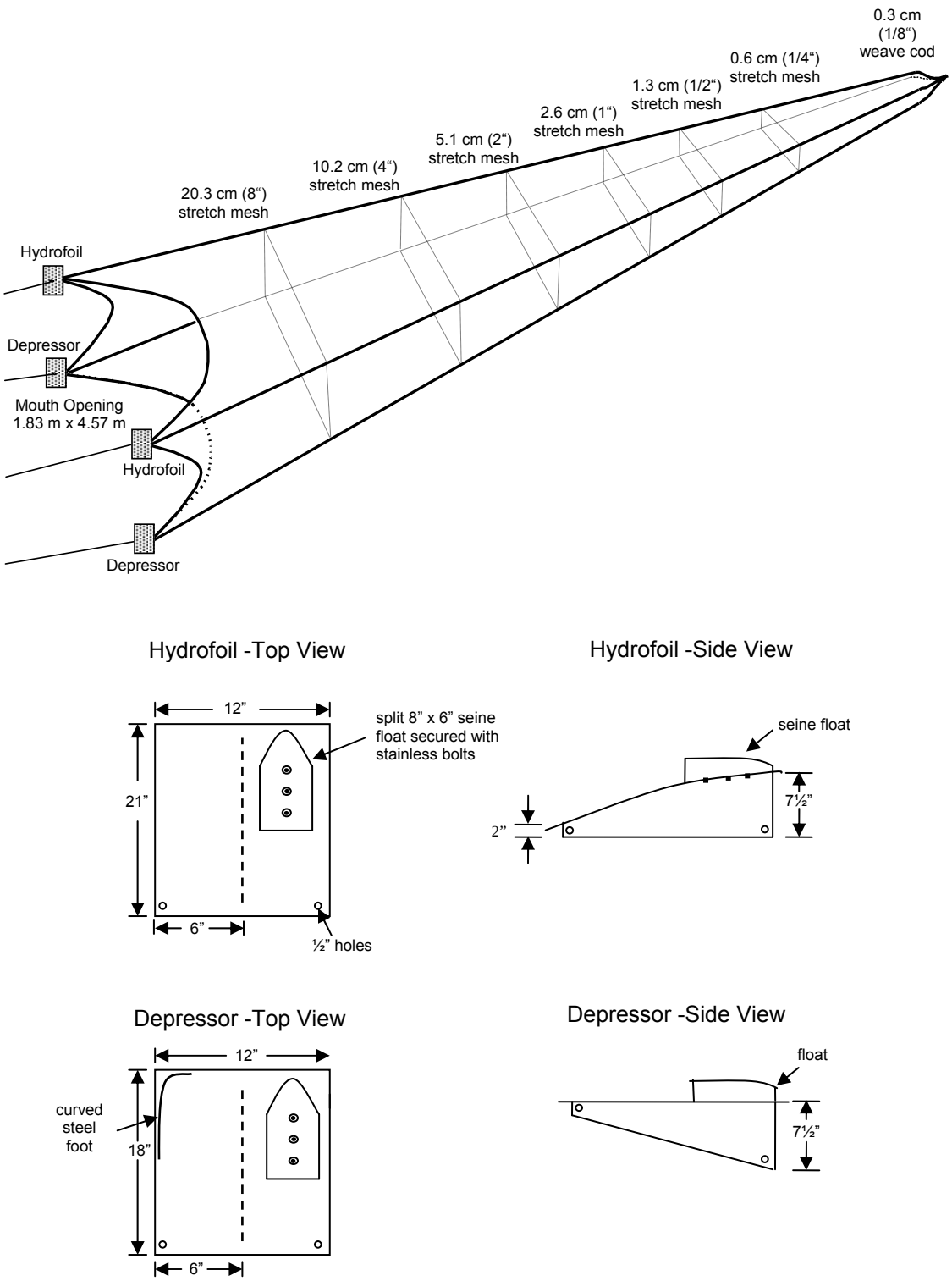

Figure 6. Schematic drawing of midwater trawl net (top), and hydrofoils and depressors (bottom) used at Sacramento during 2001-2005 field seasons.

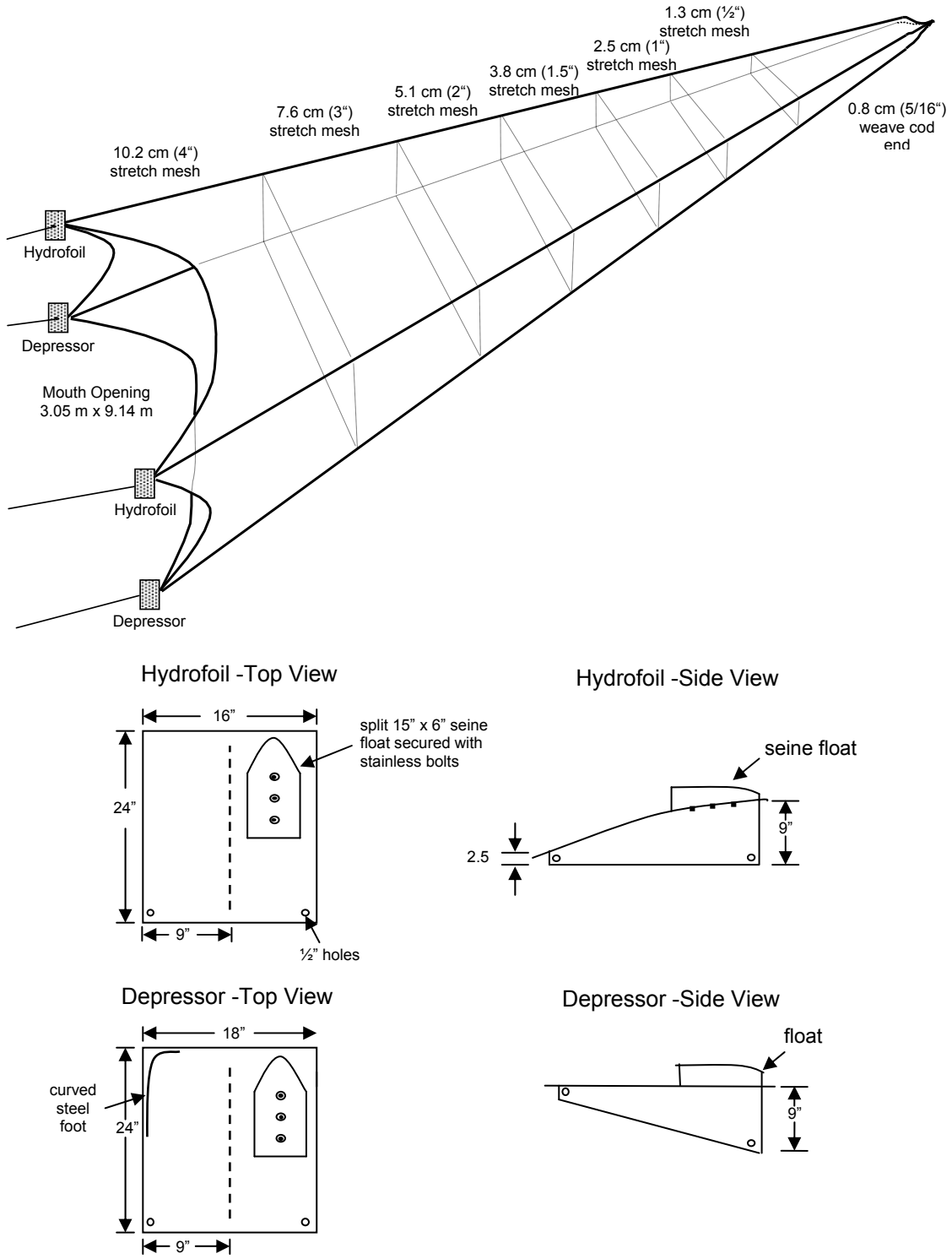

Figure 7. Schematic drawing of midwater trawl net (top) and hydrofoils and depressors (bottom) used at Chipps Island during 2001-2005 field seasons.

Kodiak trawl

A Kodiak trawl (KDTR) net was used at Mossdale and Sacramento to collect pelagic fish in the top 1.83 m of the water column. The KDTR net is larger than the midwater trawl net used in the rivers, allowing for larger volumes of water to be sampled. Nets were made of variable mesh with a fully expanded mouth opening of 1.83 x 7.62 m (6 x 25'; Figure 8). A float line and lead line enable the net to fish the top 1.83 m of the water column. The net is fished 33 m (108') from the boat. At the front of each wing is a 1.83 m bar with floats at the top and weights at the bottom to keep depth constant. An aluminum live box at the cod end minimizes fish mortality. Two boats tow the net through the water, one pulling each wing. At the end of each tow, the boats come together and the trawl line is transferred to one of the boats. The field crew on the other boat retrieves the live box from the cod end of the net and removes fish for processing. Calculations of CPUE for the KDTR employ the same equation as the MWTR (Equation 2), with a mean net mouth area of 12.54 m^2 (USFWS, 1993).

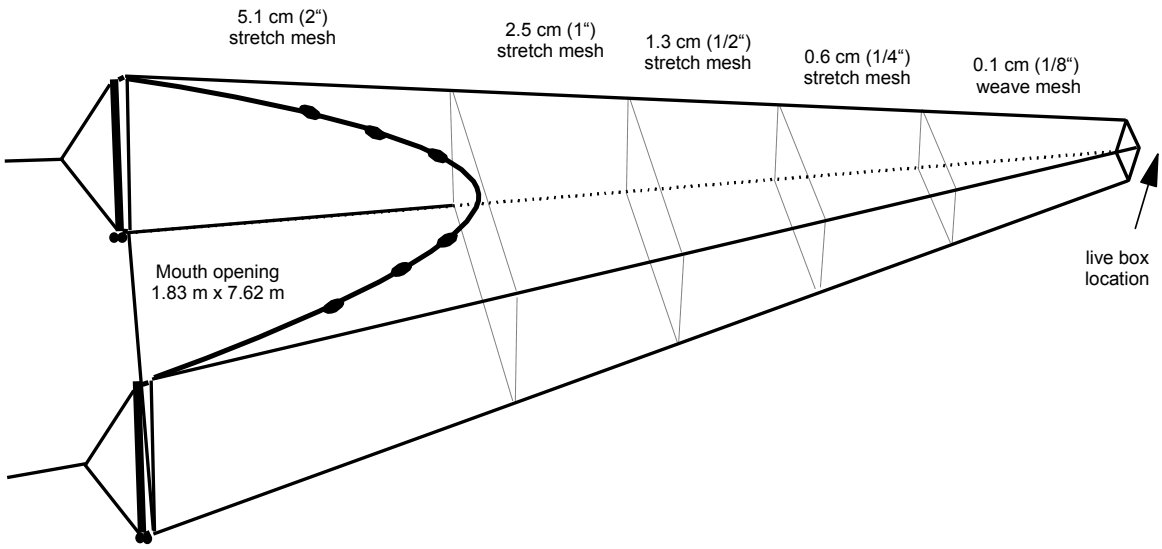

Figure 8. Schematic drawing of Kodiak trawl net used at Sacramento during 2001-2005 field seasons.

Mean CPUE calculations for Kodiak and midwater trawls
In all calculations, races of salmon (Winter, Late Fall, and Spring/Fall) and trawl locations were treated separately. At Sacramento, where we use either a midwater or Kodiak trawl depending on time of year, each gear type is treated separately, although discussed together.

First, we calculated mean daily CPUE for all trawls in a given day (usually 10 trawls). This technique eliminates unequal weighting of sites that were not sampled 10 times per day. Next, we calculated the mean of daily mean CPUE for each week. In this calculation, daily mean CPUE is treated as a sub-sample and regional weekly mean CPUE is treated as the replicate. These values were plotted against historical values by week.

We also calculated mean CPUE by month for table presentation. In this case, we first calculated mean daily CPUE. Then, we calculated mean of mean daily CPUE by month of each site separately, as we did for mean daily CPUE by week above. These monthly mean CPUE values were then compared to historical monthly mean CPUE.

Juvenile Fish Monitoring by Gear Type and Region

Region 1. Lower Sacramento River Beach Seine

Methods
Beach seining was conducted at five to eight sites per week from 8/1-7/31 for each field season during 2001-2005 to estimate densities of juvenile Chinook salmon in the lower Sacramento River. Sites were sampled one to two times per week, with more extensive sampling occurring between 10/31-1/31 of each field season, when winter-run Chinook were likely present in the system. The sampling area extended from Colusa (rm 144) downstream to Elkhorn (rm 71). Sampling substrata included sandy and muddy beaches and paved boat ramps.

Results
In the 2001-2005 field seasons, a total of 1,240 winter-run salmon were captured in the lower Sacramento River beach seines (Figures 9-13). Winter-run salmon were first detected in most field seasons during periods of increased river flows. Nearly all 158 winter-run salmon captured in the 2001 field season were captured between January and February. The second highest mean monthly CPUE observed since 1993 occurred in January 2001 (Table 2a). A total of 444 winter-run salmon were captured in 2002, the majority of which were captured in November and January. We observed the third highest mean monthly CPUE since 1993 in November 2001. In the 2003 field season, a total of 28 winter-run salmon were captured between December and March. Mean monthly CPUE peaked in December and was the lowest peak mean monthly CPUE since 1994. In 2004, 338 winter-run salmon were captured between November and February. The highest mean monthly CPUE recorded in the past 13 years was

observed in December 2003. Nearly all 272 winter-run salmon captured in the 2005 field season were captured between November and January; mean monthly CPUE peaked in December at the fifth highest since 1993.

Spring-/fall-run salmon were the most abundant races captured in the lower Sacramento River region during the 2001-2005 field seasons (n = 22,649; Figures 9-13). In 2001, we captured 3,898 spring-/fall-run salmon between January and March. The highest monthly CPUE occurred in February (Table 2b), coinciding with a period of increasing flow in the lower Sacramento River. In 2002, there were 5,378 spring-/fall-run salmon captured between December and April. The Highest mean monthly CPUE was observed in January. Lower Sacramento River region beach seines yielded 6,407 spring-/fall-run salmon between December and April of the 2003 field season. The highest monthly mean CPUE occurred in February. In the 2004 field season 7,773 spring-/fall-run salmon were captured between December and April, mean monthly CPUE was the highest at the end of January during a period of decreasing flows between the two peak flow periods. In 2005, nearly all 3,091 spring-/fall-run salmon captured were between December and May. The highest monthly mean CPUE occurred in January.

Late fall-run salmon were the least abundant race captured during 2001-2005 field seasons in the Lower Sacramento beach seines (n = 69 fish; Figures 9-13). Only three late fall-run salmon were caught during the 2001 field season, all three were yearlings from the 2000 brood year. The highest mean monthly CPUE was in November. In the 2002 field season, nine late fall-run salmon were captured between November and December at the on set of increasing flows. All nine were yearlings from the 2001 brood year. Mean monthly CPUE was highest in December. Twenty-one late fall-run salmon were captured in the 2003 field season, two yearlings from the 2002 brood year and 19 late fall fry from the 2003 brood year. The highest mean monthly CPUE occurred in May and was the third highest since 1993. In 2004, a total of 13 late fall-run salmon were captured, 11 yearlings from the 2003 brood year and 2 fry from the 2004 brood year. The highest mean monthly CPUE occurred in December. In the 2005 field season, 24 late fall-run salmon were captured, ten yearlings from the 2004 brood year and 14 fry from the 2005 brood year. The highest mean monthly CPUE in the past 13 years was observed in May (Table 2c).

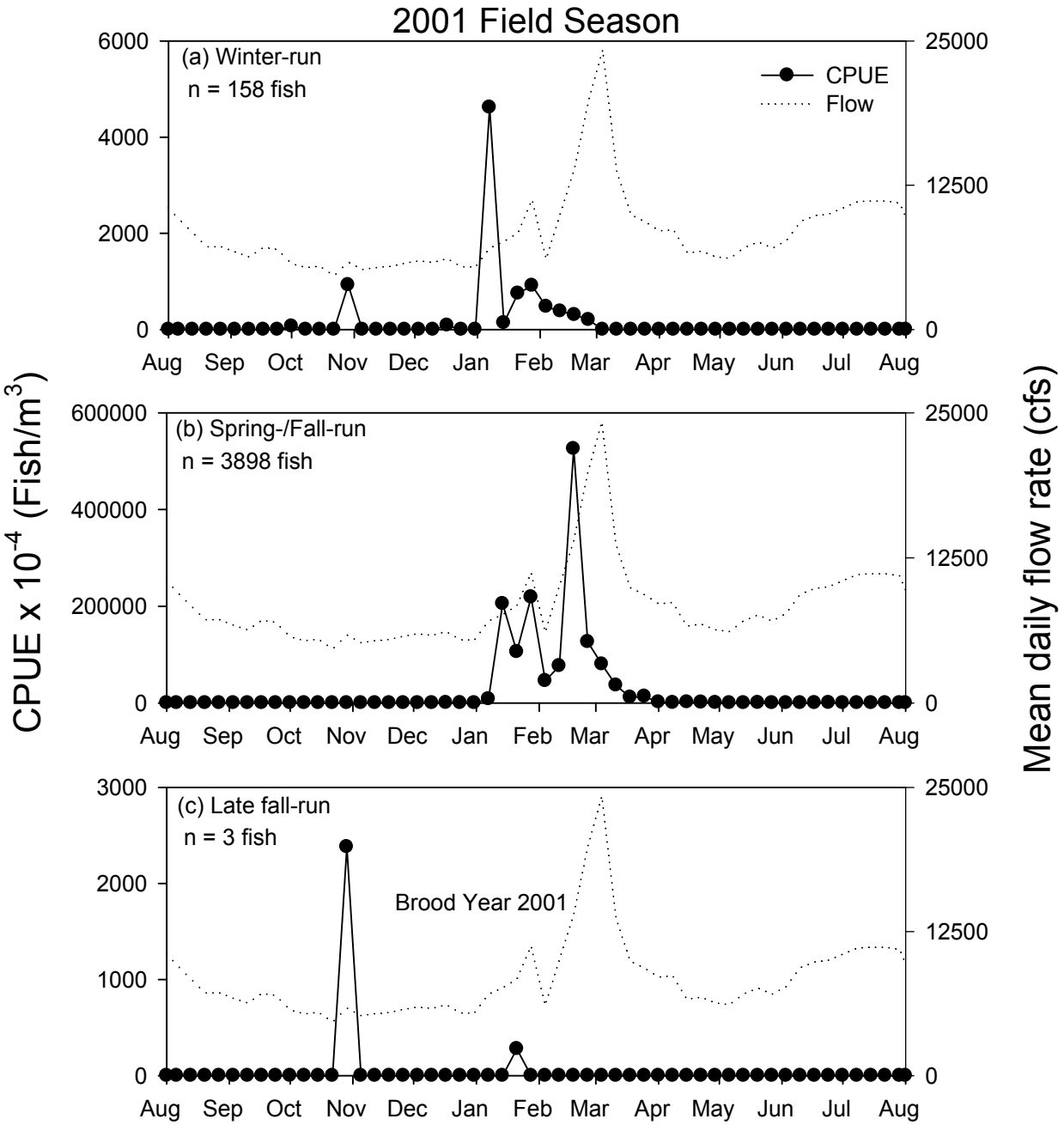

Figure 9. Catch per unit effort (x 10^{-4}) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in beach seines and concurrent mean daily flow rate in the lower Sacramento River region (Region 1) during the 2001 field season. All data were averaged by week, our standard unit of replication for seines. Flow rate was estimated at Colusa in lower Sacramento River. Sample size (n) corresponds to total number of fish caught. Fall- and spring-run salmon were combined because of difficulties in distinguishing between them at this size. Note the change in scale among panels.

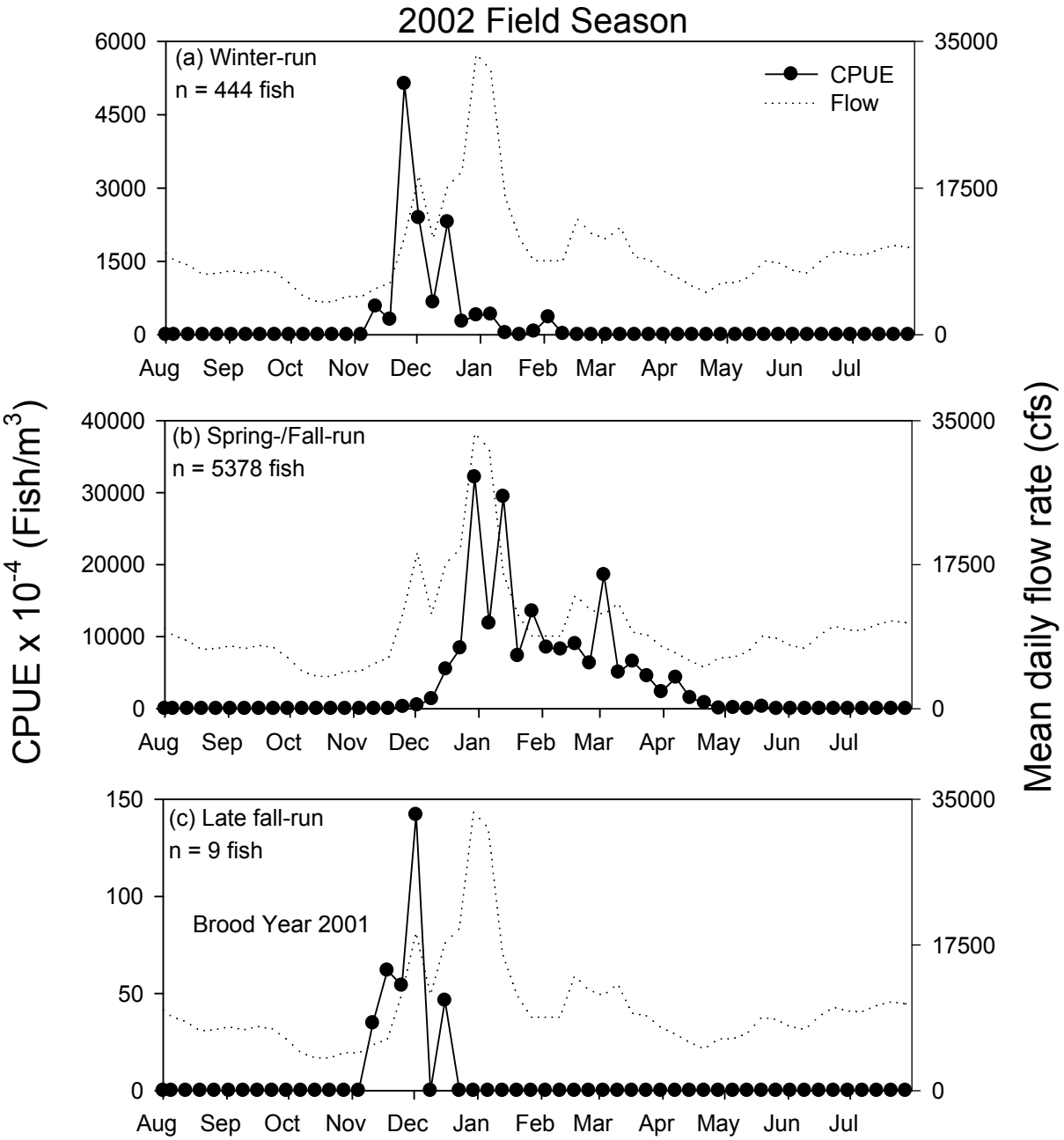

Figure 10. Catch per unit effort (x 10^{-4}) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in beach seines and concurrent mean daily flow rate in the lower Sacramento River region (Region 1) during the 2002 field season. All data were averaged by week, our standard unit of replication for seines. Flow rate was estimated at Colusa in lower Sacramento River. Sample size (n) corresponds to total number of fish caught. Fall- and spring-run salmon were combined because of difficulties in distinguishing between them at this size. Note the change in scale among panels.

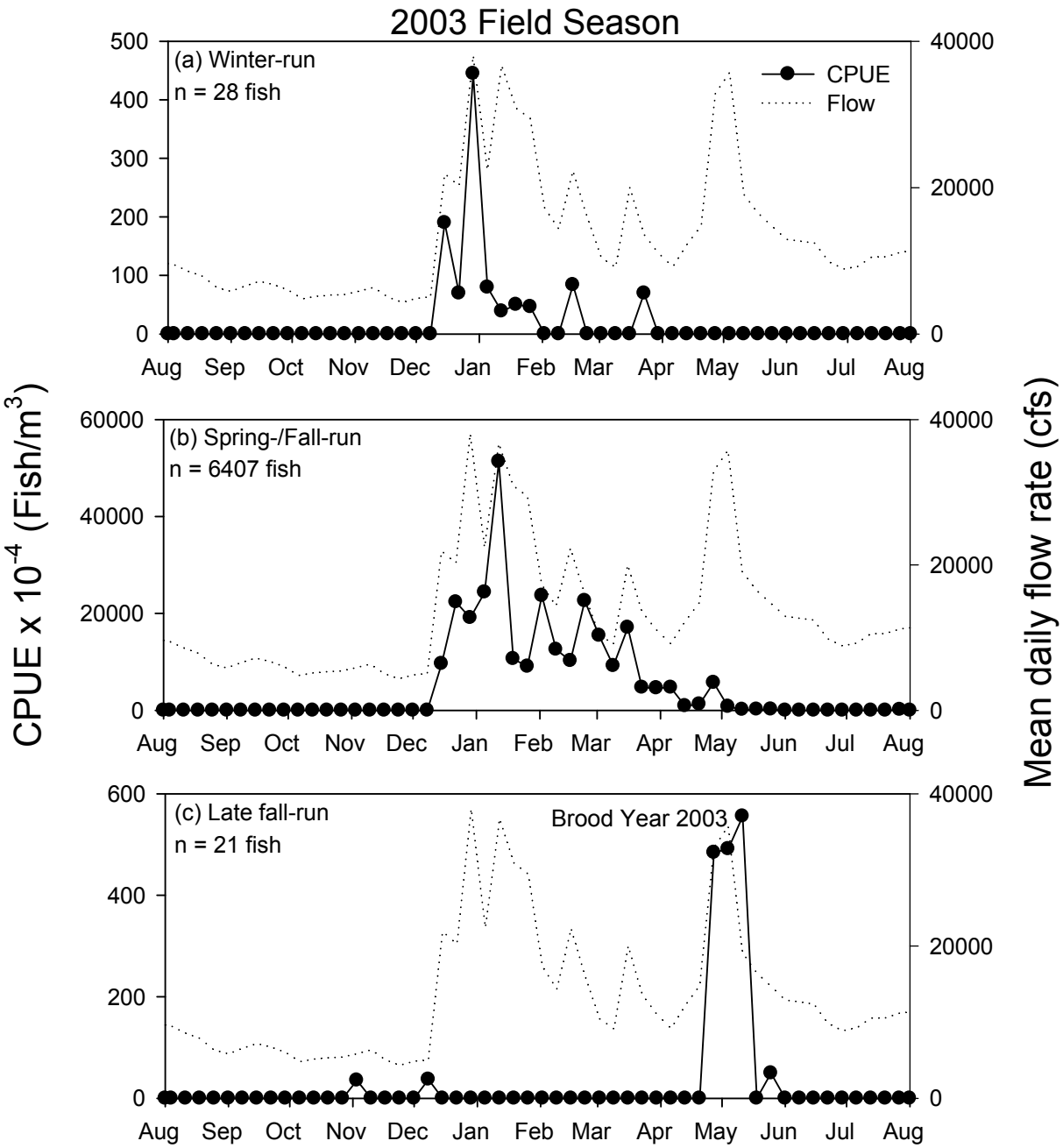

Figure 11. Catch per unit effort (x 10^{-4}) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in beach seines and concurrent mean daily flow rate in the lower Sacramento River region (Region 1) during the 2003 field season. All data were averaged by week, our standard unit of replication for seines. Flow rate was estimated at Colusa in lower Sacramento River. Sample size (n) corresponds to total number of fish caught. Fall- and spring-run salmon were combined because of difficulties in distinguishing between them at this size. Note the change in scale among panels.

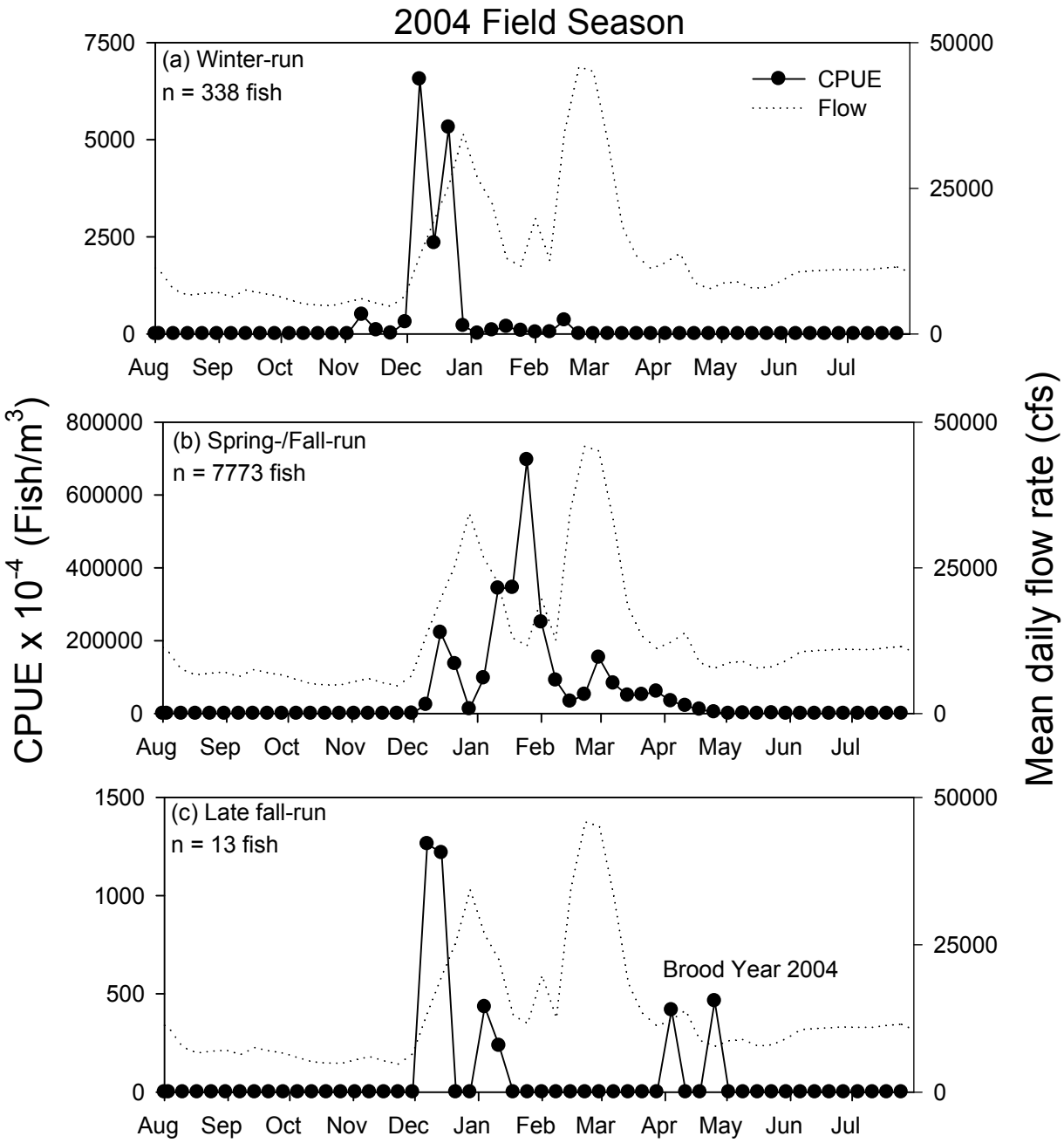

Figure 12. Catch per unit effort (x 10^{-4}) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in beach seines and concurrent mean daily flow rate in the lower Sacramento River region (Region 1) during the 2004 field season. All data were averaged by week, our standard unit of replication for seines. Flow rate was estimated at Colusa in lower Sacramento River. Sample size (n) corresponds to total number of fish caught. Fall- and spring-run salmon were combined because of difficulties in distinguishing between them at this size. Note the change in scale among panels.

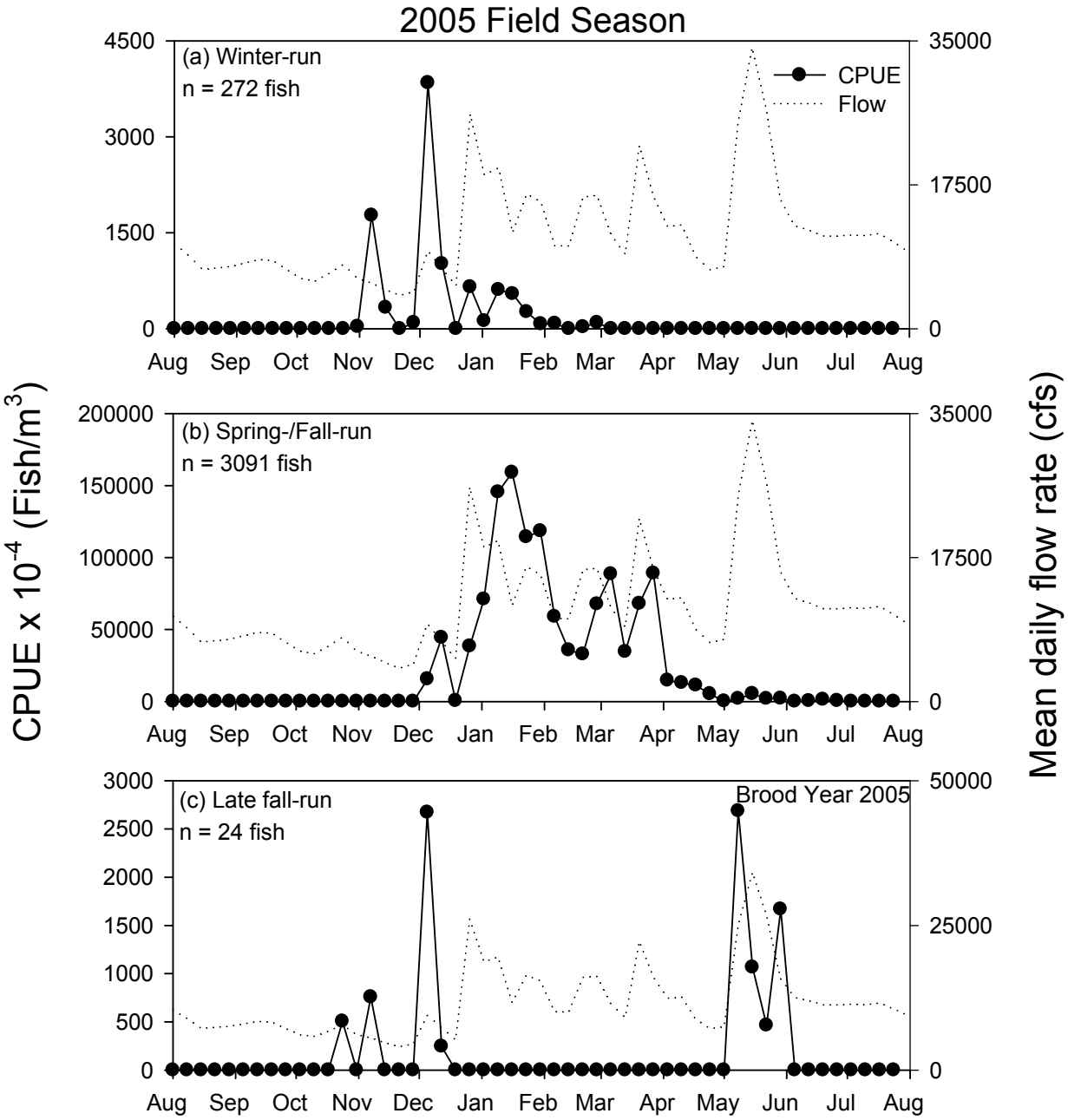

Figure 13. Catch per unit effort (x 10^{-4}) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in beach seines and concurrent mean daily flow rate in the lower Sacramento River region (Region 1) during the 2005 field season. All data were averaged by week, our standard unit of replication for seines. Flow rate was estimated at Colusa in lower Sacramento River. Sample size (n) corresponds to total number of fish caught. Fall- and spring-run salmon were combined because of difficulties in distinguishing between them at this size. Note the change in scale among panels.

Table 2. Summary table of CPUE x 10^{-4} (fish/m^3) of (a) winter-, (b) fall-/spring-run, and (c) late fall-run Chinook salmon in the lower Sacramento River region (Region 1) by month and year. Yearly mean and standard error (SE) values were calculated using years as replicates (n = 7-8). Weekly mean and SE values were calculated using weeks as replicates (n = 44-53). Shaded boxes indicate peak monthly CPUE. Water year (CDEC, 2006): AN = Above normal; C = critical; W = wet

(a) Winter-run

Field Season	Water year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Weekly mean (SE)
1993	AN	--	34.0	0	137	112	227	224	0	0	0	0	0	73.9 (18.9)
1994	C	0	0	1.05	0	4.00	51.2	56.5	0	0	0	0	0	11.2 (6.65)
1995	W	0	0	0	18.5	8.56	156	37.6	49.6	0	0	0	0	17.9 (8.61)
1996	W	0	0	0	0	238	197	45.1	11.6	2.47	0	0	0	42.0 (16.1)
1997	W	0	0	0	0	148	0	38.6	27.0	0	0	0	0	27.6 (12.1)
1998	W	0	0	6.35	352	336	316	0	0	0	0	0	0	76.3 (32.2)
1999	W	0	35.3	0	890	415	294	153	4.96	0	0	0	0	158 (59.3)
2000	AN	0	0	0	3.31	7.26	160	42.8	0	0	0	0	0	15.6 (7.48)
Yearly mean 1993-2000 (SE)		0 (0)	8.66 (5.67)	0.925 (0.786)	175 (111)	159 (56.0)	175 (38.6)	74.7 (26.4)	11.6 (6.36)	0.309 (0.309)	0 (0)	0 (0)	0 (0)	52.8 (17.5)
2001	D	0	0	5.25	238	33.1	1780	267	0	0	0	0	0	167(90.6)
2002	D	0	0	0	1580	1230	190	70.0	0	0	0	0	0	262 (119)
2003	AN	0	0	0	0	64.4	42.0	18.0	9.92	0	0	0	0	21.8 (9.89)
2004	BN	0	0	0	92.2	3050	80.7	75.0	0	0	0	0	0	310 (165)
2005	BN	0	0	0	344	781	338	32.1	13.3	0	0	0	0	184 (83.5)

Table 2. (cont.)

(b) Fall-/Spring-run

Field Season	Water year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Weekly mean (SE)
1993	AN	--	0	0	0	244	2890	2740	3570	3690	429	62.6	0	1500 (327)
1994	C	5.67	0	0.702	0	1030	1360	7420	4820	830	142	0	0	1430 (401)
1995	W	0	0	0	0	48.7	7270	7710	8530	2960	1760	207	5.43	3080 (774)
1996	W	6.58	0	0	0	1880	5940	15000	7900	2230	318	0	2.48	2790 (716)
1997	W	0	0	0	0	640	5140	3010	2950	737	58.7	4.70	0	1410 (409)
1998	W	0	0	0	0	623	6770	1500	4470	2950	2770	183	5.91	1900 (477)
1999	W	4.51	0	0	12.9	1300	8140	20900	29400	6930	627	33.9	23.5	7240 (2180)
2000	AN	0	0	0	0	183	6960	16800	11500	1820	559	13.0	0	3730 (1090)
Yearly mean 1993-2000 (SE)		2.39 (1.15)	0 (0)	0.0877 (0.0877)	1.61 (1.61)	718 (204)	5480 (822)	9240 (2540)	9040 (3070)	2770 (698)	832 (333)	63.0 (29.8)	10.5 (6.68)	2760 (788)
2001	D	0	0	0	0	8.68	4420	18700	5320	292	35.3	22.3	0	27600 (11600)
2002	D	0	0	0	57.5	3170	16400	8730	8240	1590	90.9	0	0	40500 (1630)
2003	AN	0	0	0	0	4170	13200	14100	10800	2530	1090	0	18.1	44200 (10800)
2004	BN	0	0	0	0	5240	26600	14900	12500	2760	127	0	0	53400 (17000)
2005	AN	0	0	0	0	1020	5750	5180	5690	1900	883	107	0	23800 (5670)

(c) Late fall-run

Field Season	Water year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Weekly mean (SE)
1993	AN	--	0	2.19	6.54	26.5	4.45	2.24	0	40.2	22.6	0	0	8.75 (3.29)
1994	C	2.84	1.72	35.3	6.72	18.4	0.857	11.9	0	0	0	0	0	6.81 (3.02)
1995	W	0	0	0	9.45	21.1	22.4	0	0	0	13.6	0	0	5.27 (1.82)
1996	W	14.1	0	0	0	25.1	8.56	0	0	0	0	4.99	0	4.50 (1.90)
1997	W	0	0	0	5.79	26.3	0	0	0	0	0	0	0	4.09 (2.58)
1998	W	0	0	0	45.6	78.7	3.38	0	0	0	40.3	88.1	0	21.0 (6.58)
1999	W	11.1	0	0	308	77.4	0	0	0	49.6	24.1	0	0	39.9 (17.9)
2000	AN	0	0	0	0	0	8.280	0	0	0	0	0	0	0.478 (0.478)
Yearly mean 1993-2000 (SE)		4.01 (2.28)	0.215 (0.215)	4.69 (4.38)	47.7 (37.5)	34.0 (10.1)	6.01 (2.64)	1.76 (1.47)	0 (0)	11.2 (7.40)	12.6 (5.40)	11.7 (10.9)	0 (0)	11.2 (4.30)
2001	D	0	0	0	68.0	0	3.05	0	0	0	0	0	0	50.2 (45.1)
2002	D	0	0	0	32.7	40.2	0	0	0	0	0	0	0	69.8 (36.5)
2003	AN	0	0	0	35.3	10.1	0	0	0	0	296	0	0	140 (68.8)
2004	BN	0	0	0	0	40.7	14.7	0	0	31.4	0	0	0	77.5 (35.8)
2005	BN	0	0	10.3	9.02	29.8	0	0	0	0	419	0	0	193 (81.0)

Regions 2-4. Interior Delta Beach Seine (North, Central, and South Delta)

Methods
Beach seining was conducted weekly at 12 sites in Region 2 (North Delta), ten sites in Regions 3 (Central Delta), and 10 sites in Region 4 (South Delta) between 8/1-7/31 for each field season during 2001-2005. Three sites from Region 2 (Garcia Bend, American River, and Discovery Park) were sampled up to three times per week during October-February as part of our Sacramento seine sampling (see below for Sacramento Area Beach Seine).

Results
During 2001-2005 field seasons, a total of 556 winter-run salmon were captured in beach seines conducted in the interior Delta (Figures 14-18). Nearly all 28 winter-run salmon captured in the 2001 field season were caught between mid-January and mid-March, coinciding with periods of high or increasing flows. Mean monthly CPUE peaked in February and was the third lowest mean monthly peak since 1993 (Table 3a). In the 2002 field season, 242 winter-run were captured and the highest peak mean monthly CPUE recorded since 1993 was observed in December. In the 2003 field season, 57 winter-run were captured between December and March, mean monthly CPUE peaked in December. In 2004, 120 winter-run salmon were captured, the second highest mean monthly CPUE since 1993 occurred in December. A total of 109 winter-run salmon were captured during the 2005 field season, all between the months of November and March. Winter-run mean monthly CPUE peaked in December.

Spring-/fall-run salmon were the most abundant race captured (n = 33,862; Figure. 14-18), in the interior Delta in the 2001-2005 field seasons. Fish first appeared in beach seines during periods of increasing or high flows. Consistent with all years since 1993, peak monthly CPUE of spring-/fall-run salmon occurred in either February or March each year during 2001-2005 (Table 3b). Nearly all 5,280 spring-/fall-run salmon in 2001 were caught between mid-January and late April. During the 2002 field season, 3,994 spring-/fall-run salmon were captured from November to June. The 2003 field season yielded 3,994 fish from mid-December until late June. We caught 10,794 fish in 2004 and 6,448 spring-/fall-run salmon in 2005 from December to June of each season.

In the 2001-2005 field seasons, a total of 180 late fall-run salmon were captured in the interior Delta (Figures 14-18). In 2001, five late fall-run salmon were captured, two yearlings from the 2000 brood year and three fry from the 2001 brood year. Peak monthly mean CPUE occurred in April and was the lowest on record (Table 3c). In 2002, 23 late fall-run were captured, Eighteen yearlings from the 2001 brood year and five fry from the 2002 brood year. Mean monthly CPUE peaked in December. A total of 84 fish, all fry from the 2003 brood year, were captured in the 2003 field season. Peak monthly mean CPUE during 2003 was observed in May and was the highest on record. The 2004 field season yielded 33 late fall-run Chinook salmon; 4 yearlings from the 2003 brood year and 29 fry from the 2004 brood year. Mean monthly CPUE of late-fall salmon peaked in April and was the third largest on record. In the 2005 field season, a total of 35 fish were captured, three yearlings from 2004 brood year and 32 fry from

2005 brood year. Peak mean monthly CPUE occurred in April and was the fourth largest on record.

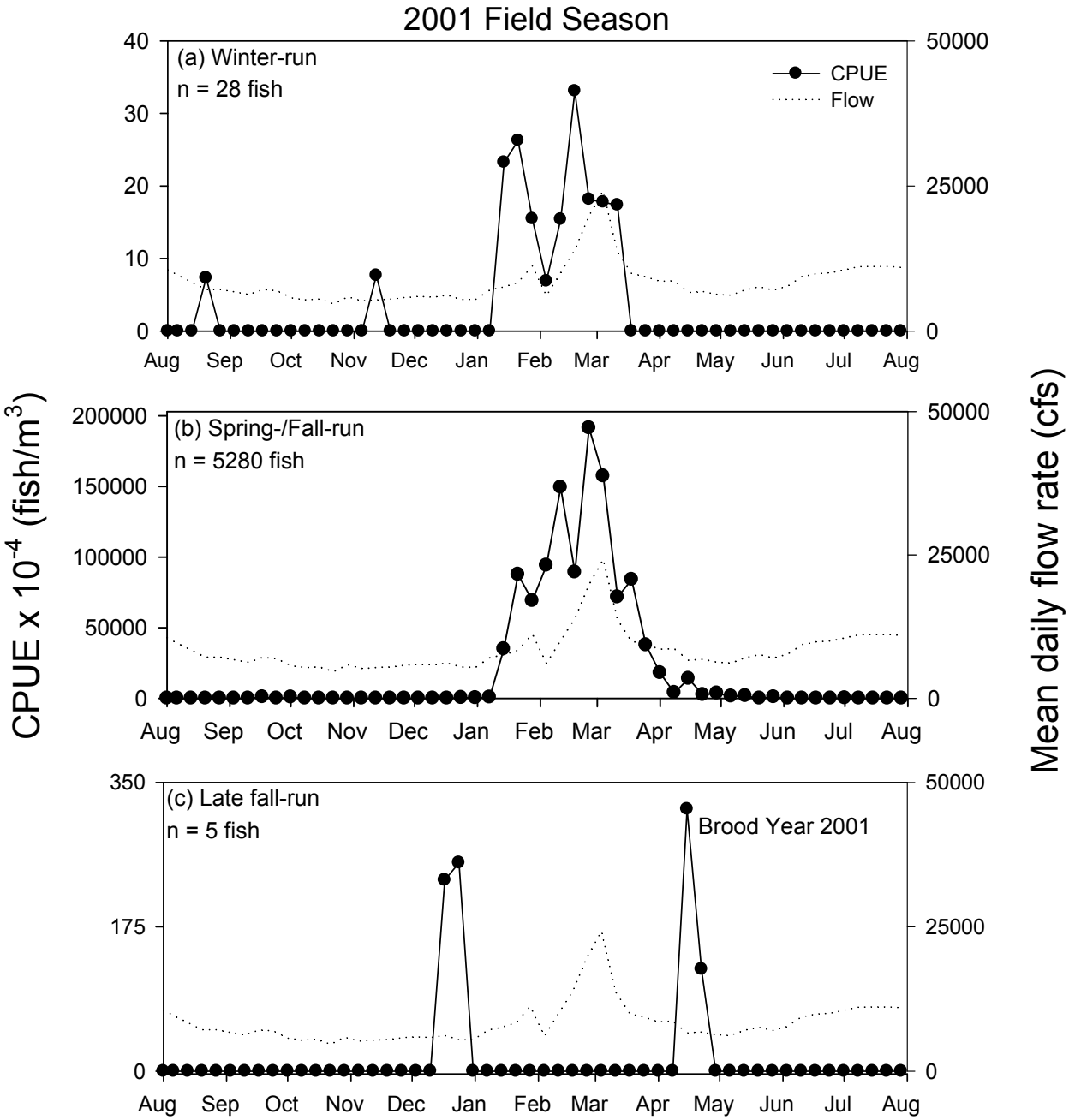

Figure 14. Catch per unit effort (x 10^{-4}) of winter-, spring-/fall-, and late fall-run Chinook salmon in beach seines and concurrent mean daily flow rate in the interior Delta (North, Central, and South; Regions 2-4) during the 2001 field season. All data were averaged by week, our standard unit of replication for seines. Mean daily flow rate was Delta Outflow calculated by CDEC. Sample size (n) corresponds to total number of fish caught. Fall- and spring-run salmon were combined because of difficulties in distinguishing between them at this size. Note the change in scale among panels.

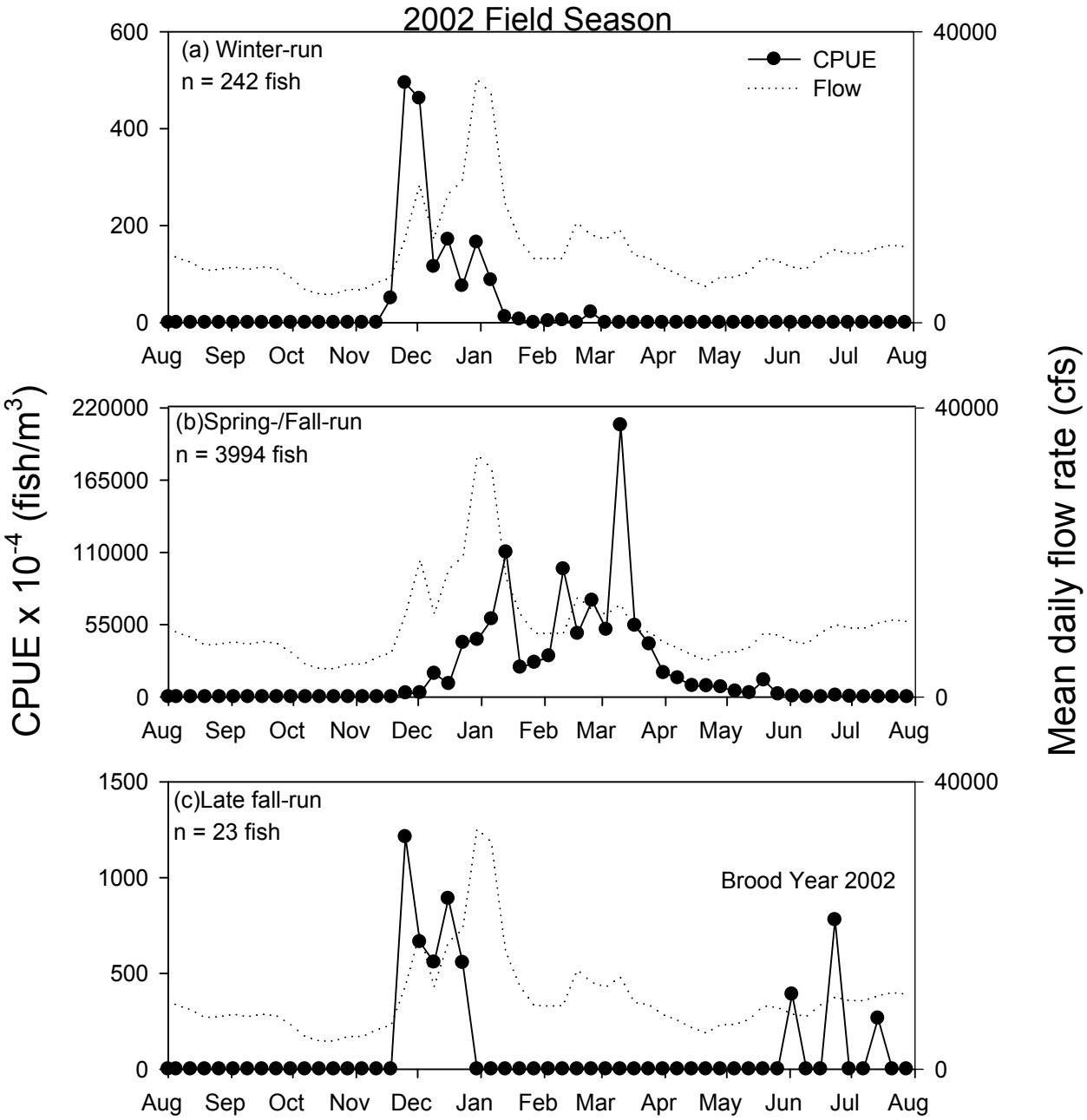

Figure 15. Catch per unit effort (x 10^{-4}) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in beach seines and concurrent mean daily flow rate in the interior Delta (North, Central, and South; Regions 2-4) during the 2002 field season. All data were averaged by week, our standard unit of replication for seines. Mean daily flow rate was Delta Outflow calculated by CDEC. Sample size (n) corresponds to total number of fish caught. Fall- and spring-run salmon were combined because of difficulties in distinguishing between them at this size. Note the change in scale among panels.

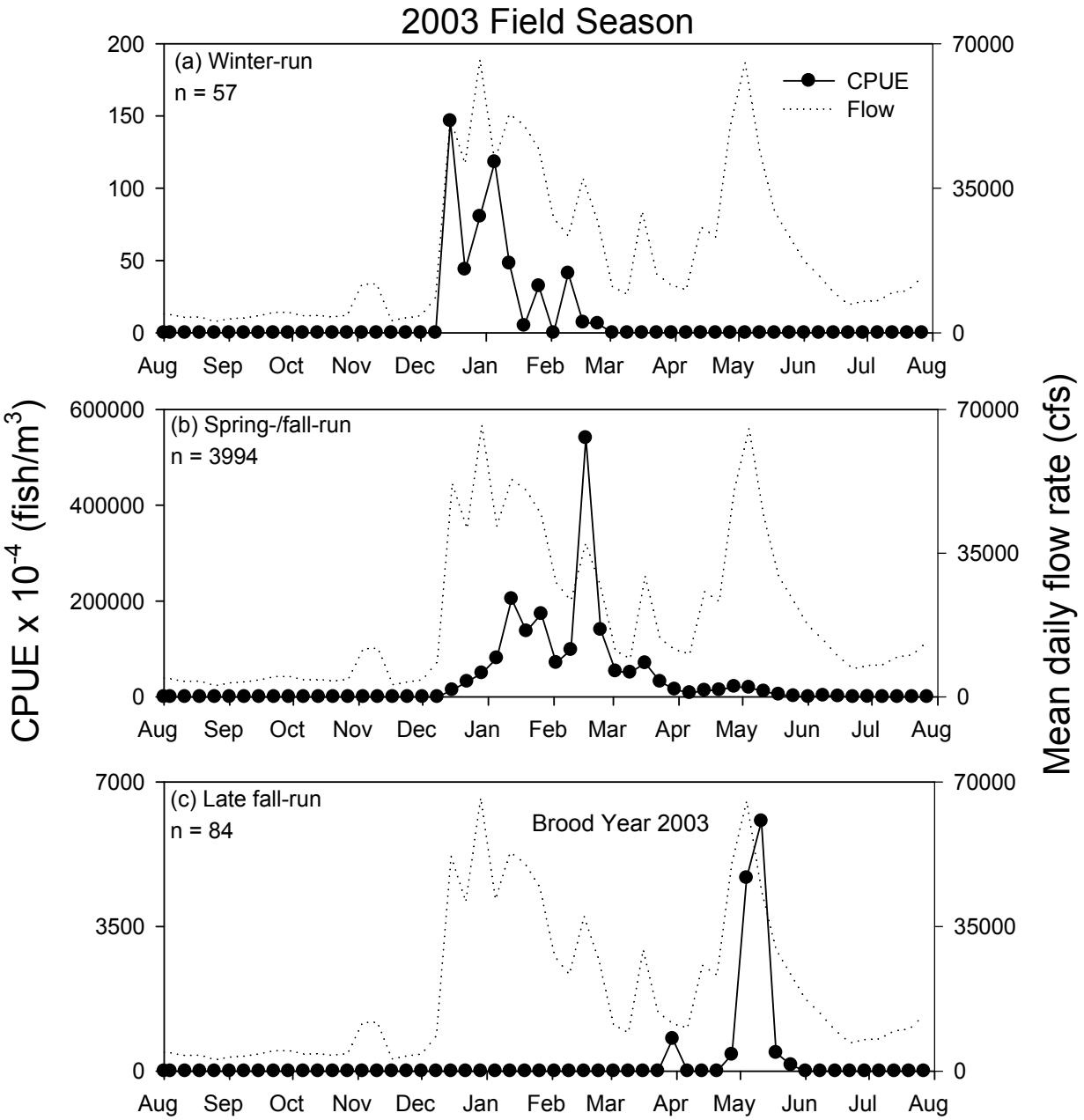

Figure 16. Catch per unit effort (x 10^{-4}) of winter-, spring-/fall-, and late fall-run Chinook salmon in beach seines and concurrent mean daily flow rate in the interior Delta (North, Central, and South; Regions 2-4) during the 2003 field season. All data were averaged by week, our standard unit of replication for seines. Mean daily flow rate was Delta Outflow calculated by CDEC. Sample size (n) corresponds to total number of fish caught. Fall- and spring-run salmon were combined because of difficulties in distinguishing between them at this size. Note the change in scale among panels.

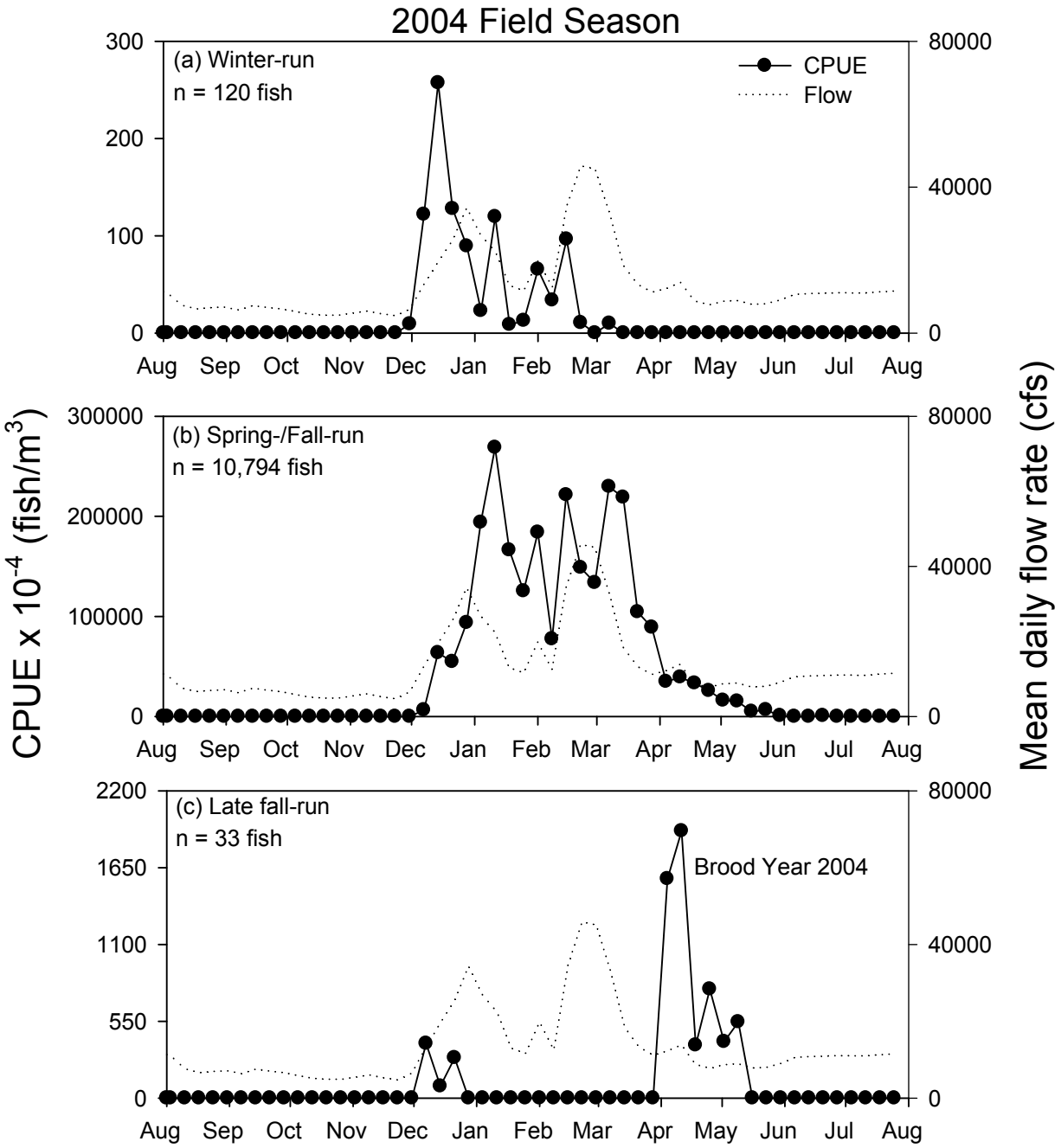

Figure 17. Catch per unit effort (x 10^{-4}) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in beach seines and concurrent mean daily flow rate in the interior Delta (North, Central, and South; Regions 2-4) during the 2004 field season. All data were averaged by week, our standard unit of replication for seines. Mean daily flow rate was Delta Outflow calculated by CDEC. Sample size (n) corresponds to total number of fish caught. Fall- and spring-run salmon were combined because of difficulties in distinguishing between them at this size. Note the change in scale among panels.

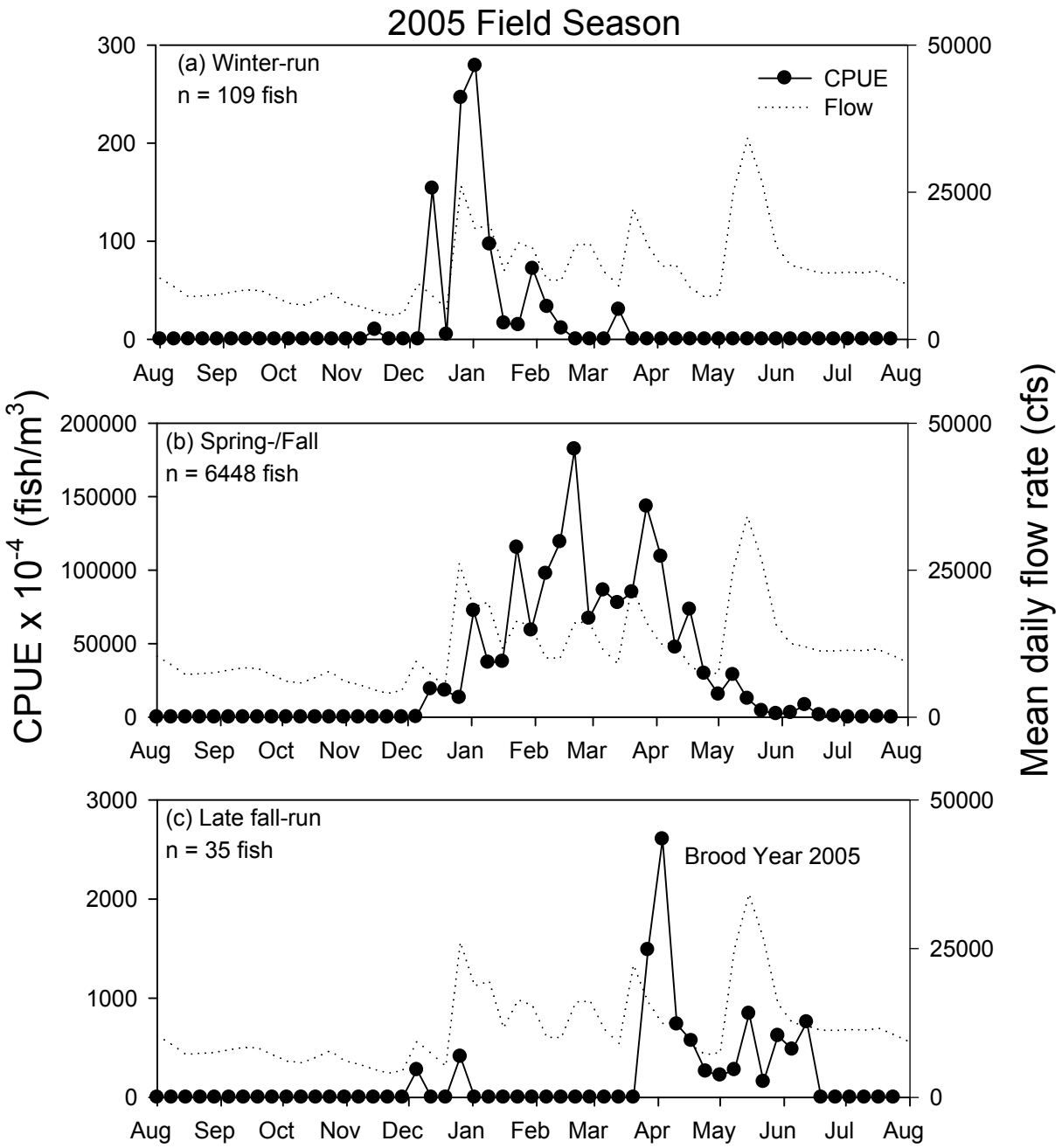

Figure 18. Catch per unit effort (x 10^{-4}) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in beach seines and concurrent mean daily flow rate in the interior Delta (North, Central, and South; Regions 2-4) during the 2005 field season. All data were averaged by week, our standard unit of replication for seines. Mean daily flow rate was Delta Outflow calculated by CDEC. Sample size (n) corresponds to total number of fish caught. Fall- and spring-run salmon were combined because of difficulties in distinguishing between them at this size. Note the change in scale among panels.

Table 3. Summary table of CPUE x 10^{-4} (fish/m^3) of (a) winter-, (b) fall-/spring-run, and (c) late fall-run Chinook salmon in the interior Delta (North, Central, and South; Regions 2-4) combined by month and year. Yearly mean and standard error (SE) values were calculated using years as replicates (n = 6-8). Weekly mean and SE values were calculated using weeks as replicates (n = 39-53). Shaded boxes indicate peak monthly CPUE. Water year (CDEC, 2006): AN = above normal; C = critical; W = wet

(a) Winter-run

Field Season	Water year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Weekly avg (SE)
1993	AN	--	0	0	37.7	8.78	58.0	35.1	6.61	0	0	0	--	19.6 (7.76)
1994	C	--	0	0	0	0	0	4.67	0	0	0	0	0	0.552 (0.552)
1995	W	0	0	0	0	0	9.76	4.16	0.427	0	0	0	0	1.38 (0.559)
1996	W	0	0	0	0	33.0	27.5	17.2	1.99	3.22	0	0	0	7.85 (2.63)
1997	W	0	0	0	0.253	7.91	7.59	2.82	13.4	0	0	0	0	3.94 (1.63)
1998	W	0	0	0	2.07	44.7	48.4	5.84	3.96	0	0	0	0	9.49 (4.04)
1999	W	0	3.94	1.85	41.7	66.9	17.1	12.2	12.7	0	0	0	0	20.2 (7.96)
2000	AN	0	0	0	0	2.98	36.78	29.87	19.00	0	0	0	0	7.15 (2.87)
Yearly mean1993-2000 (SE)		0 (0)	0.493 (0.493)	0.231 (0.231)	10.2 (6.45)	20.3 (8.87)	22.8 (7.25)	11.6 (3.78)	5.62 (1.82)	0.402 (0.402)	0 (0)	0 (0)	0 (0)	8.77 (2.66)
2001	D	1.16	0	0	0.48	0	5.67	14.7	8.56	0	0	0	0	3.56 (1.08)
2002	D	0	0	0	51.8	125	44.1	6.44	0	0	0	0	0	32.1(13.6)
2003	AN	0	0	0	0	31.0	36.1	12.1	0	0	0	0	0	10.2 (4.05)
2004	BN	0	0	0	0	80.0	29.3	44.6	1.60	0	0	0	0	18.9 (6.63)
2005	BN	0	0	0	0.893	33.8	49.1	24.3	4.34	0	0	0	0	18.6 (7.80)

Table 3. (cont.)

(b) Spring-/fall-run

Field Season	Water year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Weekly mean (SE)
1993	AN	--	0	0	0	41.6	1320	1630	4960	2670	405	124	--	1240 (346)
1994	C	--	0	0	6.64	36.3	325	4000	1430	496	53.0	2.58	0	723 (150)
1995	W	0	1.93	0	0	31.1	8760	5260	6350	2640	499	65.9	2.81	2560 (876)
1996	W	0	0	0	0	894	3300	9260	5360	1780	327	16.0	8.23	1960 (511)
1997	W	0	0	0	0	1000	2490	2640	2170	886	83.5	5.54	0	961 (206)
1998	W	1.56	0	0	0	60.4	4620	7690	4990	2710	754	121	0	1820 (425)
1999	W	0	0	0	13.6	429	3100	6870	7980	2770	572	51.3	0.855	2080 (495)
2000	AN	0	5.79	0	0	4.42	7340	34400	8970	3840	445	2.24	0	4860 (1640)
Yearly mean 1993-2000 (SE)		0.260 (0.260)	0.543 (0.358)	0 (0)	2.54 (1.78)	312 (148)	3340 (890)	6210 (1260)	4530 (777)	1910 (323)	355 (88.4)	48.4 (18.3)	1.70 (1.16)	2026 (459)
2001	D	0	14.9	12.4	0	1.19	1610	3820	40900	398	64.2	4.93	1.37	21000 (6170)
2002	D	0	0	0	11.2	519	2190	2470	4180	460	212	19	1.67	19600 (5130)
2003	AN	0	0	0	0	420	5150	8430	2240	603	394	33.7	1.02	35700 (11900)
2004	BN	0	0	0	0	1078	4980	6880	6880	1670	389	13.8	0	49200 (10600)
2005	BN	0	0	0	0	181	2060	3840	3810	2530	661	114	3.19	30100 (6230)

(c) Late fall-run

Field Season	Water year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Weekly mean (SE)
1993	AN	--	0	0	4.82	3.83	5.14	0	0	9.51	1.44	5.61	--	3.92 (1.47)
1994	C	--	0	0	0	6.12	6.65	0	0	0	0	0	0	1.39 (0.805)
1995	W	0	0	0	0.233	8.63	11.4	2.41	0	3.99	10.3	0	0	2.77 (1.14)
1996	W	0	0	0	0	1.79	0.612	0.882	0	2.31	17.1	0	1.39	1.77 (0.830)
1997	W	0	0	0	3.47	3.01	9.08	0	0	0	2.39	0	0	3.32 (2.40)
1998	W	0	0	0	1.50	7.79	0	0	0	73.1	13.3	7.81	0	9.38 (4.99)
1999	W	0	0	0.992	10.5	13.5	1.39	0	0	44.7	4.79	0	0	8.80 (3.82)
2000	AN	0	0	0	0	6.09	0	3.90	0	0	2.47	0	0	1.19 (0.55)
Yearly mean 1993-2000(SE)		0 (0)	0 (0)	0.124 (0.124)	2.56 (1.30)	5.89 (1.40)	4.29 (1.57)	0.581 (0.319)	0 (0)	16.7 (9.66)	6.27 (2.28)	1.68 (1.12)	0.198 (0.198)	4.67 (1.14)
2001	D	0	0	0	0	1.39	0	0	0	3.80	0	0	0	17.5 (8.88)
2002	D	0	0	0	4.71	19.0	0	0	0	0	0	13.9	1.82	102 (36.8)
2003	AN	0	0	0	0	0	0	0	0	10.8	118	0	0	240 (146)
2004	BN	0	0	0	0	3.03	0	0	0	50.1	8.47	0	0	122 (50.6)
2005	BN	0	0	0	0	1.76	0	0	0	48.8	15.2	12.8	0	187 (62.7)

Region 5. Lower San Joaquin River

Methods

Lower San Joaquin River beach seine sampling started in 1994 to document the distribution and abundance of Chinook salmon in the San Joaquin River. Prior to the 2000 field season sampling on the San Joaquin River was typically conducted from January to June of each year, starting in 2000 sampling was conducted year around. During 2001-2005, sampling at the majority of sites was conducted once per week year round, except during August-November of 2001 and July of 2005, when sampling was conducted every two weeks.

During the 2001-2005 field seasons, we sampled 8-10 sites from Mossdale (rm 56) to north of the Tuolumne River (rm 83; Fig. 4).

Results

Spring-run salmon were extirpated from three San Joaquin River tributaries (Stanislaus, Tuolumne, and Merced Rivers) by 1930 and from the mainstem by 1947 because of dam construction (Fry 1961 and Yoshivana et. al. 1998). As a result, all Chinook salmon in the San Joaquin River are classified as fall-run salmon regardless of their size at a given date.

We captured 150 total fall-run salmon in Region 5 during the 2001 through 2005 field seasons (Figure 19). Salmon ranged in size from 28-84 mm (FL). During the 2002, 2003, and 2004 field seasons annual mean CPUE were lowest since 1994 (Table 4). In 2001, 102 fish were captured from mid-February to mid-May. The highest monthly mean CPUE occurred in March, coinciding with a peak in San Joaquin River flows. Only three salmon were captured in the 2002 field season. Mean monthly CPUE was highest in January, well after peak river flows for the year. Six salmon were captured in the 2003 field season. The highest mean monthly CPUE occurred in February during increasing flows. In 2004, we captured 16 fall-run salmon from mid-February to mid-April. The highest mean monthly CPUE occurred in March, coinciding with peak river flows. In 2005, 23 fall-run salmon were captured from mid-January to late April. Mean monthly CPUE was highest in late February.

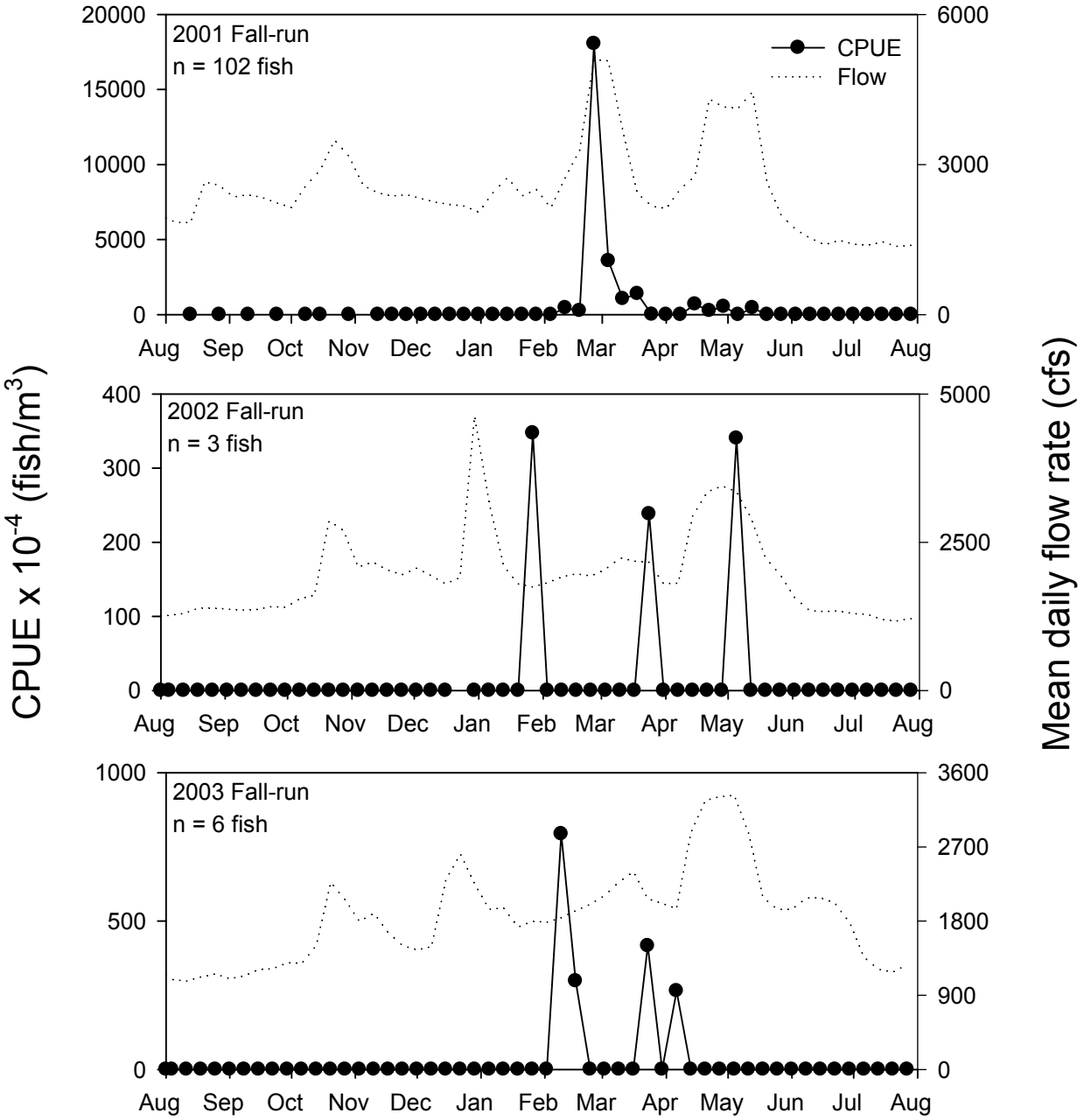

Figure 19. Catch per unit effort (x 10^{-4}) of fall-run Chinook salmon in beach seines and mean daily flow rate in the San Joaquin River region (Region 5) during the 2001-2005 field season. All data were averaged by week, our standard unit of replication for seines. Flow rate was estimated at Vernalis in the San Joaquin River by CDEC. Sample size (n) corresponds to total number of fish caught. Weeks during which we did not sample have no points on the graph. Note the change in scale among panels.

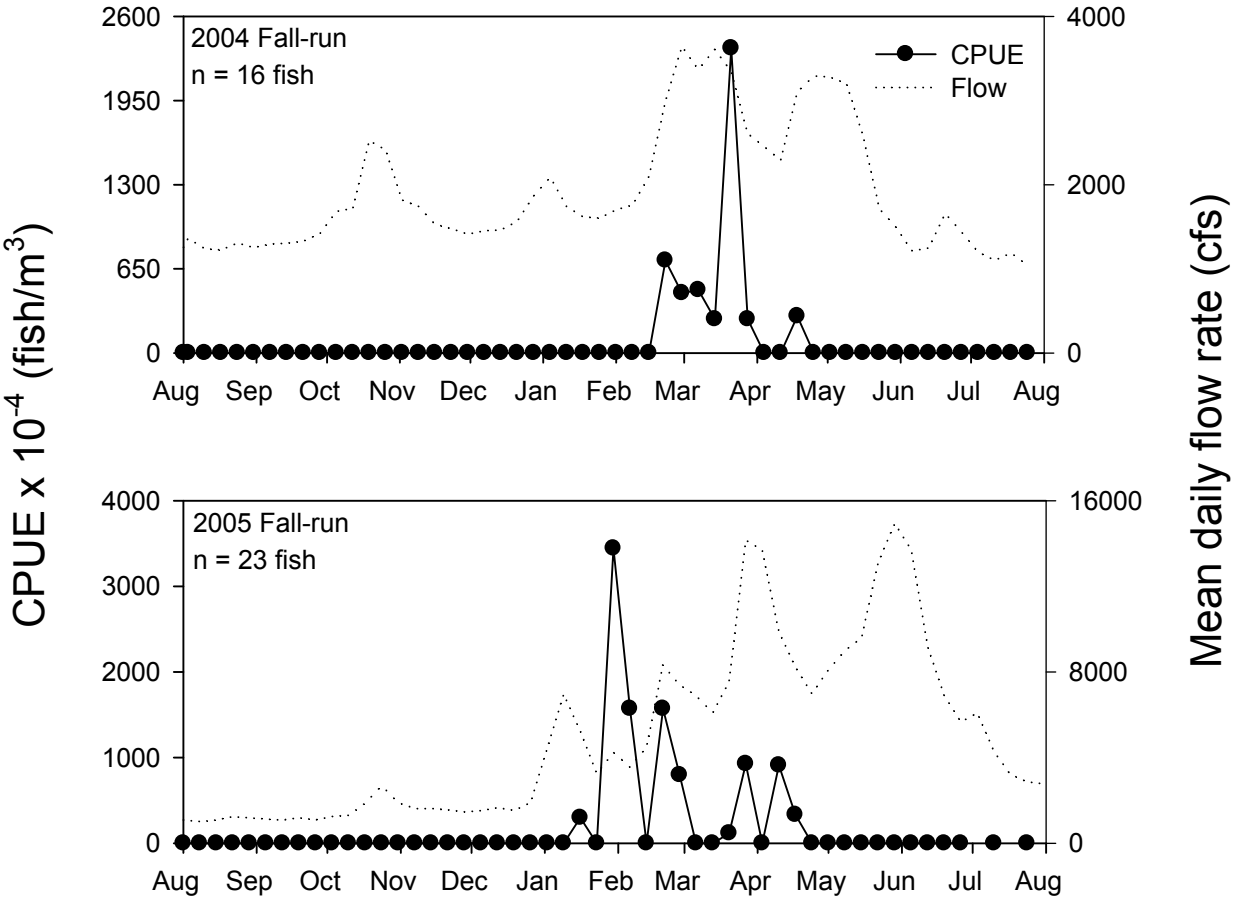

Figure 19 (cont.)

Table 4. Summary table of CPUE x 10^{-4} (fish/m^3) of fall-run Chinook salmon in the San Joaquin River region (Region 5) by month and year. Yearly mean and standard error (SE) values were calculated using years as replicates (n = 1-7). Weekly mean and SE values were calculated using weeks as replicates (n = 10-38). Shaded boxes indicate peak monthly CPUE. Water year (CDEC, 2006): AN = above normal; BN = below normal; C = critical; D = dry; W = wet

Field Season	Water year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Weekly mean (SE)
1994	C	--	--	--	--	--	--	--	0	453	0	0	--	189 (150)
1995	W	--	--	--	--	--	--	190	332	0	32.6	154	--	131 (44.0)
1996	W	--	--	--	--	--	0	42.1	9.08	99.8	0	0	--	287 (12.9)
1997	W	--	--	--	--	--	0	0	415.6	161.0	0	0	--	244 (182)
1998	W	--	--	--	--	--	899	4100	167	448	22.3	0	--	707 (210)
1999	AN	--	--	--	--	--	1650	6330	2420	753	110	19.8	--	1700 (480)
2000	AN	0	0	0	0	0	0	641	734	247	59.5	0	0	182 (53.7)
Yearly mean 1994-2000 (SE)		0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	509 (333)	1880 (1100)	797 (345)	309 (98.0)	32.0 (15.4)	24.9 (21.8)	0 (0)	491(214)
2001	D	0	0	0	0	0	0	12.1	998	39.5	24.3	0	0	647 (445)
2002	D	0	0	0	0	0	43.4	0	8.5	0	8.50	0	0	18.9 (10.8)
2003	BN	0	0	0	0	0	0	45.5	14.9	6.61	0	0	0	34.8 (18.8)
2004	D	0	0	0	0	0	0	19.8	127	8.88	0	0	0	89.5 (49.5)
2005	W	0	0	0	0	0	10.6	309	71.8	47.9	0	0	0	179 (84.3)

Region 6. San Francisco/San Pablo Bays

Methods

Beach seining in San Francisco and San Pablo Bays was originally conducted by USFWS between December and May during 1980-1982. CDFG also sampled monthly year-round in the Bays during 1980-1986, but no sampling was conducted during 1987-1996. Beach seining was restarted by the DJFMP in 1997 to document the presence of Chinook salmon fry in downstream bays between December and May.

Seining was conducted year-round for the first time by USFWS in the 2000 field season. Ten seine sites were separated into two seine routes of five sites sampled per week. As a result, each individual site was sampled once every two weeks. In the 2003 field season, one site was eliminated (Pt. Molate, SP000E) due to inaccessibility. Data from 2001-2005 are presented in biweekly increments in an attempt to include all sites in calculations. For each site, we calculated mean CPUE for multiple sampling dates, when necessary, during each two-week period. Means from each site were averaged to provide an estimate of mean CPUE of all sites during each sampling period. Sites sampled during 2001-2005 were a subset of those sampled by CDFG in the 1980s (Orsi 1999).

Results

A total of 96 juvenile salmon were caught during 2001-2005 (Figure 20), all of which were spring/fall-run ranging in size from 32-82 mm FL. In 2001, all six fish were captured in May, coinciding with peak mean monthly CPUE and decreased Delta outflow (Table 5). The only salmon captured in 2002 was in January just after peak outflow. In 2003, one salmon was captured in June, just after outflow peaked for the season. In the 2004 field season, 87 fish were captured. The first fish was detected in mid-January and the last in mid-May. Peak mean monthly CPUE occurred during March. The only salmon captured in 2005 was caught in mid-May during increasing Delta outflow.

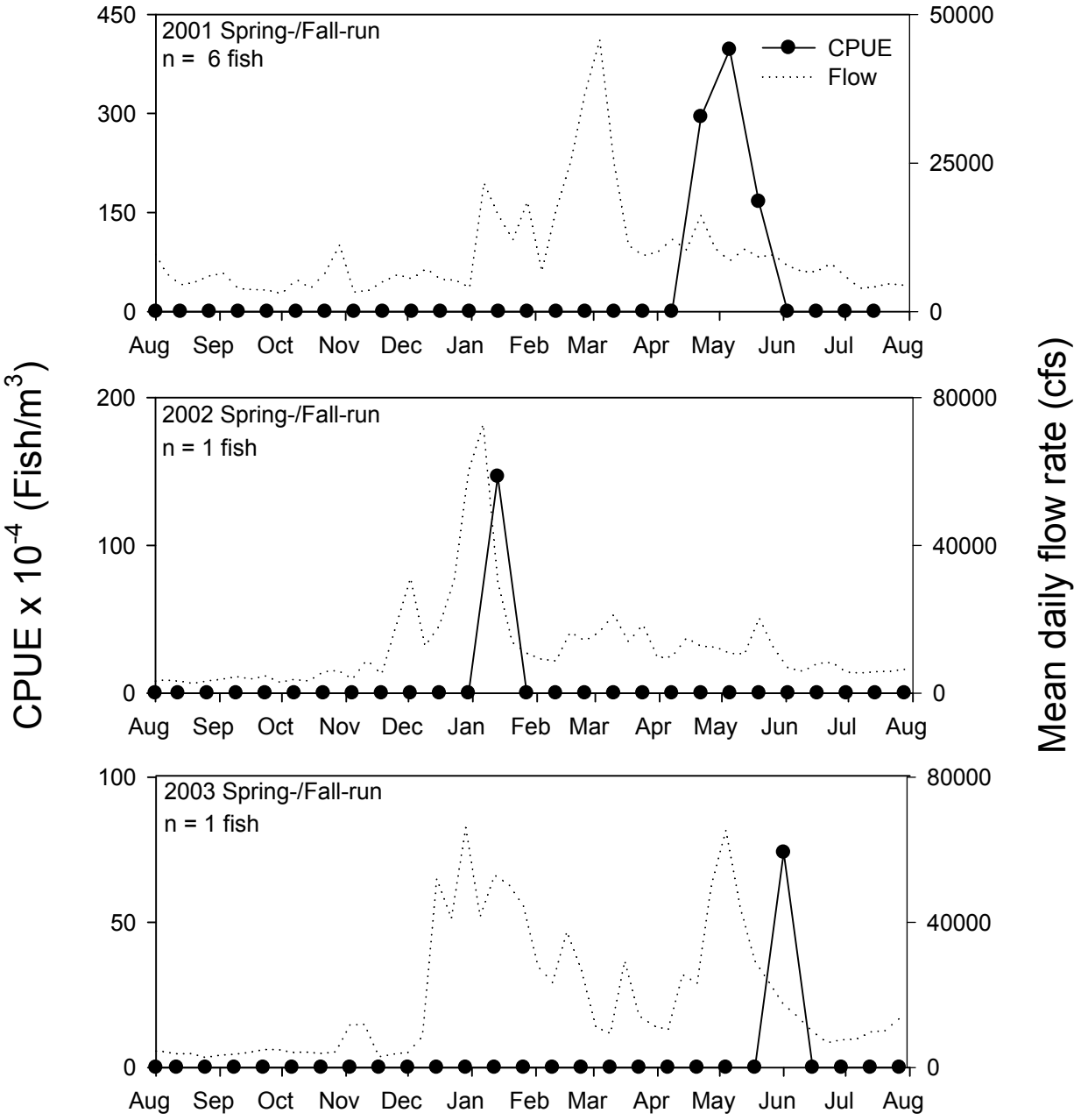

Figure 20. Catch per unit effort (x 10^{-4}) of spring-/fall-run Chinook salmon in beach seines in San Francisco/San Pablo Bays (Region 6) and Delta outflow during the 2001-2005 field season. All data were averaged biweekly because each site was sampled every other week. Delta outflow was calculated by CDEC. Fall- and Spring-run salmon were combined because of the close overlap in size and emigration timing of these two races. No other races of salmon were collected in bay seines. Sample size (n) corresponds to total number of fish caught during each field season. Note the change in scale among panels.

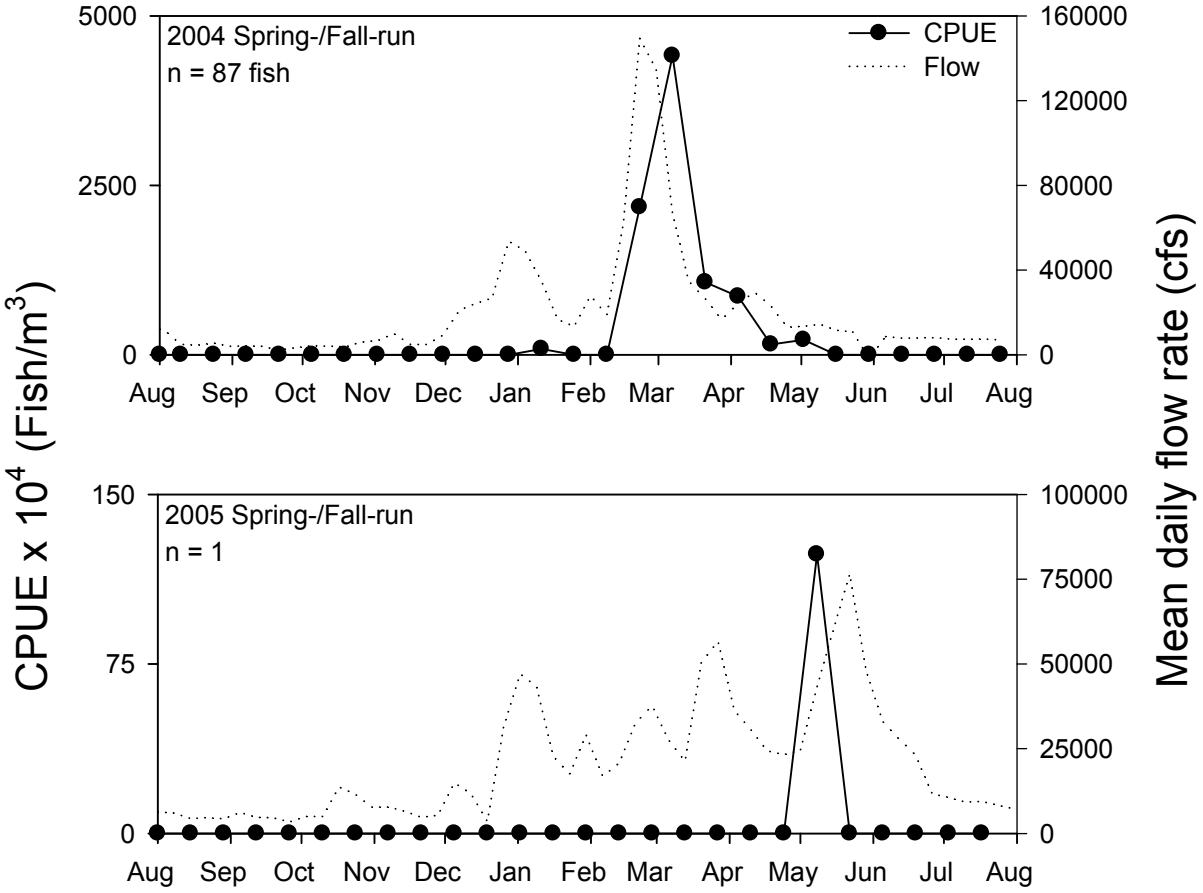

Figure 20 (cont.)

Table 5. Summary table of CPUE x 10^4 (fish/m^3) of spring-/fall-run Chinook salmon in San Francisco/San Pablo Bays (Region 6) by month and year. Yearly mean and standard error (SE) values were calculated using years as replicates (n = 6-7 for 1981-1987; n = 1-4 for 1997-2000). Weekly mean and SE values were calculated using one week periods as replicates (n = 5-18) for 1981-1987 data and two week periods as replicates for 1997-2000 data (n = 4-52). Calculations of SE were not possible when n = 1. Data from 1980-1986 were collected by CDF&G; data from 1997-2005 were collected by STWFO. No race other than spring-/fall-run has ever been collected in bay seines in this sampling. Shaded boxes indicate peak monthly CPUE. Water year (CDEC, 2006): D = dry; W = wet; AN = above normal; B = below normal

Field Season	Water year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Weekly mean (SE)
1981	D	0	0	0	0	0	0	260	28.4	520	77.7	0	0	74.4 (41.6)
1982	W	0	0	0	0	0	24.4	206	28.6	47.4	6.31	2.72	0	27.2 (15.0)
1983	W	0	0	0	0	0	0	302	477	215	63.3	55.8	61.3	74.5 (34.7)
1984	W	0	0	0	0	0	15.3	0	0	0	0	1.86	55.8	8.71 (5.66)
1985	D	0	0	0	0	0	0	0	0	0	0	0	0	0 (0)
1986	W	0	55.6	0	0	0	43.3	768	52.4	22.9	8.65	7.44	0	57.7 (44.7)
1987	D	0	0	0	0	0	--	--	--	--	--	--	--	0 (0)
Yearly mean 1981-1987 (SE)		0 (0)	7.94 (7.94)	0 (0)	0 (0)	0 (0)	13.8 (7.20)	256 (115)	97.7 (76.2)	134 (83.8)	26.0 (14.3)	11.3 (8.96)	19.5 (12.4)	34.6 (12.7)
1997	W	--	--	--	--	--	88.9	93.0	13.0	--	--	--	--	64.3 (37.0)
1998	W	--	--	--	--	--	239	385	240	--	--	--	--	280 (97.7)
1999	W	--	--	--	0	0	0	21.8	37.9	15.2	5.56	0	0	9.88 (4.95)
2000	AN	0	0	0	0	0	0	29.9	22.2	6.31	0	0	0	5.31 (3.19)
Yearly mean 1997-2000 (SE)		0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	89.5 (53.2)	130 (86.4)	72.4 (53.8)	101 (96.2)	2.78 (2.78)	0 (0)	0 (0)	89.9 (64.8)
2001	D	0	0	0	0	0	0	0	0	0	40.2	0	0	33.0 (19.4)
2002	D	0	0	0	0	0	4.88	0	0	0	0	0	0	5.43 (5.43)
2003	AN	0	0	0	0	0	0	0	0	0	0	4.12	0	2.74 (2.74)
2004	BN	0	0	0	0	0	5.41	0	380	56.1	12.2	0	0	332 (188)
2005	BN	0	0	0	0	0	0	0	0	0	7.72	0	0	4.75 (4.75)

Sacramento Area Beach Seine

Methods

Starting in the 1994 field season, sampling intensity was increased during October-February at eight sites near the city of Sacramento. The goal was to increase detection of entry into the Delta by less common races and life stages of Chinook salmon, particularly winter-run fry and winter-, spring-, and late fall-run yearlings. This effort was put forth in order to provide additional information to managers of water project operations (e.g., Delta Cross Channel gate closures). Two sites were chosen from the lower Sacramento region (Elkhorn and Verona), three from the North Delta region (American River, Discovery Park, and Garcia Bend) and three additional sites (Sherwood Harbor, Miller Park, and Sand Cove), all of which were on the Sacramento River (Table 1). Sampling was conducted up to three times per week during October-February until the 2001 field season. During the 2002-2005 field seasons, increased sampling occurred during October-January. Because the goal of seining in the Sacramento area is to target less common races, we have separated spring-run sized from fall-run sized fish and only report spring-run sized.

Results

There were three winter-run fry caught during 2001 in Sacramento, one in October and two in November (Figure. 21). Mean monthly CPUE peaked in November 2000, which is earlier than previous years. From early January to late February 2001 we caught 59 yearling-sized winter-run Chinook salmon. Mean monthly CPUE for winter-run yearlings peaked in February of 2001, which is later than previous years (Table 6b). In 2002, we captured 350 winter-run fry and 92 winter-run yearlings from November to January (Figure 22). Mean monthly CPUE of both fry and yearlings peaked in December, coinciding with a small peak in water flow (Table 6a). In 2003, we caught 17 winter-run fry and 37 winter-run yearlings in December and January only (Figure 23). Peak mean monthly CPUE of both fry and yearlings were observed in December (Table 6a, b) and coincided with increased flows in the Sacramento River. In 2004, we caught 168 winter-run fry and 149 winter-run yearlings from November to January (Fig. 24). Mean weekly CPUE of winter-run fry was the second highest on record and mean weekly CPUE of yearlings was the highest on record (Table 6a, b). Mean monthly CPUE of both life stages peaked in December. In 2005, we caught 66 winter-run fry from October to January and 178 winter-run yearlings from November to January (Figure 25). Mean monthly CPUE of winter-run fry peaked in December, whereas mean monthly CPUE of winter-run yearlings peaked in January.

Spring-run fry were much more abundant than winter-run fry in the Sacramento area during the sampling period. We captured 1,498 individuals between December and February of 2001-2005, all during periods of increasing flows (Figure 21-25). There were no spring-run yearlings captured during any of these years, which is consistent with all previous years since 1995-1997 (Figure 21-25; Table 6d). This lack of yearling catch is most likely due to spring-run individuals being too young to obtain yearling size during this time of year. In 2001, we caught 16 spring-run fry. Catches coincided with increased flows at Freeport (Figure 21). Mean weekly CPUE of fry in 2001 was the

lowest on record (Table 6c). In 2002, we captured 267 fry. Mean monthly CPUE peaked in mid- December and was somewhat inconsistent with flow rate patterns (Figure 22). In 2003, we caught 407 fish. Mean monthly CPUE peaked in January. Catch patterns overlapped flow rate patterns very well (Figure 23). In 2004, there were 505 fish captured and mean weekly CPUE was the highest on record (Table 6c). Mean monthly CPUE peaked in December and was the highest mean monthly CPUE on record. In 2005, there were 301 spring-run fry captured and coincided somewhat with flow rate patterns (Figure 25). Monthly mean CPUE peaked in December and was the second highest mean monthly CPUE on record.

Consistent with all other years sampled at Sacramento, there were no late fall-run run fry captured during our sampling period (Figure 21-25, Table 6e). The most likely reason for this is that late fall-run individuals emigrate downstream primarily between May and November, which is outside of our sampling period for Sacramento area seining. Those late fall-run individuals that were caught were larger, and, therefore, categorized as yearlings. In 2001-2005 we captured a total of 48 late fall-run yearlings. Mean monthly CPUE peaked in December of every field season, which did not coincide well with the hydrograph at Freeport (Figure 21-25; Table 6f). In 2001, five late fall-run yearlings were captured, three in December and two in January. In 2002, there were 16 fish captured between November and January and weekly Mean CPUE was the second highest on record. The only late fall-run fish captured in the 2003 field season was caught in December. In December weekly average CPUE of late fall-run yearlings was the lowest on record. In 2004, a total of 12 fish were captured between December and January. In 2005, 14 fish were captured between November and December.

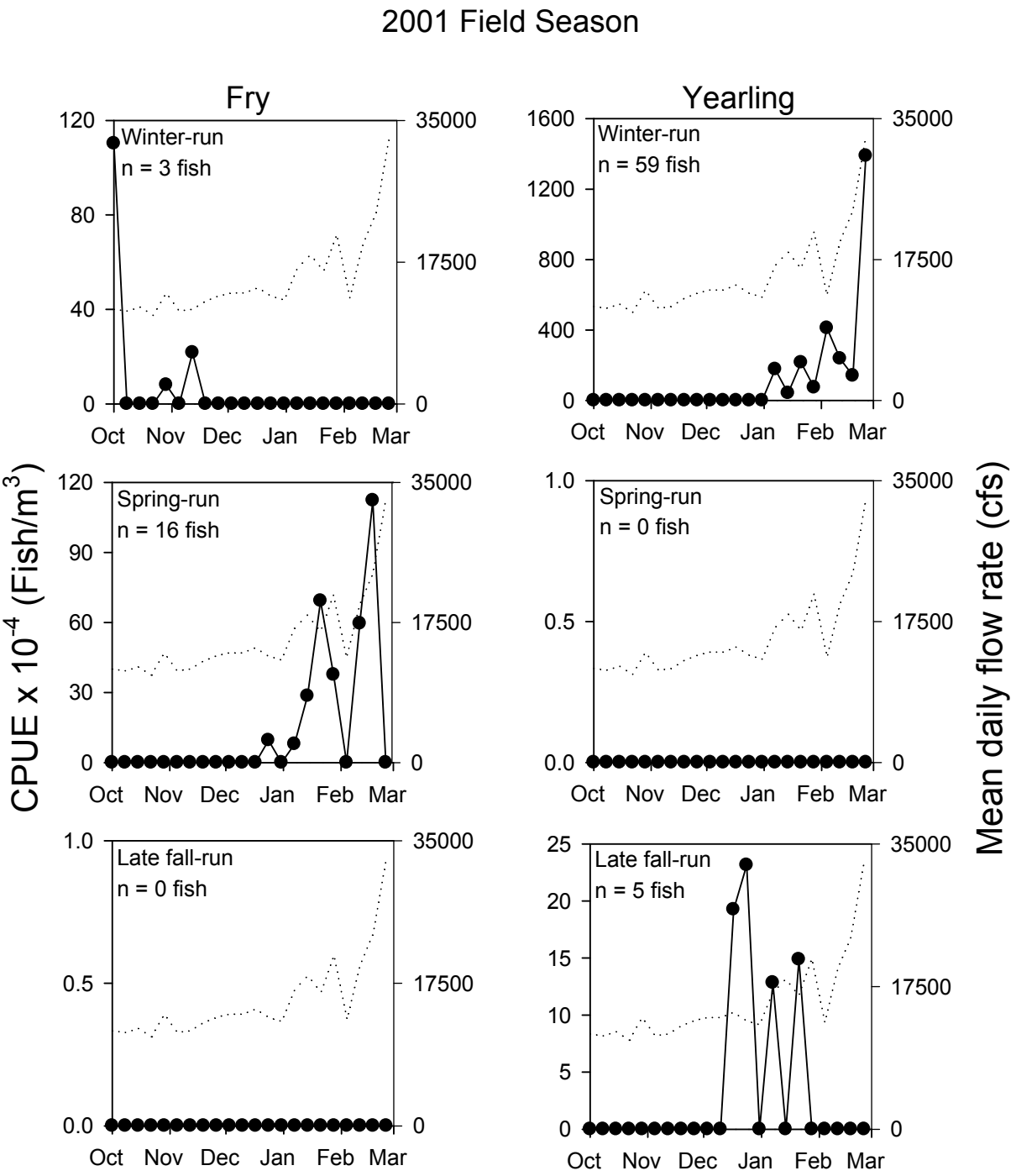

Figure 21. Catch per unit effort (x 10^{-4}) of fry and yearlings from winter-, spring-, and late fall-run raced salmon in Sacramento area beach seines and concurrent mean daily flow rates at Freeport during the 2001 field season. All data were averaged by week, our standard unit of replication for seines. Sample size (n) corresponds to total number of fish caught during the 2001 field season. Note the change in scale among panels.

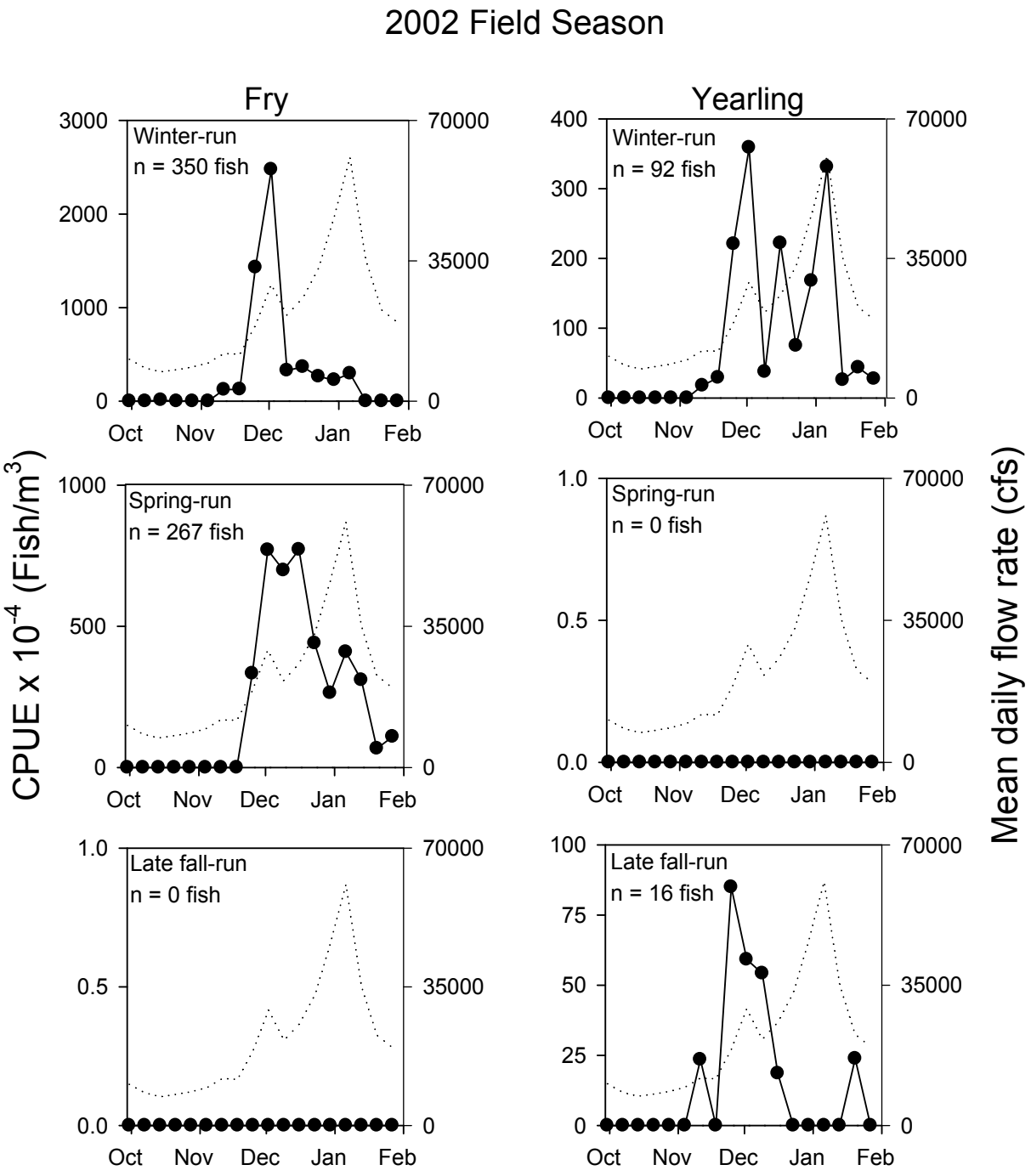

Figure 22. Catch per unit effort (x 10^{-4}) of fry and yearlings from winter-, spring-, and late fall-run raced salmon in Sacramento area beach seines and concurrent mean daily flow rates at Freeport during the 2002 field season. All data were averaged by week, our standard unit of replication for seines. Sample size (n) corresponds to total number of fish caught during the 2002 field season. Note the change in scale among panels.

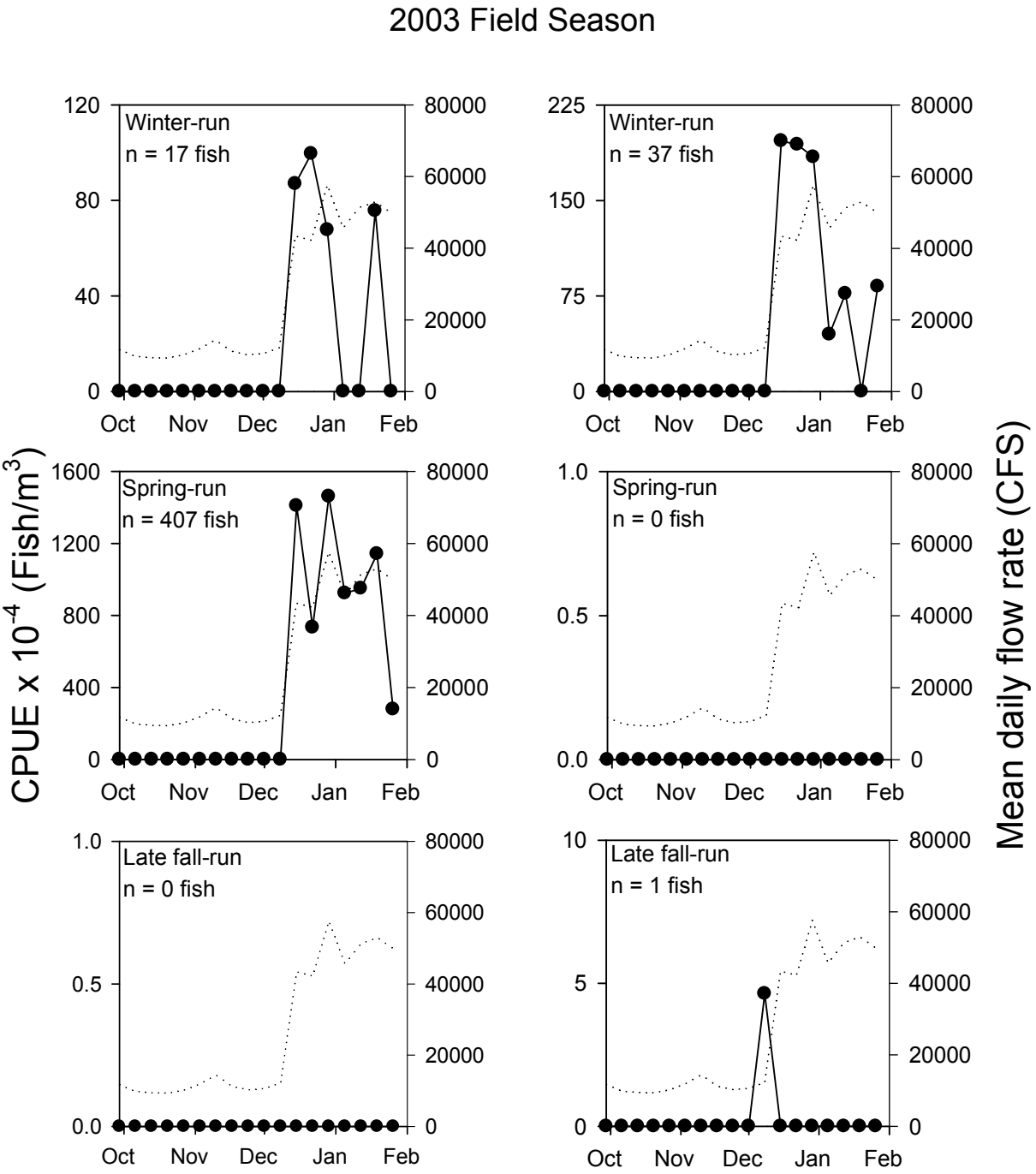

Figure 23. Catch per unit effort (x 10^{-4}) of fry and yearlings from winter-, spring-, and late fall-run raced salmon in Sacramento area beach seines and concurrent mean daily flow rates at Freeport during the 2003 field season. All data were averaged by week, our standard unit of replication for seines. Sample size (n) corresponds to total number of fish caught during the 2003 field season. Note the change in scale among panels.

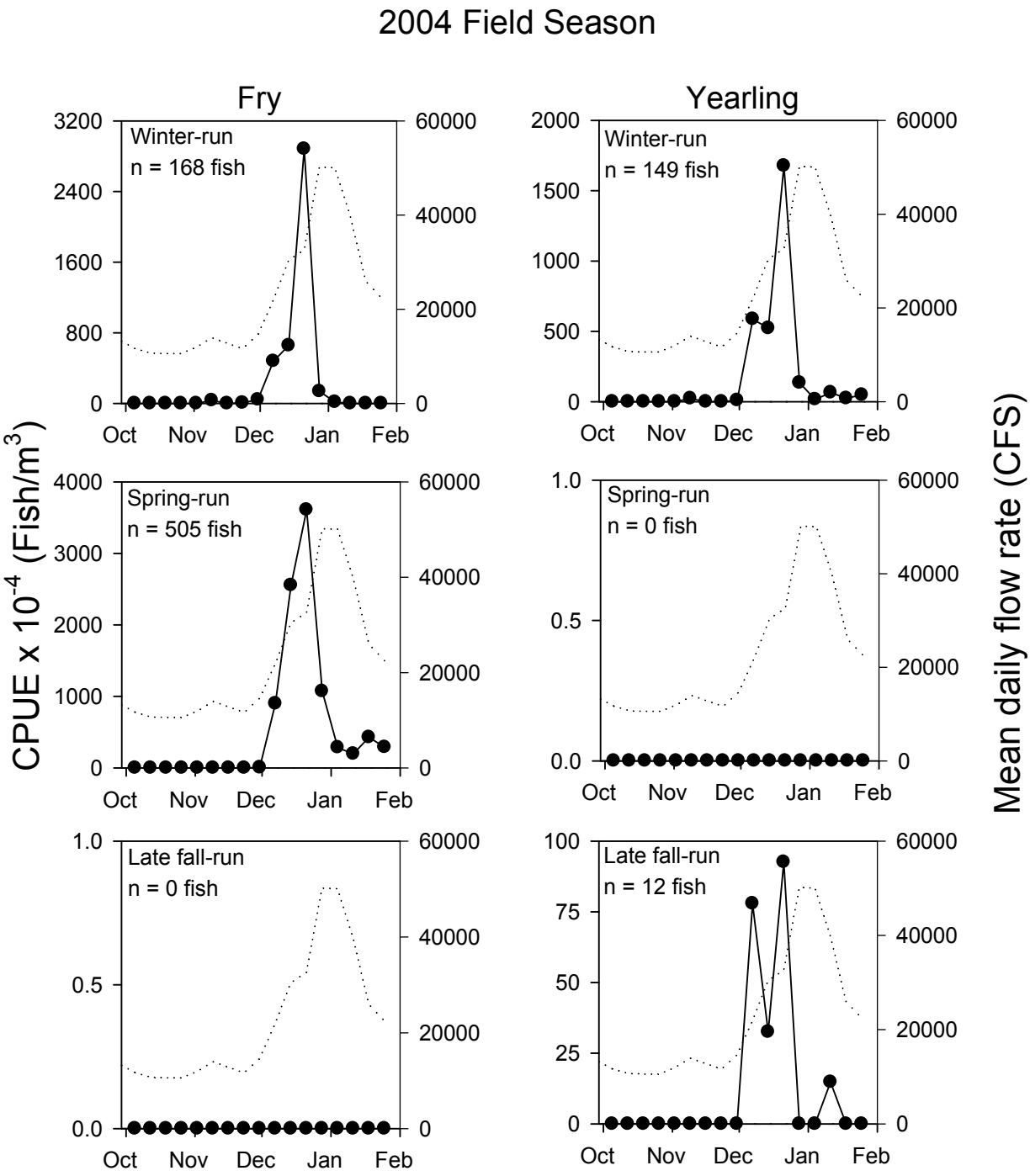

Figure 24. Catch per unit effort (x 10^{-4}) of fry and yearlings from winter-, spring-, and late fall-run raced salmon in Sacramento area beach seines and concurrent mean daily flow rates at Freeport during the 2004 field season. All data were averaged by week, our standard unit of replication for seines. Sample size (n) corresponds to total number of fish caught during the 2004 field season. Note the change in scale among panels.

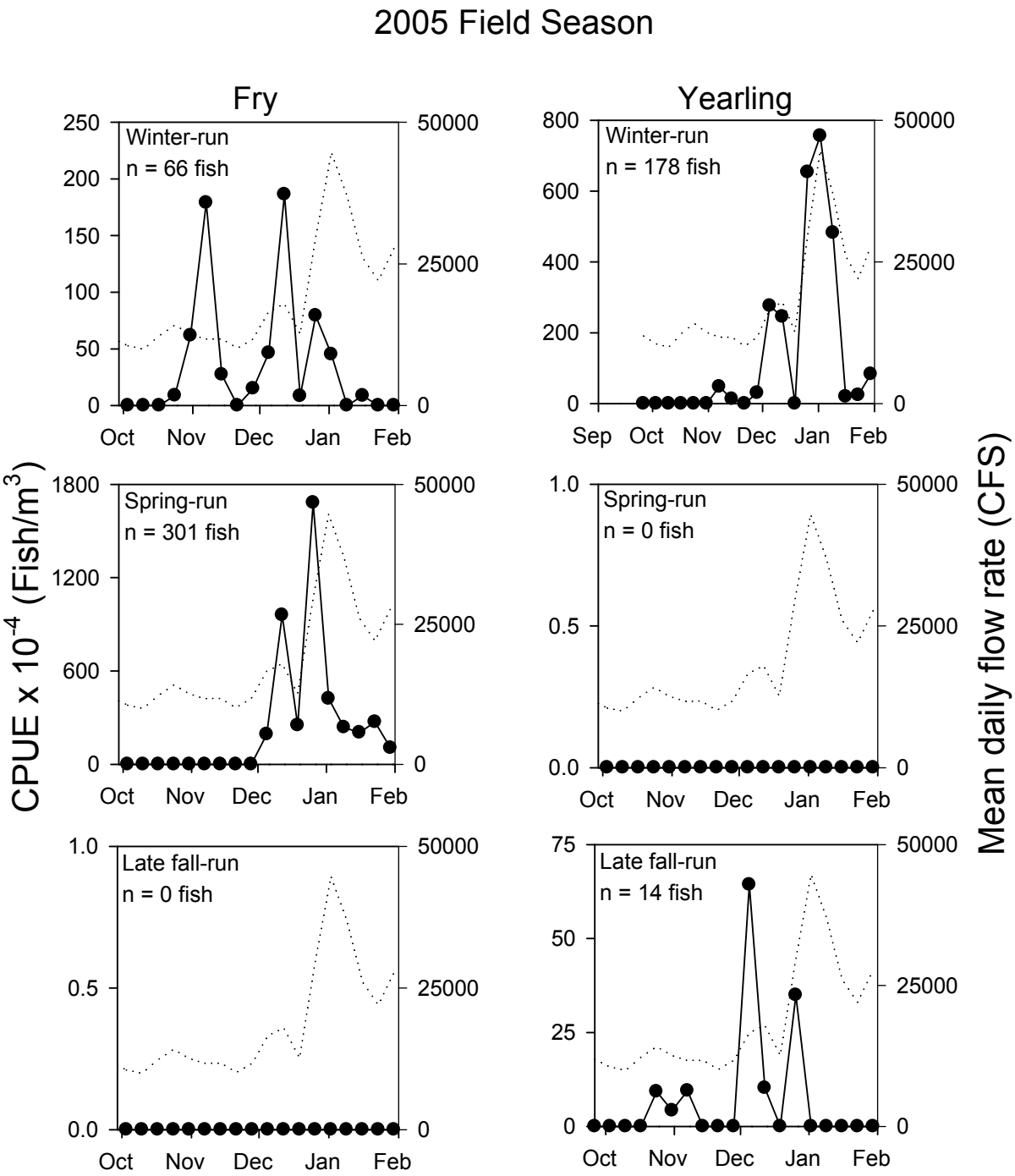

Figure 25. Catch per unit effort (x 10^{-4}) of fry and yearlings from winter-, spring-, and late fall-run raced salmon in Sacramento area beach seines and concurrent mean daily flow rates at Freeport during the 2005 field season. All data were averaged by week, our standard unit of replication for seines. Sample size (n) corresponds to total number of fish caught during the 2005 field season. Note the change in scale among panels.

Table 6. Summary table of CPUE x 10^{-4} (fish/m^3) of less common Chinook salmon races by age class during 1994-2005 field seasons in Sacramento area beach seines by month and year. Yearly mean and standard error (SE) values were calculated using years as replicates (n = 6). Weekly mean and SE values were calculated using weeks as replicates (n = 12-24). Shaded boxes indicate peak monthly CPUE. Water year (CDEC, 2006): AN = above normal; D =dry; C = critical; W = wet

(a) Winter-run fry

Field Season	Water year	Oct	Nov	Dec	Jan	Feb	Weekly mean (SE)
1995	W	0	0	0	2.63	0	0.752(0.752)
1996	W	0	0	49.7	2.48	0	10.9 (8.69)
1997	W	0	0	16.5	0	0	4.19 (2.91)
1998	W	0	34.8	56.2	6.39	0	17.2 (9.75)
1999	W	6.94	223	137	9.77	0	86.0 (51.7)
2000	AN	0	3.31	2.21	3.34	0	1.75 (0.972)
Yearly mean 1995-2000 (SE)		1.16 (1.16)	43.5 (36.3)	43.6 (21.0)	4.10 (1.41)	0 (0)	20.1 (8.01)
2001	D	4.59	7.19	0	0	0	6.36 (5.05)
2002	D	3.09	365	689	112	--	376 (176)
2003	AN	0	0	34.4	18.8	--	22.0 (9.88)
2004	BN	0	7.49	693	3.23	--	283 (192)
2005	BN	2.00	58.1	72.5	12.6	--	43.9 (15.9)

(b) Winter-run yearlings

Field Season	Water year	Oct	Nov	Dec	Jan	Feb	Weekly mean (SE)
1995	W	0	0	2.58	57.7	12.6	19.0 (7.78)
1996	W	0	0	157	74.3	90.5	65.7 (22.3)
1997	W	0	0.886	128	8.13	17.8	44.8 (18.7)
1998	W	0	57.1	153	189	0	79.2 (28.2)
1999	W	0	169	239	96.0	177	148 (44.1)
2000	AN	0	0	4.47	92.7	28.2	22.2 (11.1)
Yearly mean 1995-2000 (SE)		0 (0)	37.9 (27.9)	114 (38.1)	86.4 (24.4)	54.3 (27.7)	63.1 (5.35)
2001	D	0	0	0	103	205	122 (64.6)
2002	D	0	59.6	174	126	--	104 (32.0)
2003	AN	0	0	90.0	89.2	--	51.9 (20.1)
2004	BN	0	3.97	519	43.7	--	207 (116)
2005	BN	0	12.1	259	264	--	175 (66.1)

Table 6 (contin)

(c) Spring-run fry

Field Season	Water year	Oct	Nov	Dec	Jan	Feb	Weekly mean (SE)
1995	W	0	0	50.7	332	756	234 (79.5)
1996	W	0	0	415	568	224	276 (77.9)
1997	W	0	0	593	1010	451	488 (130)
1998	W	0	0	335	208	0	116 (38.0)
1999	W	0	39.2	435	149	137	163 (44.4)
2000	AN	0	0	63.4	450	336	177 (52.9)
Yearly mean 1995-2000 (SE)		0 (0)	6.53 (6.53)	315 (88.5)	453 (128)	317 (108)	242 (13.8)
2001	D	0	0	1.58	29.4	29.8	28.1 (11.1)
2002	D	0	74.2	587	261	--	278 (74.6)
2003	AN	0	0	529	737	--	460 (148)
2004	BN	0	0	1340	293	--	622 (277)
2005	BN	0	0	716	224	--	288 (119)

(d) Spring-run yearlings

Field Season	Water year	Oct	Nov	Dec	Jan	Feb	Weekly mean (SE)
1995	W	0	0	0	0	14.7	2.84 (2.00)
1996	W	0	0	0	0	8.24	2.02 (1.34)
1997	W	0	0	0	0	27.5	3.95 (3.37)
1998	W	0	0	0	0	0	0 (0)
1999	W	0	0	0	0	0	0 (0)
2000	AN	0	0	0	0	0	0 (0)
Yearly mean 1995-2000 (SE)		0 (0)	0 (0)	0 (0)	0 (0)	8.40 (4.53)	1.47 (0.567)
2001	D	0	0	0	0	0	0 (0)
2002	D	0	0	0	0	--	0 (0)
2003	AN	0	0	0	0	--	0 (0)
2004	BN	0	0	0	0	--	0 (0)
2005	BN	0	0	0	0	--	0 (0)

(e) Late fall-run fry

Field Season	Water year	Oct	Nov	Dec	Jan	Feb	Weekly mean (SE)
1995	W	0	0	0	0	0	0 (0)
1996	W	0	0	0	0	0	0 (0)
1997	W	0	0	0	0	0	0 (0)
1998	W	0	0	0	0	0	0 (0)
1999	W	0	0	0	0	0	0 (0)
2000	AN	0	0	0	0	0	0 (0)
Yearly mean 1995-2000 (SE)		0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
2001	D	0	0	0	0	0	0 (0)
2002	D	0	0	0	0	--	0 (0)
2003	AN	0	0	0	0	--	0 (0)
2004	BN	0	0	0	0	--	0 (0)
2005	BN	0	0	0	0	--	0 (0)

Table 6 (cont.)

(f) Late fall-run yearlings

Field Season	Water year	Oct	Nov	Dec	Jan	Feb	Weekly mean (SE)
1995	W	0	0.611	33.4	35.0	0	13.2 (5.20)
1996	W	0	0	22.5	4.02	3.53	6.07 (3.82)
1997	W	0	5.82	29.0	0	0	9.37 (4.83)
1998	W	0	5.24	43.2	3.38	0	9.40 (5.77)
1999	W	3.72	78.6	73.6	2.63	0	35.9 (19.3)
2000	AN	0	0	9.14	0	0	1.63 (1.31)
Yearly mean 1995-2000 (SE)		0.62 (0.62)	15.0 (12.8)	35.1 (0.62)	7.51 (5.55)	0.588 (0.588)	12.6 (2.59)
2001	D	0	0	8.07	6.19	0	3.19 (1.52)
2002	D	0	22.17	34.6	6.80	--	17.6 (7.06)
2003	AN	0	0	1.16	0	--	0.309 (0.309)
2004	BN	0	0	35.7	3.28	--	14.5 (7.79)
2005	BN	2.53	2.98	23.5	0	--	8.38 (4.64)

Sacramento Trawls

Methods

Data from midwater and Kodiak trawls is used to estimate the relative abundance and timing of juvenile Chinook salmon entering the Delta from the Sacramento River. Trawling has been conducted at Sherwood Harbor, approximately 5 km downstream of Sacramento (rm 55), since 1988, except during 1990, when sampling was conducted approximately 34 km downstream near Courtland, CA (rm 27). Sampling was conducted only during spring from 1988-1993, but has been conducted year-round since 1994. Ten 20-minute tows are conducted between three and seven days/week depending on the need to index the relative abundance of juvenile salmon entering the Delta.

Since December 1994, Kodiak trawls have been conducted from mid-October through March and midwater trawls have been conducted the remainder of the year. During periods of high flow when large debris moves downstream, midwater trawls are used in place of Kodiak trawls for safety reasons due to their smaller size and better maneuverability.

During the 2001-2005 field seasons, midwater trawls were conducted at Sacramento from August-September and from April-July. During the 2004 field season, midwater trawls were conducted at Sacramento from mid-February to mid-March only due to high flows and large debris moving downstream.

All trawling was conducted in the middle of the channel in an upstream direction within 1.5 km of Sherwood Harbor. Occasionally, inclement weather, mechanical problems, excessive fish catch, or some other uncontrollable event reduced tow times or number of tows on a given sampling day.

Results

A total of 448 winter-run salmon, 432 in Kodiak trawls and 16 in midwater trawls, were captured in Sacramento trawls between 2001-2005 field seasons (Figures 26-30). Historically, mean monthly CPUE of winter-run salmon has peaked during February-March, as it did in 2001. Monthly mean CPUE peaked during November in 2002 and during December in each year from 2003-2005 (Table 7a). In 2001, 68 winter-run Chinook salmon were captured, 89 fish in 2002, 86 fish in 2003, 113 fish in 2004, and 92 fish in 2005.

We caught 34,928 spring-/fall-run salmon in Sacramento trawls during the 2001-2005 field seasons (Figures 26-30). Most were caught between late January and late June, and coincided with increasing flows in the Sacramento River. We caught 7,870 spring/fall salmon in 2001, 5,426 fish in 2002, 6,134 fish in 2003, 9,531 fish in 2004, and 5,967 fish in 2005. Peak monthly CPUE occurred in February during 2001, in April during 2002, 2003, and 2004, and in May during the 2005 field season (Table 7b).

A total of 85 late fall-run Chinook juveniles were caught in Sacramento trawls during the 2001-2005 field seasons (Figures 26-30). We caught nine late fall-run salmon in 2001, all of which were yearlings from 2000 brood year. We caught 24 late fall-run salmon in 2002 between August and January, and all 24 were yearlings from the 2001 brood year. We captured 32 late fall-run salmon in 2003, 27 yearlings from brood year 2002 and five fry from brood year 2003. We captured five late fall-run salmon in 2004, all five were yearlings from brood year 2003. In 2005, 15 late fall-run salmon were caught, seven yearlings from 2004 brood year and eight fry from the 2005 brood year. In the 2001, 2003, and 2004 field seasons, mean monthly CPUE peaked during December. In 2002, mean monthly CPUE peaked in November. In 2005, mean monthly CPUE peaked in May.

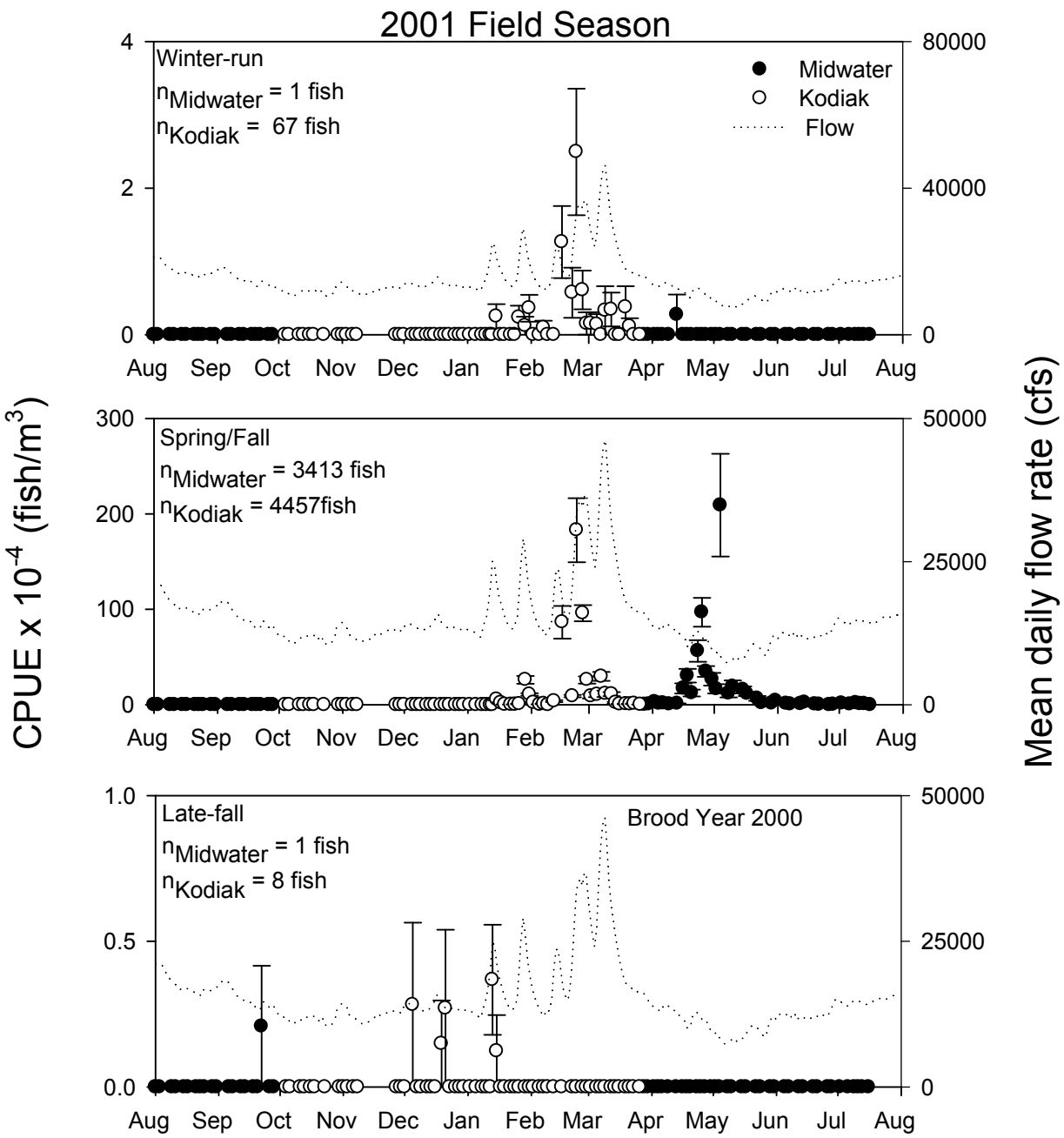

Figure 26. Mean daily CPUE (x 10^{-4}) of winter-, spring/fall-, and late fall-run Chinook salmon in trawls at Sherwood Harbor (Sacramento trawls) and concurrent mean daily flow rates at Freeport, Sacramento River during the 2001 field season. Sample size (n) corresponds to total number of fish caught in each trawl during the 2001 field season. Note the change in scale among panels. Error bars are ± 1 SE.

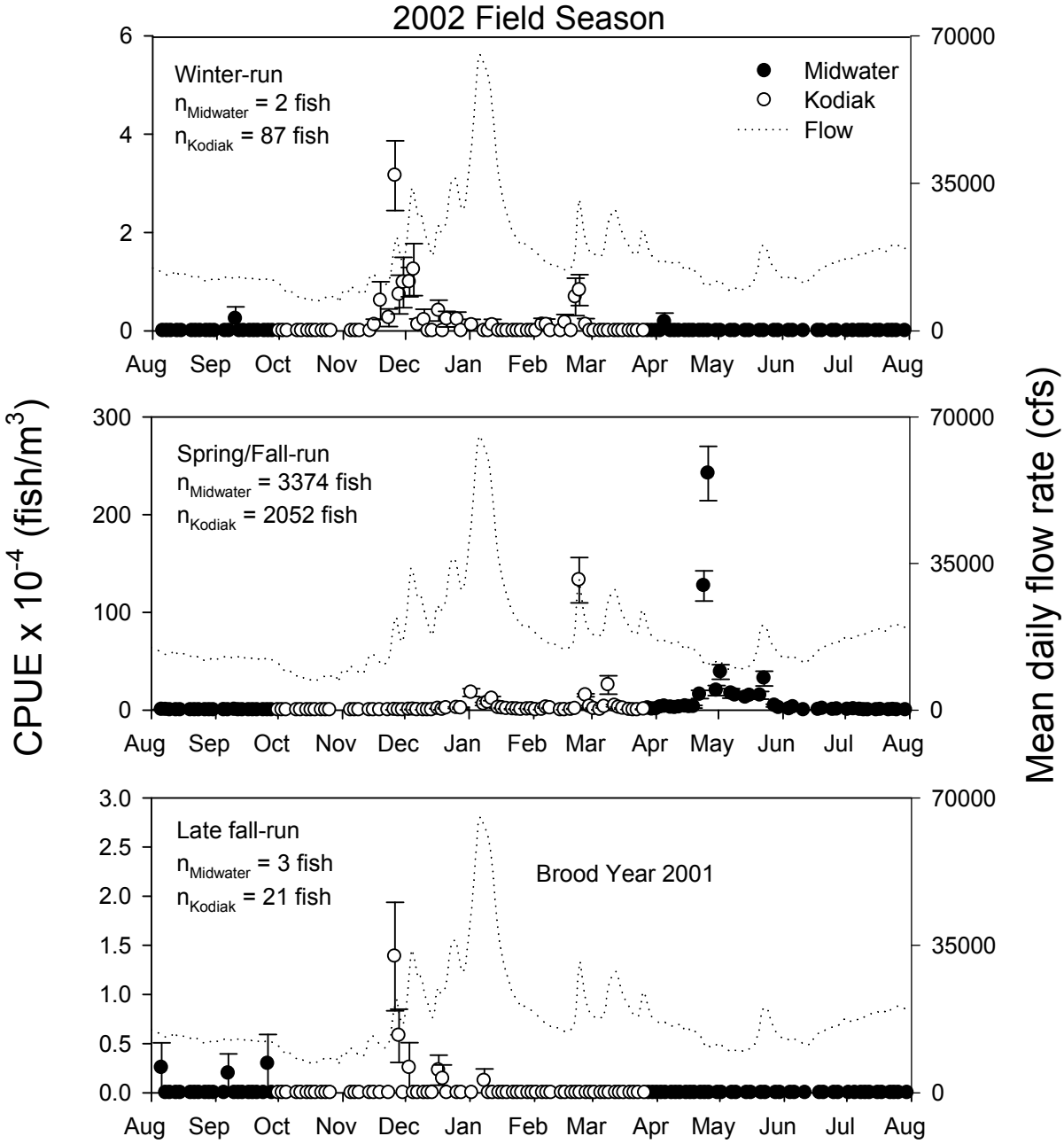

Figure 27. Mean daily CPUE (x 10^{-4}) of winter-, spring/fall-, and late fall-run Chinook salmon in trawls at Sherwood Harbor (Sacramento trawls) and concurrent mean daily flow rates at Freeport, Sacramento River during the 2002 field season. Sample size (n) corresponds to total number of fish caught in each trawl during the 2002 field season. Note the change in scale among panels. Error bars are ± 1 SE.

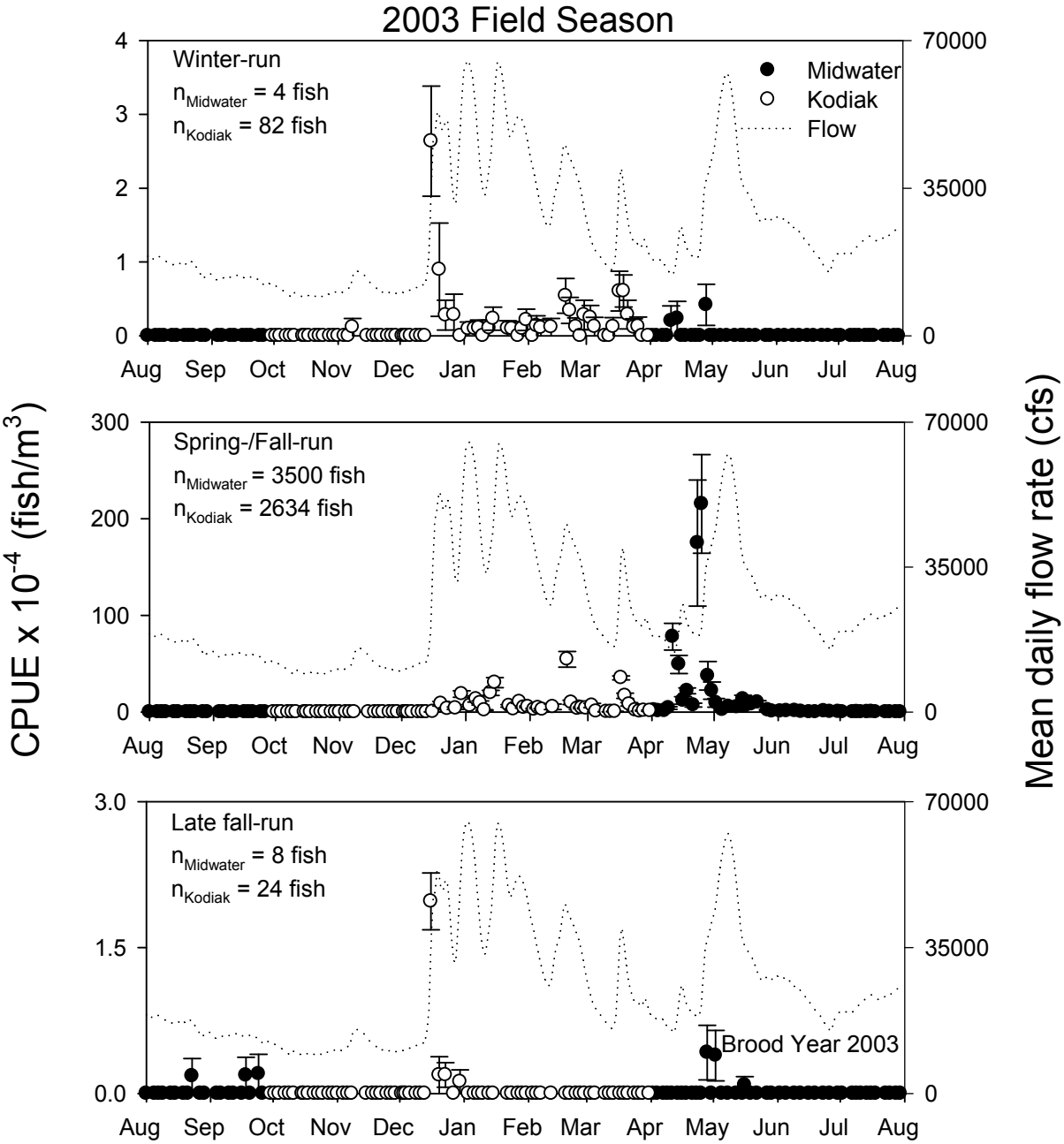

Figure 28. Mean daily CPUE (x 10^{-4}) of winter-, spring/fall-, and late fall-run Chinook salmon in trawls at Sherwood Harbor (Sacramento trawls) and concurrent mean daily flow rates at Freeport, Sacramento River during the 2003 field season. Sample size (n) corresponds to total number of fish caught in each trawl during the 2003 field season. Note the change in scale among panels. Error bars are ± 1 SE.

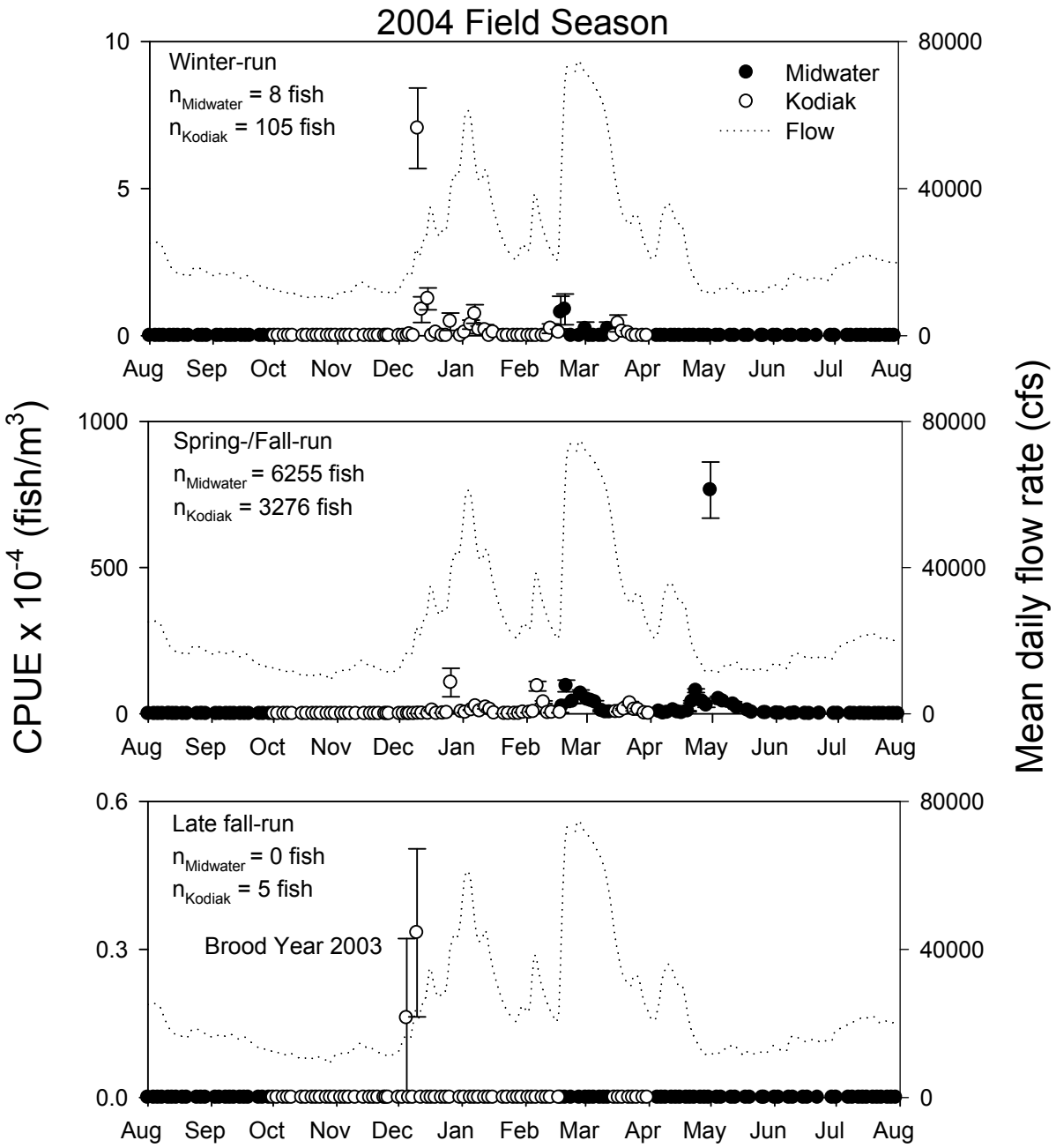

Figure 29. Mean daily CPUE (x 10^{-4}) of winter-, spring/fall-, and late fall-run Chinook salmon in trawls at Sherwood Harbor (Sacramento trawls) and concurrent mean daily flow rates at Freeport, Sacramento River during the 2004 field season. Sample size (n) corresponds to total number of fish caught in each trawl during the 2004 field season. Note the change in scale among panels. Error bars are ± 1 SE.

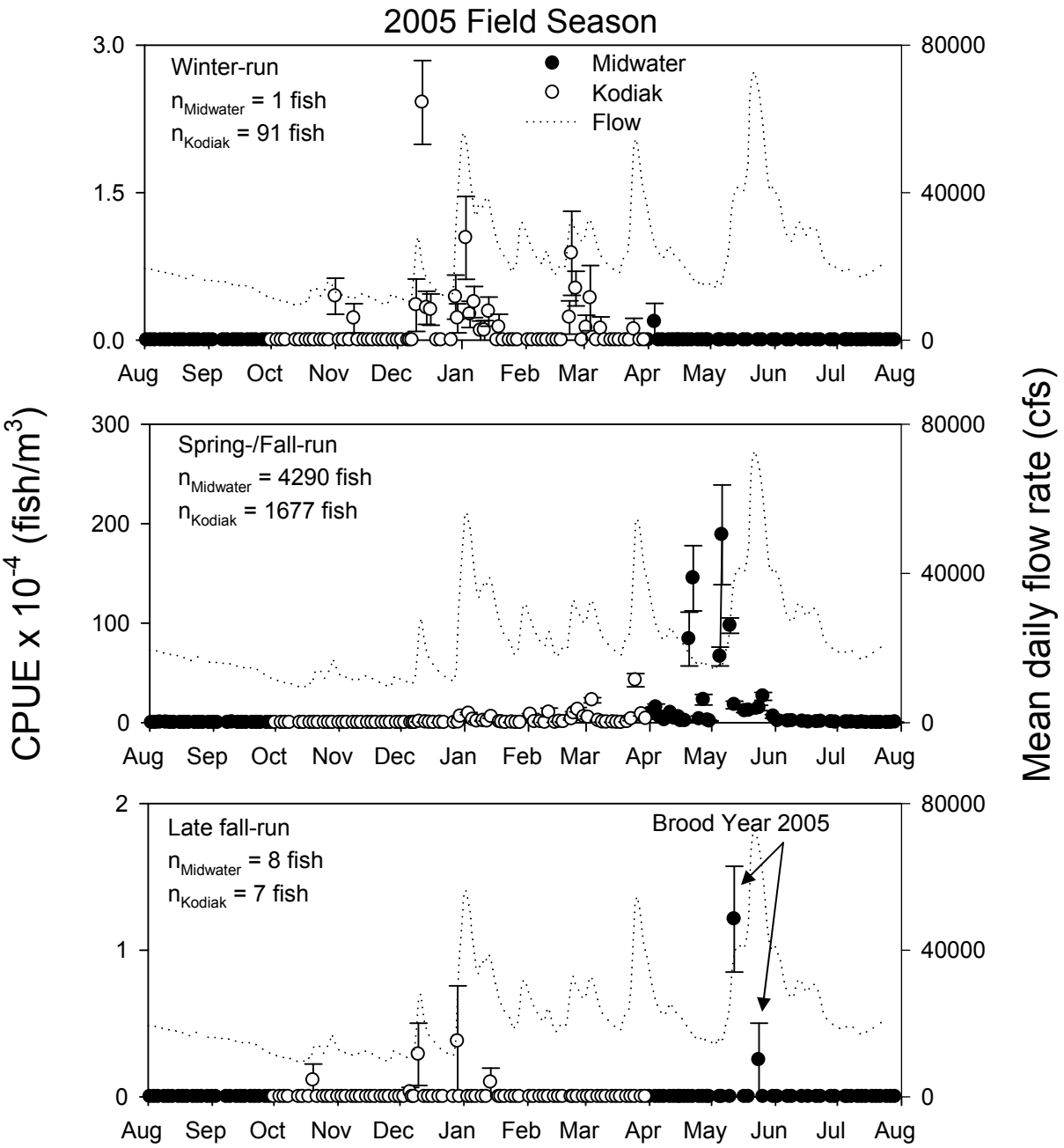

Figure 30. Mean daily CPUE (x 10^{-4}) of winter-, spring/fall-, and late fall-run Chinook salmon in trawls at Sherwood Harbor (Sacramento trawls) and concurrent mean daily flow rates at Freeport, Sacramento River during the 2005 field season. Sample size (n) corresponds to total number of fish caught in each trawl during the 2005 field season. Note the change in scale among panels. Error bars are ± 1 SE.

Table 7. Summary table of CPUE x 10^{-4} (fish/m^3) of (a) winter-, (b) fall/spring-run, and (c) late fall-run Chinook salmon in midwater and Kodiak trawls at Sherwood Harbor (Sacramento trawls) by month and year. Yearly mean and standard error (SE) values were calculated using years as replicates (n = 3-7 for MWTR, n = 5 for KDTR). Weekly mean and SE values were calculated using weeks as replicates (n = 20-42 for MWTR, n = 16-29 for KDTR). Shaded boxes indicate peak monthly CPUE. Water year (CDEC, 2006): AN = above normal; BN = below normal; C = critical; D = dry; W = wet

(a) Winter-run

Field Season	Water year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Weekly mean (SE)
1993 MWTR	AN	--	0	0	0	0.0462	0.112	0.178	0.650	0.366	0	0	--	0.1435 (0.0519)
1994 MWTR	C	--	0	0	0	0	0	0.107	0.0238	0.0536	0	0	--	0.0193 (0.0189)
1995 MWTR	W	--	0	0	0	0	--	--	0.274	0.281	0	0	0	0.0543 (0.0394)
1995 KDTR	W	--	--	0	0	0.0259	0.0328	0.268	0.892	0.344	--	--	--	0.269 (0.0367)
1996 MWTR	W	0	0	0	--	--	--	--	--	0.0132	0	0	0	0.00212 (0.00333)
1996 KDTR	W	--	--	0	0	0.239	0.137	0.201	0.769	0.0604	--	--	--	0.249 (0.0107)
1997 MWTR	W	0	0	0	--	--	0	0.0407	0	0.0181	0	0	0	0.00472 (0.00412)
1997 KDTR	W	--	--	0	0.0105	0.0456	0	0.200	0.144	--	--	--	--	0.0536 (0.0130)
1998 MWTR	W	0	0	0	--	--	--	--	0	0.0743	0	0	--	0.0130 (0.0101)
1998 KDTR	W	--	0	0	0.0678	0.0807	0.0189	0.125	0	--	--	--	--	0.0831 (0.0204)
1999 MWTR	W	--	--	--	--	0.532	--	--	0.109	0.00843	0	0	0	0.0317 (0.00567)
1999 KDTR	W	--	0	0.0157	0.475	0.145	0.0463	0.0313	0.106	--	--	--	--	0.124 (0.0142)
2000 MWTR	AN	0	0	0	--	--	--	--	0.164	0	0	0	0	0.00630 (0.00630)
2000 KDTR	AN	--	--	0	0	0	0.147	0.218	0.206	--	--	--	--	0.102 (0.0386)
Yearly mean 1993-2000 MWTR (SE)		0 (0)	0 (0)	0 (0)	0 (0)	0.144 (0.130)	0.0373 (0.0373)	0.108 (0.0396)	0.174 (0.0878)	0.102 (0.0498)	0 (0)	0 (0)	0 (0)	0.0344 (0.0167)
Yearly mean 1995-2000 KDTR (SE)		--	0 (0)	0.00315 (0.00315)	0.111 (0.0919)	0.0895 (0.0364)	0.0638 (0.0257)	0.174 (0.0341)	0.353 (0.154)	0.202 (0.142)	--	--	--	0.147 (0.0368)
2001 MWTR	D	0	0	--	--	--	--	--	0	0.0228	0	0	0	0.0105 (0.0105)
2001 KDTR	D	--	--	0	0	0	0.069	0.519	0.133	--	--	--	--	0.136 (0.0674)
2002 MWTR	D	0	0.0222	--	--	--	--	--	0	0.0138	0	0	0	0.0541 (0.0313)
2002 KDTR	D	--	--	0	0.587	0.314	0.0194	0.187	0	--	--	--	--	0.167 (0.0719)
2003 MWTR	AN	0	0	--	--	--	--	--	--	0.0658	0	0	0	0.0317 (0.0187)
2003 KDTR	AN	--	0	0	0.0107	0.341	0.104	0.183	0.186	--	--	--	--	0.154 (0.0669)
2004 MWTR	BN	0	0	--	--	--	--	0.419	0.0769	0	0	0	0	0.0689 (0.0545)
2004 KDTR	BN	--	--	0	0	0.701	0.142	0.0491	0.0804	--	--	--	--	0.177 (0.110)
2005 MWTR	AN	0	0	--	--	--	--	--	--	0.0124	0	0	0	0.00689 (0.00689)
2005 KDTR	AN	--	--	0	0.0515	0.291	0.192	0.136	0.0602	--	--	--	--	0.116 (0.0453)

Table 7 (cont.)

(b) Spring-/Fall-run

Field Season	Water year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Weekly mean (SE)
1993 MWTR	AN	--	0.0182	0	0.0416	0.263	1.80	2.47	2.38	50.9	58.3	8.37	--	12.0 (4.87)
1994 MWTR	C	--	0.0416	0	0.00738	0.0865	2.61	14.1	0.781	93.7	30.8	1.53	--	15.9 (7.75)
1995 MWTR	W	--	0	0	0	0.0861	--	--	18.0	18.1	13.6	4.06	0.293	5.87 (1.74)
1995 KDTR	W	--	--	--	--	0	12.4	8.17	58.80	9.43	--	--	--	14.5 (4.33)
1996 MWTR	W	0.0834	0	0	--	--	--	--	--	31.4	30.8	1.47	0.204	8.96 (3.47)
1996 KDTR	W	--	--	0	0	2.52	32.5	172	18.2	51.2	--	--	--	36.7 (17.2)
1997 MWTR	W	0	0	0	--	--	2.48	0.913	1.67	56.6	13.2	0.881	0.598	9.35 (4.12)
1997 KDTR	W	--	--	0	0.00964	1.22	20.4	4.23	3.33	--	--	--	--	2.27 (0.982)
1998 MWTR	W	0.167	0	0	--	--	--	--	7.35	25.9	19.3	8.77	--	10.0 (3.06)
1998 KDTR	W	--	--	0	0.0129	0.309	72.6	53.0	12.2	--	--	--	--	28.8 (13.1)
1999 MWTR	W	--	--	--	--	0	--	--	5.46	32.8	52.6	2.07	0.140	17.9 (6.88)
1999 KDTR	W	--	0	0	0.0167	0.145	14.5	35.4	4.57	--	--	--	--	8.02 (3.02)
2000 MWTR	AN	0.0643	0	0	--	--	--	--	17.5	55.8	12.2	0.321	0.0212	9.38 (5.23)
2000 KDTR	AN	--	--	0	0	0	12.3	18.6	4.72	--	--	--	--	6.18 (2.06)
Yearly mean 1993-2000 MWTR (SE)		0.0787 (0.0344)	0.00854 (0.00607)	0 (0)	0.0163 (0.0128)	0.109 (0.0553)	2.30 (0.253)	5.83 (4.17)	7.59 (2.76)	45.7 (8.53)	28.9 (6.39)	3.43 (1.19)	0.251 (0.0973)	11.2 (1.40)
Yearly mean 1995-2000 KDTR (SE)		--	0 (0)	0 (0)	0.00785 (0.00340)	0.699 (0.409)	27.5 (9.55)	48.6 (25.8)	16.97 (8.69)	30.3 (20.9)	--	--	--	16.1 (5.60)
2001 MWTR	D	0	0	--	--	--	--	--	0.251	23.5	29.9	0.803	0.930	22.8 (11.8)
2001 KDTR	D	--	--	0	0	0	3.28	40.8	7.01	--	--	--	--	9.34 (4.58)
2002 MWTR	D	0.0605	0.0469	--	--	--	--	--	1.35	33.2	17.0	0.957	0.203	22.1 (14.3)
2002KDTR	D	--	--	0	0.0256	0.857	4.43	14.4	3.66	--	--	--	--	4.02 (1.90)
2003 MWTR	AN	0	0	--	--	--	--	--	--	48.2	6.25	0.573	0.0455	25.7 (15.1)
2003 KDTR	AN	--	0	0	0	2.90	10.1	10.1	6.15	--	--	--	--	5.06 (1.59)
2004 MWTR	BN	0.0302	0	--	--	--	--	57.8	25.5	83.3	21.0	0.601	0.0508	50.2 (27.3)
2004 KDTR	BN	--	--	0	0	9.50	7.83	22.1	11.8	--	--	--	--	6.80 (2.23)
2005 MWTR	AN	0.0358	0.032	--	--	--	--	--	--	21	49.1	0.939	0.129	28.4 (12.8)
2005 KDTR	AN	--	--	0	0	0.572	1.96	4.44	6.94	--	--	--	--	2.29 (0.762)

Table 7 (cont.)

(c) Late fall-run

Field Season	Water year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Weekly mean (SE)
1993 MWTR	AN	--	0	0	0.591	0.101	0.00721	0.00749	0	0.0200	0	0	--	0.0706 (0.0520)
1994 MWTR	C	--	0.173	0.183	0.00654	0.0550	0.0138	0.0281	0	0	0	0	--	0.0399 (0.0189)
1995 MWTR	W	--	0	0	0.0121	0.446	--	--	0	0	0	0	0.0134	0.0528 (0.0394)
1995 KDTR	W	--	--	--	--	0.0484	0.0897	0	0	0	--	--	--	0.0539 (0.0889)
1996 MWTR	W	0.0132	0.0157	0	--	--	--	--	--	0.00660	0	0	0	0.00564 (0.00329)
1996 KDTR	W	--	--	0	0	0.0697	0.0423	0	0	0	--	--	--	0.0206 (0.0742)
1997 MWTR	W	0	0	0	--	--	0.0958	0	0	0	0	0	0	0.00412 (0.00412)
1997 KDTR	W	--	--	0	0.0374	0.0526	0.150	0.0139	0	--	--	--	--	0.0272 (0.0190)
1998 MWTR	W	0.0823	0.0578	0.0560	--	--	--	--	0	0.0161	0	0.0140	--	0.0368 (0.0101)
1998 KDTR	W	--	--	0	0.108	0.0431	0	0	0	0	--	--	--	0.0283 (0.0281)
1999 MWTR	W	--	--	--	--	0.107	--	--	0	0.0150	0	0	0	0.00866 (0.00566)
1999 KDTR	W	--	0	0.00737	0.134	0.0640	0	0	0	--	--	--	--	0.0309 (0.0668)
2000 MWTR	AN	0.0312	0.0231	0	--	--	--	--	0	0	0	0	0	0.00677 (0.00492)
2000 KDTR	AN	--	--	0	0.00807	0.00583	0.00724	0	0	--	--	--	--	0.00373 (0.00213)
Yearly mean 1993-2000 MWTR (SE)		0.317 (0.018)	0.0385 (0.0237)	0.0341 (0.0260)	0.203 (0.194)	0.177 (0.0903)	0.0390 (0.0285)	0.0119 (0.00842)	0 (0)	0.00721 (0.00302)	0 (0)	0.00175 (0.00175)	0.00268 (0.00300)	0.0282 (0.00900)
Yearly mean 1995-2000 KDTR (SE)		--	0 (0)	0.00147 (0.00147)	0.0574 (0.0270)	0.0473 (0.00922)	0.0482 (0.0248)	0.00231 (0.00231)	0 (0)	0 (0)	--	--	--	0.0274 (0.00664)
2001 MWTR	D	0	0.0231	--	--	--	--	--	0	0	0	0	0	0.00801 (0.00801)
2001 KDTR	D	--	--	0	0	0.0539	0.0351	0	0	--	--	--	--	0.0153 (0.00771)
2002 MWTR	D	0.0231	0.0449	--	--	--	--	--	0	0	0	0	0	0.0277 (0.0156)
2002 KDTR	D	--	--	0	0.197	0.0569	0.0101	0	0	--	--	--	--	0.0362 (0.0265)
2003 MWTR	AN	0.0163	0.043	--	--	--	--	--	--	0.0323	0.0475	0	0	0.0541(0.0313)
2003 KDTR	AN	--	0	0	0	0.206	0	0	0	--	--	--	--	0.0458 (0.0401)
2004 MWTR	BN	0	0	--	--	--	--	0	0	0	0	0	0	0(0)
2004 KDTR	BN	--	--	0	0	0.0353	0	0	0	--	--	--	--	0.00631 (0.00486)
2005 MWTR	AN	0	0	--	--	--	--	--	--	0	0.162	0	0	0.0541 (0.0455)
2005 KDTR	AN	--	--	0.00931	0	0.0500	0.00816	0	0	--	--	--	--	0.0102 (0.00560)

Kodiak Trawl at Mossdale

Methods

Kodiak trawling at Mossdale has been conducted since 1997 to index juvenile salmon moving into the Delta from the San Joaquin River basin. All San Joaquin River Chinook salmon captured in the Kodiak trawl are classified as fall-run. Although we attempt to sample year-round, this is rarely possible because sampling is not possible when flows on the San Joaquin River are too low. This is usually an issue during late summer and fall months before significant rainfall has occurred. Region 4 of CDFG has sampled at Mossdale in place of the DJFMP during spring months (April, May and June) since 1989 (San Joaquin River Group Authority, 2005).

During the 2001 field season, sampling was conducted from mid-February through July. In the 2002 field season, trawls were conducted from August, to early September, January 7th through the 18th and from late February through mid-July. In 2003, trawls were conducted from mid-December through July. In the 2004 and 2005 field seasons, sampling was conducted year around. Low river flows prevented us from conducting year around trawls prior to 2004.

Results

We observed a steady decline in mean weekly CPUE of fall-run juvenile Chinook salmon at Mossdale during 2001-2005 field seasons (Table 8). A total of 15,559 fall-run salmon were caught during the 2001-2005 field seasons (Figure 31). In 2001, 4,254 fall-run salmon were captured between February and July. The second highest average CPUE on record occurred in April (Table 8). In 2002, we caught 3,914 salmon between January and mid-June (Figure 31b). The highest mean monthly CPUE recorded since 1997 occurred in May 2002 (Table 8). In 2003, we caught 2,860 salmon between late January and mid-June (Figure 31c). Mean monthly CPUE for 2003 peaked in April. In 2004, we caught 2,151 salmon between January and May and mean monthly CPUE peaked in May (Table 8; Figure 31d). In the 2005 field season, we captured 2,380 fall-run salmon between January and July (Figure 31e). Peak CPUE during the 2005 field season occurred in May (Table 8).

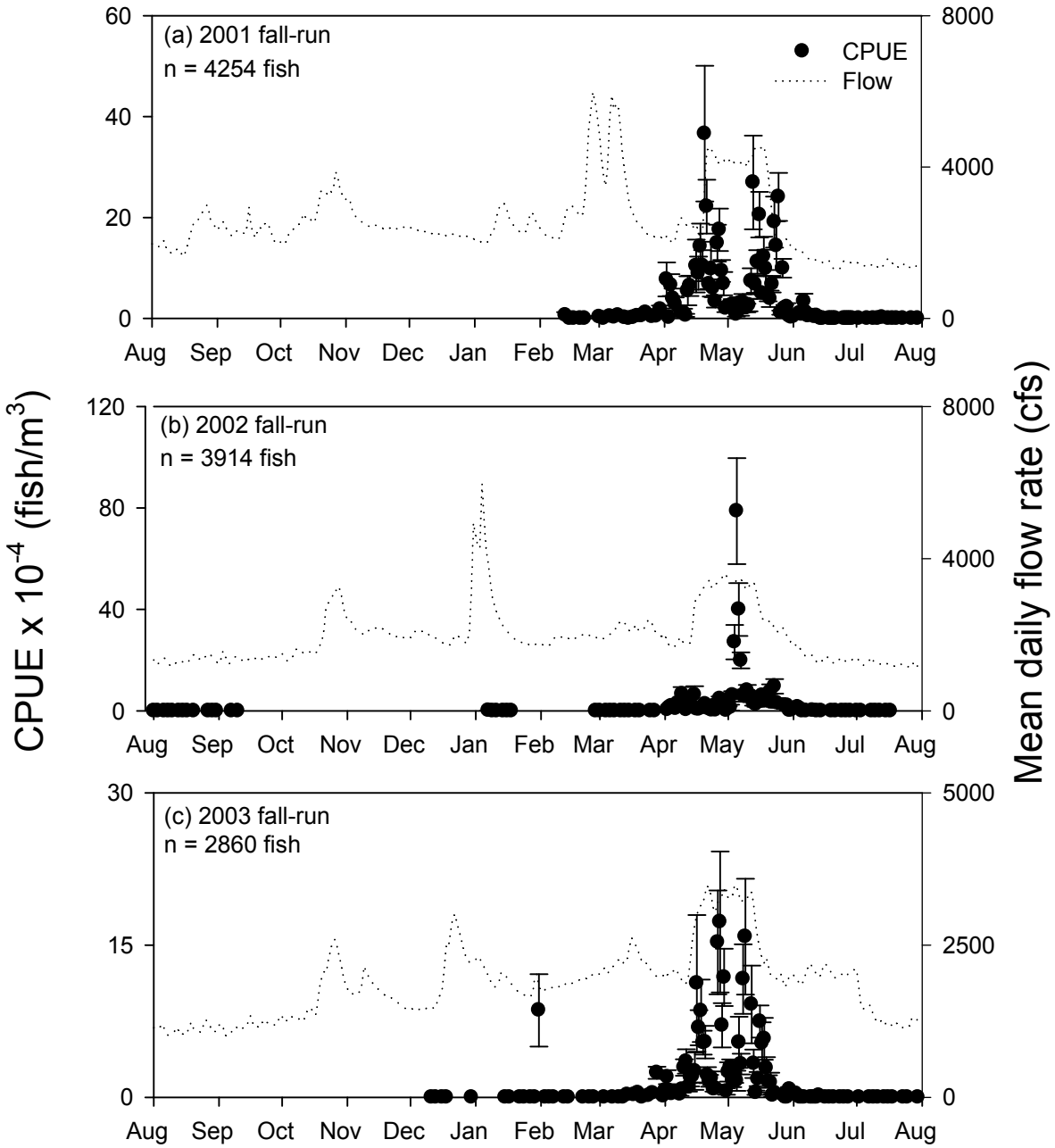

Figure 31. Mean daily CPUE (x 10^{-4}) of fall-run Chinook salmon juveniles in Kodiak trawls at Mossdale, San Joaquin River and concurrent mean daily flow rate at Vernalis during the (a) 2001, (b) 2002, (c) 2003, (d) 2004, and (e) 2005 field seasons. Sample size (n) corresponds to total number of fish caught during each field season. Note the change in scale among panels. Error bars are ± 1 SE.

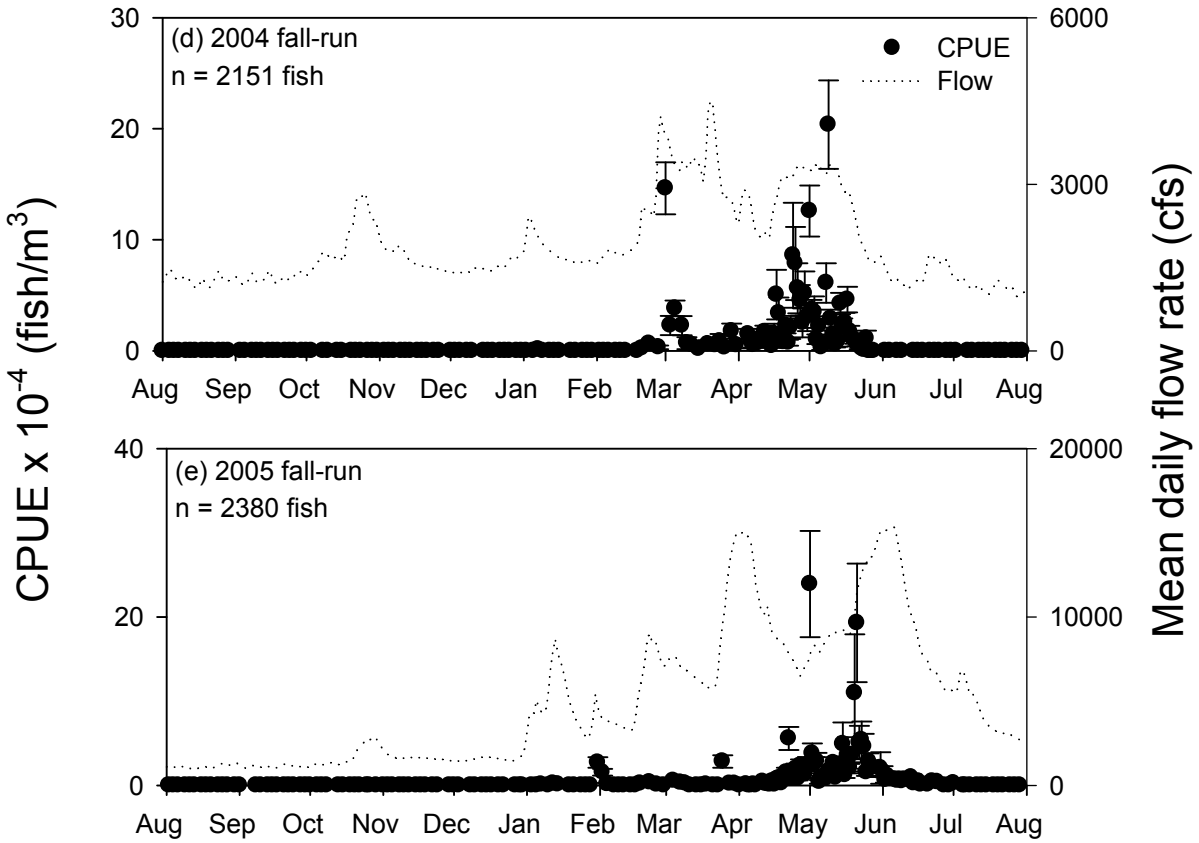

Figure 31 (cont.)

Table 8. Summary table of CPUE x 10^{-4} (fish/m^3) of fall-run Chinook salmon in Mossdale Kodiak trawls by month and year. Yearly mean and standard error (SE) values were calculated using years as replicates (n = 1-4). Weekly mean and SE values were calculated using weeks as replicates (n = 14-37). Standard error calculations were not possible when n = 1. Shaded boxes indicate peak monthly CPUE for each year. Shaded boxes indicate peak monthly CPUE. Water year (CDEC, 2006): AN = above normal; BN = below normal; D = dry; W = wet

Field Season	Water year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Weekly mean (SE)
1997	W	--	0	0	0	0	--	--	0.325	2.14	1.06	0.393	--	0.493 (0.154)
1998	W	--	--	--	--	--	--	--	--	2.58	6.09	2.50	--	3.47 (0.802)
1999	AN	--	--	--	0	0	0.810	3.09	0.630	1.32	1.94	0.962	--	1.04 (0.231)
2000	AN	--	--	0	0	0	0.113	3.26	0.681	2.92	2.05	0.372	--	1.03 (0.349)
Yearly mean 1997-2000 (SE)		--	0	0 (0)	0 (0)	0 (0)	0.462 (0.349)	3.18 (0.085)	0.545 (0.111)	2.24 (0.346)	2.79 (1.12)	1.06 (0.500)	--	1.506 (0.666)
2001	D	--	--	--	--	--	--	0.125	0.455	8.62	7.071	0.409	0.016	2.82 (0.940)
2002	D	0	0	--	--	--	0.0144	0	0	1.97	9.61	0.207	0	1.62 (0.815)
2003	BN	--	--	--	--	0	1.23	0	0.332	4.15	3.52	0.0435	0	1.12 (0.359)
2004	D	0	0	0	0	0	0.01	0.115	2.22	2.65	2.72	0	0	0.591 (0.200)
2005	W	0	0	0	0	0	0.264	0.218	0.37	0.929	4.17	0.539	0.0196	0.514 (0.175)

Midwater Trawl at Chipps Island

Methods

The DJFMP has conducted midwater trawling at Chipps Island since May 1976. This sampling was initiated as a way to gain information about fall-run juvenile salmon emigrating from the Delta towards the Pacific Ocean. Originally, ten 20-minute tows were conducted three to seven days each week from April to July. Sampling was conducted seven days per week only during experimental releases of coded wire tagged (CWT) salmon (usually December-January and April-May) to better recover these experimental fish released upstream and in the Delta. CWT information is used to estimate survival of salmon emigrating through the Delta (see sections below). Sampling effort has increased since 1976. In 1996, we began sampling year round to better understand the temporal patterns of salmon emigrating downstream. In 1998, we began conducting 20 tows per day in split shifts to coincide with CWT salmon releases from the Vernalis Adaptive Management Plan (VAMP) (April-May). This doubling of effort was implemented to increase the number of CWT salmon recovered from VAMP releases.

Trawls were conducted within a 3 km section of river upstream of the western tip of Chipps Island. Trawls were conducted in both directions (upstream and downstream) regardless of tide in three channel locations: north, south, and middle. Occasionally, inclement weather, mechanical problems, or excessive catch reduced tow duration or number of tows per day.

During the 2001-2005 field seasons, ten 20-minute tows were conducted between three and seven days per week depending on the need to recover CWT salmon for survival studies. Sampling generally was conducted three days per week, except during CWT recapture periods. Recapture periods during the 2001-2005 field seasons were as follows: 2001 field season – January 21 – February16, April 16 – June 15; 2002 field season – January 16 – February 2, April 1 – June 21; 2003 field season – October 6 – November 14, December 8 – December 28, April 24 – June 14; 2004 field season – December 7 – January 30, April 24 – July 2; 2005 field season – December 6 – January 21, April 11 – July 1. During these recapture periods, sampling increased to seven days/week. Efforts during VAMP releases were increased further to twenty 20-minute tows seven days per week. The VAMP periods during the 2001-2005 field seasons were: May 3 – June 2, 2001, April 1 – May 28, 2002, April 21 – May 31, 2003, April 24 – May 22 2004 and June 11 – June 24, 2005.

Results

A total of 709 winter-run Chinook salmon were captured in Chipps Island trawls during 2001-2005 (Figures 32-36). Average monthly CPUE peaked in March during each field season, consistent with all other years since 1994 (Table 9a). In 2001, we caught 110 winter-run Chinook salmon between January and May. In the 2002 field season, we caught 116 winter-run salmon between December and May. In 2003, we caught 244 winter-run fish between December and May. In 2004, 115 winter-run salmon were

caught between December and April. In 2005, we captured 124 winter-run salmon between December and May.

A total of 74,148 spring/fall-run Chinook salmon were caught at Chipps Island during the 2001-2005 field seasons (Figures 32-36). The majority of the spring/fall-run were captured between March and June of each field year. Specifically, mean monthly CPUE peaked in May during 2001 and 2002 field seasons, and in April during 2003, 2004, and 2005 field seasons (Table 9b). We caught 10,335 spring/fall-run in 2001, 9,282 in 2002, 20,375 in 2003, 13,231 in 2004, and 20,925 in 2005.

We caught 206 late fall-run salmon between 2001-2005 field seasons (Figures 32-36). Peak mean monthly CPUE occurred during December for all years (Table 9c). We caught 21 late fall-run fish in 2001. There were 20 yearling size smolts from the 2000 brood year that were captured between October and February and ranged between 103-191 mm (FL). Only one late fall fry from the 2001 brood year was captured on 7/14/01. In 2002, we caught 33 late fall-run salmon; 32 were yearlings from the 2001 brood year ranging between 79-185 mm (FL) and one fry (62 mm) from the 2002 brood year captured on 7/19/02. In 2003, 85 late fall-run fish were captured between September and January; all were late fall-run yearlings from the 2002 brood year ranging in size from 81 to 175 mm (FL). In the 2004 field season, we caught 43 late fall-run fish, all of which were 2003 brood year yearlings and ranged between 87-178 mm (FL). In 2005, there were 24 late fall-run salmon captured between August and January, all were yearlings from the 2004 brood year that ranged in size from 90 to156 mm (FL).

As in past years, most salmon migrated through the Delta during April and May, reflecting the influence of hatchery releases of fall-run salmon from CNFH on overall abundances.

Figure 32. Mean daily CPUE (x 10^{-4}) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in midwater trawls at Chipps Island and concurrent daily Delta outflow during the 2001 field season. Sample size (n) corresponds to total number of fish caught during the 2001 field season. Note the change in scale among panels. Error bars are ± 1 SE.

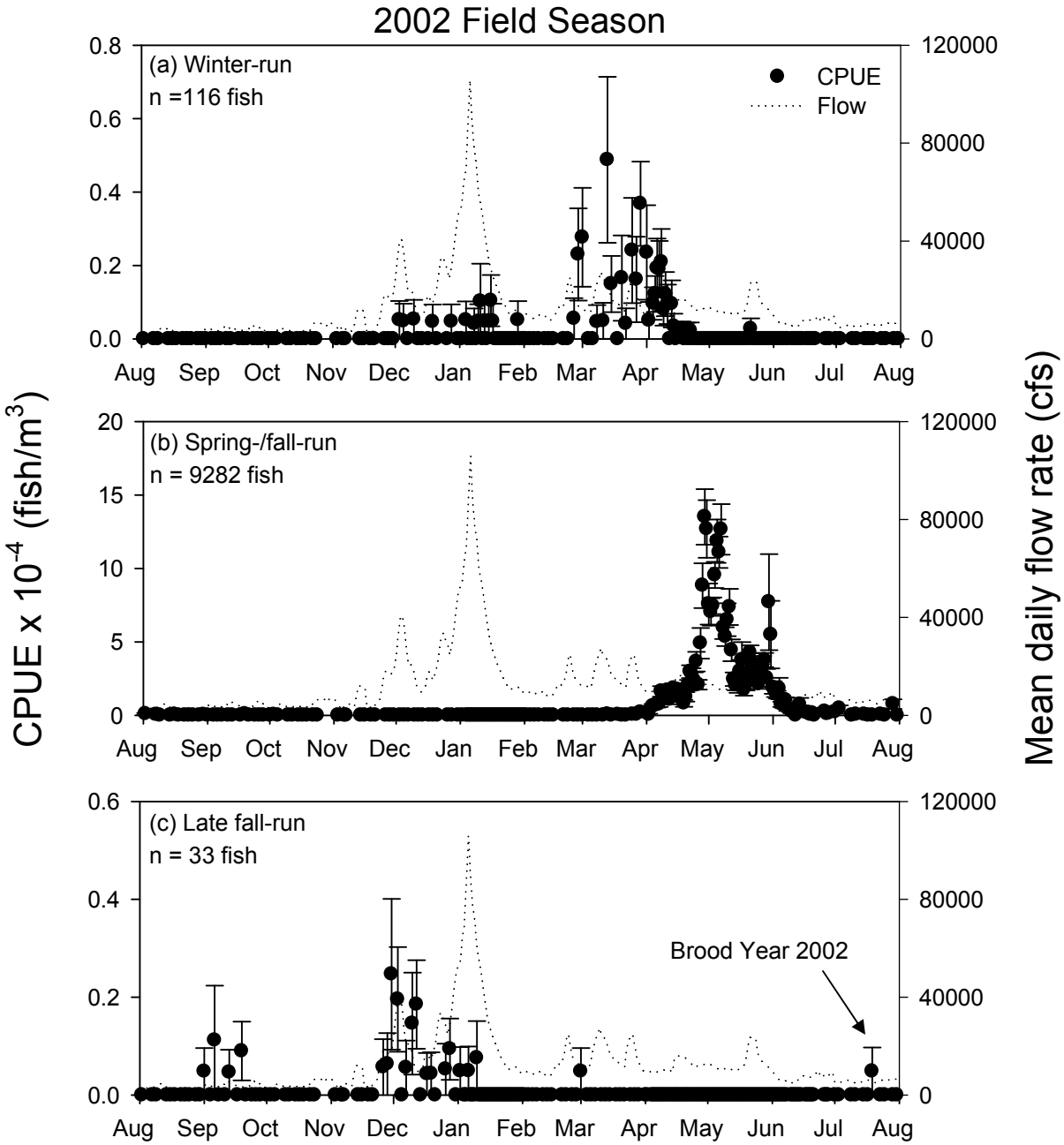

Figure 33. Mean daily CPUE (x 10^{-4}) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in midwater trawls at Chipps Island and concurrent daily Delta outflow during the 2002 field season. Sample size (n) corresponds to total number of fish caught during the 2002 field season. Note the change in scale among panels. Error bars are ± 1 SE.

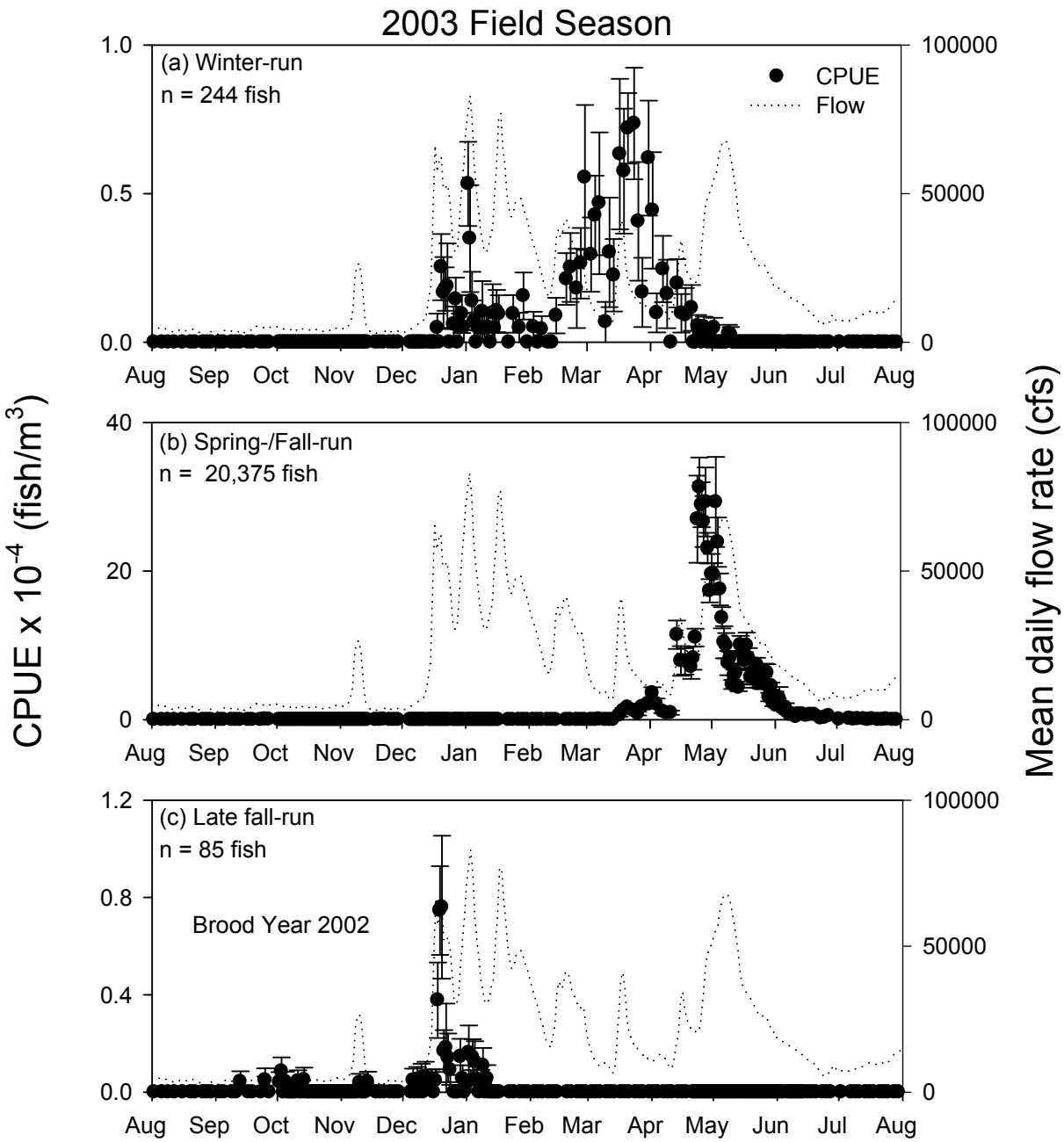

Figure 34. Mean daily CPUE (x 10^{-4}) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in midwater trawls at Chipps Island and concurrent daily Delta outflow during the 2003 field season. Sample size (n) corresponds to total number of fish caught during the 2003 field season. Note the change in scale among panels. Error bars are ± 1 SE.

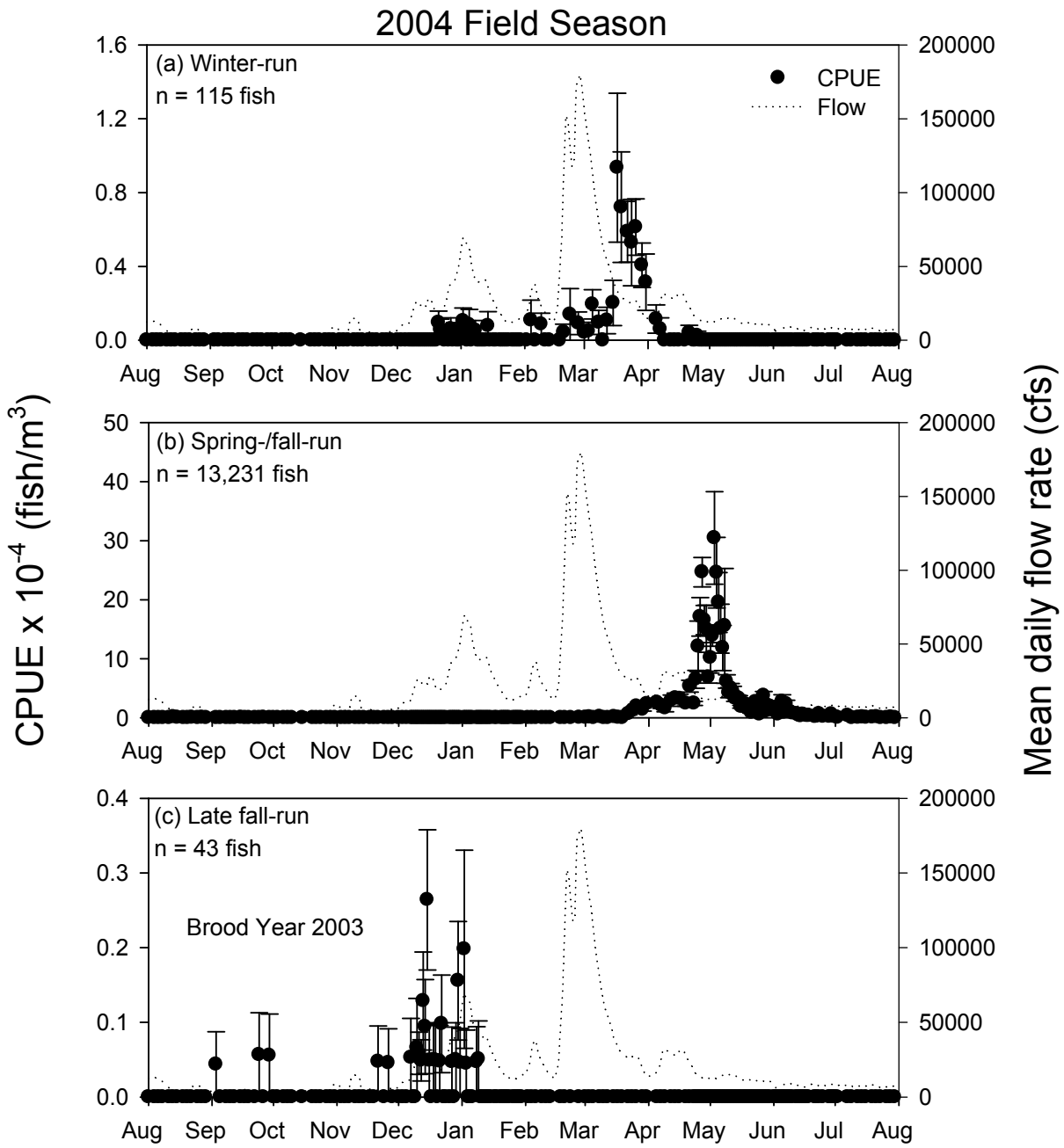

Figure 35. Mean daily CPUE (x 10^{-4}) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in midwater trawls at Chipps Island and concurrent daily Delta outflow during the 2004 field season. Sample size (n) corresponds to total number of fish caught during the 2004 field season. Note the change in scale among panels. Error bars are ± 1 SE.

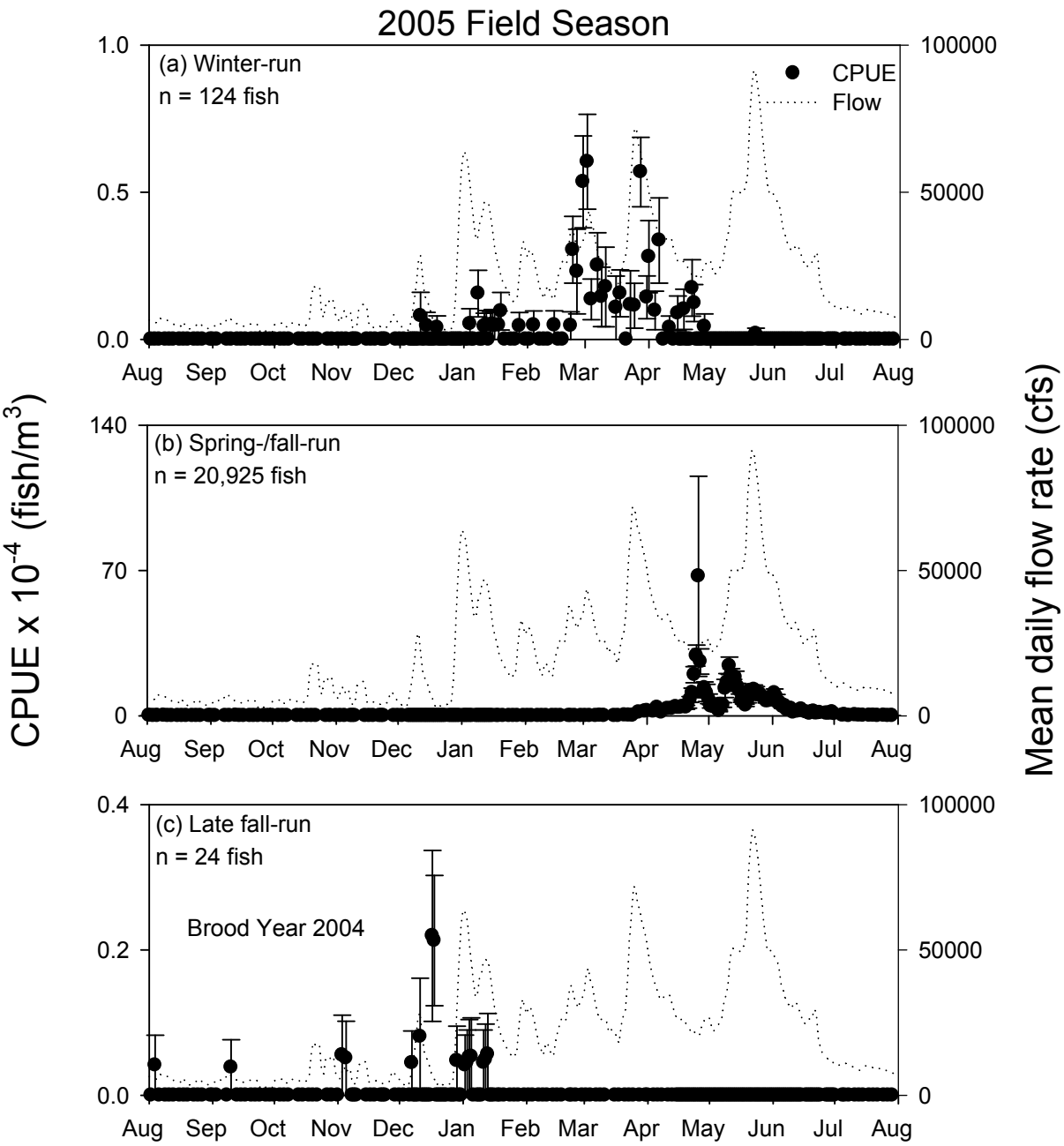

Figure 36. Mean daily CPUE (x 10^{-4}) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in midwater trawls at Chipps Island and concurrent daily Delta outflow during the 2005 field season. Sample size (n) corresponds to total number of fish caught during the 2005 field season. Note the change in scale among panels. Error bars are ± 1 SE.

Table 9. Summary table of CPUE x 10^{-4} (fish/m^3) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in midwater trawls at Chipps Island by month and year. Among-year mean and standard error (SE) values were calculated using years as replicates (n = 7-8). Within-year mean and SE values were calculated using weeks as replicates (n = 14-49). Shaded boxes indicate peak monthly CPUE for each year. Water year (CDEC, 2006): AN = above normal; BN = below normal; C = critical; D = dry; W = wet

(a) Winter-run

Field Season	Water year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Weekly mean (SE)
1993	AN	--	--	--	--	--	--	--	--	0.328	0.00347	0	0	0.0919 (0.0506)
1994	C	--	--	--	0	0	0.00313	0.00708	0.0834	0.0225	0.00136	0	--	0.0151 (0.00544)
1995	W	--	--	0	0	0	0.0141	0.136	0.392	0.2906	0.00473	0	0	0.0836 (0.0275)
1996	W	0	0	0	0	0.0639	0.0745	0.112	0.650	0.0760	0.00407	0	0	0.0853 (0.0323)
1997	W	0	--	0	0	0.00203	0.02370	0.0852	0.239	0.0676	0.00289	0	0	0.0417 (0.0121)
1998	W	0	0	0	0	0.0108	0.0289	0.0161	0.214	0.0444	0.00140	0	--	0.0316 (0.0124)
1999	W	--	0	0	0	0.0207	0.0110	0.0835	0.258	0.0865	0	0	0	0.0437 (0.0194)
2000	AN	0	0	0	0	0	0.0124	0.107	0.290	0.0655	0.00143	0	0	0.0401 (0.0147)
Yearly mean 1993-2000(SE)		0 (0)	0 (0)	0 (0)	0 (0)	0.0139 (0.00883)	0.0240 (0.00900)	0.0781 (0.0185)	0.304 (0.0671)	0.123 (0.0415)	0.00242 (0.000573)	0 (0)	0 (0)	0.0541 (0.0101)
2001	D	0	0	0	0	0	0.0147	0.0647	0.254	0.0294	0.000701	0	0	0.0330 (0.0120)
2002	D	0	0	0	0	0.0205	0.0187	0.0238	0.153	0.0565	0.000900	0	0	0.0228 (0.00781)
2003	AN	0	0	0	0	0.0493	0.0989	0.1500	0.434	0.0912	0.00334	0	0	0.0682 (0.0188)
2004	BN	0	0	0	0	0.0112	0.0144	0.0471	0.343	0.0150	0	0	0	0.097 (0.0170)
2005	BN	0	0	0	0	0.00613	0.0302	0.101	0.210	0.0584	0.000613	0	0	0.0341 (0.0116)

Table 9 (contin.)

(b) Spring/fall-run

Field Season	Water year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Weekly mean (SE)
1993	AN	--	--	--	--	--	--	--	--	7.07	12.9	4.83	0.487	7.25 (1.83)
1994	C	--	--	--	0.0433	0	0	0.00309	0.0164	6.01	2.54	0.200	--	0.977 (0.497)
1995	W	--	--	0.0513	0.0338	0	0.623	0.416	0.934	8.48	15.1	4.52	0.330	2.87 (0.789)
1996	W	0.0406	0.0639	0.167	0.0131	0.0308	0.126	4.42	1.83	8.77	13.3	2.15	0	2.63 (0.648)
1997	W	0.141	--	0	0.00908	0.0143	0.235	0.00547	0.0896	3.92	2.15	0.360	0.0978	0.634 (0.223)
1998	W	0.0388	0.0214	0.00265	0	0.00198	0.466	0.645	2.22	12.4	14.8	4.60	--	3.00 (0.770)
1999	W	--	0.0596	0.0377	0	0	0.0372	0.935	0.516	4.55	9.97	2.60	0.0763	1.65 (0.458)
2000	AN	0	0.0150	0.275	0.0103	0	0.00229	0.148	1.04	10.8	5.16	0.633	0.140	1.58 (0.515)
Yearly mean 1993-2000 (SE)		0.0551 (0.0301)	0.0340 (0.0127)	0.0890 (0.0448)	0.0157 (0.00629)	0.00673 (0.00447)	0.213 (0.0927)	0.939 (0.595)	0.950 (0.316)	7.75 (1.04)	9.49 (1.92)	2.49 (0.670)	0.189 (0.079)	2.57 (0.736)
2001	D	0.0271	0.0572	0.0563	0.0162	0	0	0.00426	0.0543	5.38	5.88	0.438	0.0885	0.888 (0.390)
2002	D	0.0211	0.00716	0.00460	0	0	0	0	0.0317	2.64	5.11	0.576	0.145	0.694 (0.260)
2003	AN	0	0.0103	0	0.00211	0	0	0	0.718	13.7	9.30	1.06	0.0462	1.75 (0.641)
2004	BN	0.0204	0.00768	0	0	0	0	0.00460	0.572	7.80	6.59	0.785	0.0790	1.09 (0.453)
2005	BN	0.0202	0.00880	0.00619	0	0	0	0	0.391	11.0	9.83	3.20	0.201	1.87 (0.637)

Table 9. (cont.)

(c) Late fall-run

Field Season	Water year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Weekly mean (SE)
1993	AN	--	--	--	--	--	--	--	--	0	0	0	0	0 (0)
1994	C	--	--	--	0.0280	0.0815	0.00579	0.0168	0	0	0	0.00198	--	0.0177 (0.00571)
1995	W	--	--	0	0.0207	0.0768	0.0444	0	0	0	0.00127	0	0	0.0134 (0.00521)
1996	W	0	0.00562	0.0123	0	0.184	0.0606	0.00256	0	0	0.00133	0	0	0.0209 (0.00948)
1997	W	0	--	0	0	0.151	0.0295	0	0	0	0	0	0	0.0139 (0.00675)
1998	W	0.0188	0.0367	0.0197	0.0291	0.100	0.0280	0	0	0	0	0	--	0.0232 (0.0629)
1999	W	--	0.0657	0	0.233	0.0939	0.00647	0.00306	0	0	0	0	0.0191	0.0371 (0.0132)
2000	AN	0	0.00825	0.00500	0.0453	0.0436	0.00854	0.0112	0	0	0	0	0	0.0100 (0.00393)
Yearly mean 1993-2000 (SE)		0.00627 (0.00627)	0.0360 (0.0173)	0.0064 (0.00409)	0.0518 (0.0366)	0.115 (0.0176)	0.0291 (0.00873)	0.00374 (0.00267)	0 (0)	0 (0)	0.000372 (0.000240)	0.000283 (0.000283)	0.00383 (0.00383)	0.0170 (0.00382)
2001	D	0	0	0.00460	0.0331	0.0469	0.0140	0.00323	0	0	0	0	0.00430	0.00985 (0.00389)
2002	D	0	0.0247	0	0.0368	0.0680	0.00601	0	0.00369	0	0	0	0.00442	0.0111 (0.00371)
2003	AN	0	0.00915	0.00876	0.00398	0.121	0.0351	0	0	0	0	0	0	0.0128 (0.00619)
2004	BN	0	0.01300	0	0.00777	0.0483	0.0136	0	0	0	0	0	0	0.00649 (0.00236)
2005	BN	0.00318	0.00319	0	0.00816	0.0224	0.0163	0	0	0	0	0	0	0.00408 (0.00159)

Absolute Abundance Estimates

Methods

Absolute abundance estimates of juvenile salmon migrating downstream past Chipps Island have been calculated each year from 1980 to 2000, excluding 1987, using methods set forth in USFWS (1987). No control (downstream) releases were conducted in 1987, prohibiting the calculation of absolute abundance estimates. Abundance estimates are based on recovery rates calculated from Chipps Island midwater trawls and ocean recovery estimates obtained from the Regional Mark Processing Center (RMPC) web site, <www.rmpc.org>, operated by the Pacific States Marine Fisheries Commission (PSMFC 2006). Calculating estimates of salmon abundance after 2003 at the time of publication of this document would not be accurate because ocean harvests are not yet complete. Fish are available for capture in the ocean primarily between three and five years after downstream migration. Therefore, these estimates will be calculated for future annual reports.

Chipps Island has been chosen for recovery of CWT juveniles because all emigrating juveniles originating in both the Sacramento and San Joaquin rivers must pass through this narrow constriction of the confluence on their way towards the ocean. Prior to release, all CWT juvenile Chinook salmon are marked externally by removing the adipose fin. If a fin clip is observed by field technicians upon recovery, the fish is returned to the laboratory for processing. The CWT is removed from the fish and read under a microscope. Tags are read independently by two different readers with any discrepancies resolved by a third reader. Each release group has a unique CWT code such that recovered fish can be traced back to their original hatchery and related release information.

Information on methods for adult ocean recovery estimates can be found on the RMPC web site.

Trawl recovery rate at Chipps Island was calculated for each release group in each field season as follows:

First, ocean recovery rates of the control group (Benicia, Port Chicago, or Ryde), $R_{control}$ were calculated as:

$$R_{control} = \frac{N_{control,\ recovered}}{N_{control,\ released}} \qquad (3)$$

where $N_{control,\ recovered}$ is the estimated ocean recovery of fish from the control release and $N_{control,\ released}$ is the number of fish released at the control site.

Similarly, ocean recovery of each upstream release group, $R_{release}$, was calculated as:

$$R_{release} = \frac{N_{release,\ recovered}}{N_{release,\ released}} \quad (4)$$

where $N_{release,\ recovered}$ is the estimated ocean recovery of fish from the upstream release group and $N_{release,\ released}$ is the number of fish released at the upstream site.

From these two ocean recovery rates, a survival rate of each upstream release group to Chipps Island relative to the control group, $\hat{s}_{release}$, was calculated as:

$$\hat{s}_{release} = \frac{R_{release}}{R_{control}} \quad (5)$$

This calculation assumes that the difference in ocean recovery rates between the two groups is due to mortality between the upstream and downstream location. The downstream location is assumed to approximate the ocean recovery rate of fish had they been released at Chipps Island.

Next, an estimate of the number of fish surviving to Chipps from the upstream release site, $N_{Chipps,survived}$, was calculated as:

$$N_{\text{Chipps, survived}} = \hat{s}_{release} \times N_{\text{release, released}} \quad (6)$$

We then calculated the number of fish available for capture at Chipps, $N_{Chipps,\ available}$, as:

$$N_{\text{Chipps, available}} = N_{\text{Chipps, survived}} \times p_{time} \quad (7)$$

where p_{time} is the proportion of time from the first recovery to the last recovery at Chipps that sampling was conducted, or:

$$p_{time} = \frac{t_{sampled}}{t_{total}} \quad (8)$$

where $t_{sampled}$ is the amount of time trawled (in minutes) and t_{total} is the amount of time (in minutes) encompassing the entire sampling period.

Finally, trawl recovery rate for each release group, $TRR_{release}$, was determined as the proportion of fish available at Chipps that were recovered at Chipps, or:

$$TRR_{release} = \frac{N_{Chipps,\ recovered}}{N_{Chipps,\ available}} \quad (9)$$

Annual mean trawl recovery rate, $\overline{TRR}$, was then calculated by averaging all $TRR_{release}$ values within a year, or:

$$\overline{TRR} = \sum_{i=1}^{n} TRR_{release} \qquad (10)$$

Releases where $\hat{s}_{release} \geq 1.0$ were not included in $\overline{TRR}$ calculations because they were outside the boundaries of reasonable estimates. Further, releases where $\hat{s}_{release} = 0$ were not used because recovery rates could not be estimated from null values. No fry releases were included in these calculations because it is thought that they experience greater mortality and are therefore recovered in lower numbers than smolts. Also, only fall-run releases were included in calculations of $\overline{TRR}$. These criteria have changed from previous annual reports to improve our estimates, and therefore, values of $\overline{TRR}$ and absolute abundance have also changed.

If $\hat{s}_{control}$ is unusually low in a year, $\hat{s}_{release}$ from many other releases would be >1. When this occurs, Ryde, which is approximately 25 miles upstream, is used as the control group. This has only occurred in two years: 1998, 1993. In addition, in 1995, Rodeo, which is just downstream of Carquinez Strait in San Pablo Bay, was used as the control site owing to unusually low ocean survival rates from Ryde.

In our estimates of trawl recovery rates at Chipps Island, we must assume that salmon are equally distributed in time and space and that our net is 100% efficient in catching fish located in the water that is sampled. Although these assumptions may be violated, they provide the best estimate currently available and are, therefore, used to estimate abundance.

Estimated absolute abundance, N_i, was calculated for each month within a year by expanding fish catches at Chipps Island, n_i, using $\overline{TRR}$ for each year as:

$$N_i = \frac{n_i}{P_{time} \times \overline{TRR}} \qquad (11)$$

Results

Mean trawl recovery rate for the 2001 field season was 0.0033 ± 0.0006 (Figure 37; Appendices 1,2). Mean trawl recovery rate for 2002 was 0.0032 ± 0.0005 and that for 2003 was 0.00600 ± 0.00125. Recovery rates for all three years were lower than historical trawl recovery rates from 1980-2003 (0.0092 ± 0.0016).

We estimated that 512,282 winter-run, 18,138,042 spring-/fall-run, and 153,804 late fall-run juvenile salmon passed Chipps Island during the 2001 field season (Table 10). We estimated that 377,635 winter-run, 12,566,916 spring-/fall-run, and 235,285 late fall-run juvenile salmon passed Chipps Island during the 2002 field season (Table 10). We

estimated that 567,621 winter-run, 19,868,975 spring-/fall-run, and 137,661 late fall-run juvenile salmon passed Chipps Island during the 2003 field season (Table 10). Winter-run salmon abundance estimates for the 2001-2003 field seasons were highest in March, which is consistent with previous years. The spring-/fall-run abundance estimates were highest in May of the 2001 and 2002 field seasons and peaked in April in the 2003 field season. The late-fall abundance estimates were highest in December for all three years, which is consistent with estimates from previous years.

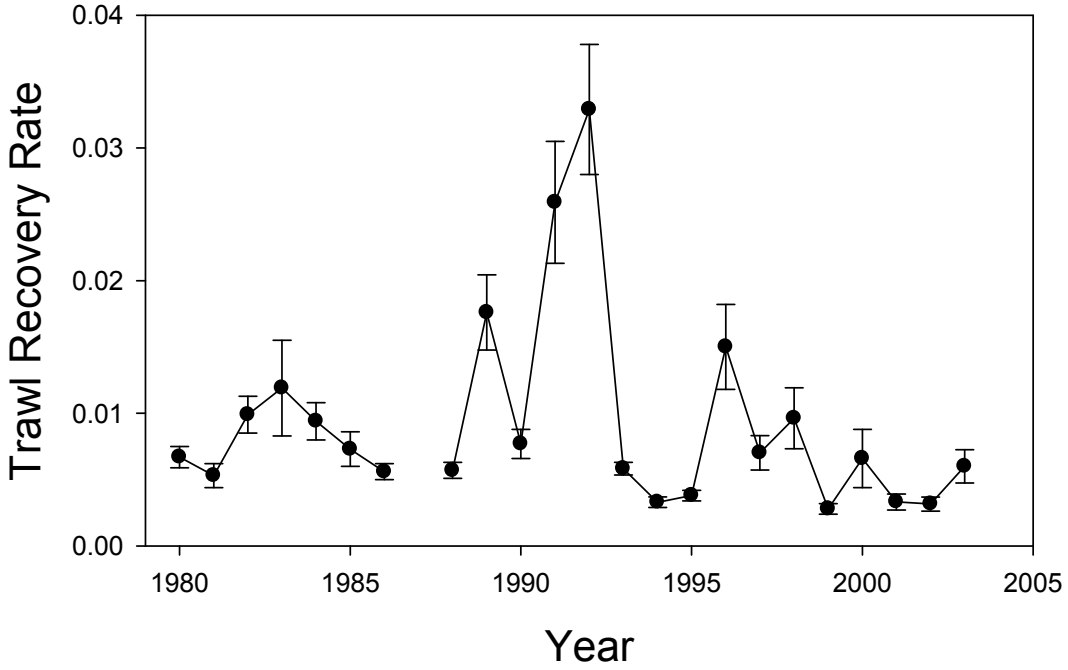

Figure 37. Recovery rates of juvenile CWT Chinook salmon in mid water trawls at Chipps Island between 1980 and 2003. No recovery rate was calculated for 1987 because no control release was conducted. No recovery rates for 2004 and 2005 due to insufficient data available for ocean recovery rates estimates. Error bars are ± 1 SE.

Table 10. Abundance estimates of (a) Winter-, (b) Spring-/fall-, and (c) Late fall-run juvenile Chinook salmon passing Chipps Island by month and field season.

(a) Winter

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Aug	--	--	0	0	0	--	0	0	0	0
Sep	--	--	0	--	0	0	0	0	0	0
Oct	--	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0
Dec	0	0	29,835	1,319	6,268	19,380	0	0	34,304	38,533
Jan	5,099	21,258	30,590	18,417	17,243	11,283	6,691	17,455	24,880	72,959
Feb	10,041	168,638	34,546	59,253	9,239	67,566	57,743	77,752	32,303	100,800
Mar	146,669	576,841	264,607	173,495	133,634	274,159	181,936	372,608	211,759	305,912
Apr	37,735	461,435	31,388	48,608	21,641	70,890	30,530	46,281	73,141	46,901
May	2,069	7,850	1,731	1,894	909	0	1,170	1,187	1,248	2,516
Jun	0	0	0	0	0	0	0	0	0	0
Jul	--	0	0	0	--	0	0	0	0	0
Total	201,613	1,236,022	392,697	302,986	188,934	443,279	278,071	515,282	377,635	567,621

(b) Spring/fall

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Aug	--	--	17,714	25,336	94,177	--	0	31,459	35,316	0
Sep	--	--	19,193	14,303	--	60,919	14,856	80,975	6,285	7,310
Oct	--	68,116	69,925	2,120	0	101,831	153,931	71,384	8,213	0
Nov	58,898	46,742	8,571	0	6,510	0	8,438	26,358	0	1,899
Dec	2,627	0	14,917	1,045	9,235	0	0	0	0	0
Jan	0	971,492	47,496	256,178	51,902	35,460	1,338	0	0	0
Feb	5,021	554,730	1,651,909	321,045	3,591	698,186	83,150	3,702,	0	0
Mar	25,288	1,386,535	761,714	1,422,956	65,061	531,184	671,476	81,002	50,154	522,358
Apr	10,552,297	12,770,430	3,406,841	8,168,233	2,701,036	4,924,895	7,535,194	7,844,628	4,125,951	11,409,045
May	4,333,244	22,683,179	5,890,144	9,285,850	1,252,855	9,187,206	3,419,396	9,173,327	7,322,168	7,116,631
Jun	397,059	6,484,172	1,186,006	2,655,140	261,530	2,935,843	378,557	698,436	819,058	768,953
Jul	--	491,946	0	--	69,960	61,450	83,106	126,772	199,770	42,779
Total	15,374,434	45,457,343	13,074,431	22,152,207	4,515,857	18,536,972	12,349,442	18,138,042	12,566,916	19,868,975

Table 10 (cont.)

(c) Late fall

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Aug	--	--	0	12,668	0	--	0	0	0	0
Sep	--	--	1,745	21,454	--	66,457	7,428	0	0	7,310
Oct	--	0	4,662	12,719	0	0	4,810	,7138	57,492	7,620
Nov	42,835	25,968	0	12,720	0	126,368	37,969	43,929	47,848	3,797
Dec	136,628	113,906	74,586	51,190	97,629	85,597	21,325	74,122	109,774	94,021
Jan	10,198	72,277	16,100	14,779	20,091	6,447	5,353	17,455	7,464	24,913
Feb	25,103	0	1,047	0	0	3,754	6,929	3,702	0	0
Mar	0	0	0	0	0	0	0	0	5,573	0
Apr	0	0	0	0	0	0	0	0	0	0
May	0	1,963	577	0	0	0	0	0	0	0
Jun	7,941	0	0	0	0	0	0	0	0	0
Jul	--	0	0	--	0	30,725	0	7,457	7,135	0
Total	222,705	214,114	98,717	125,530	117,721	319,348	83,813	153,804	235,285	137,661

Although numerous sources of error exist in our abundance estimates, two sources are worth particular mention. First, some fish releases yielded $\hat{s}_{release} \geq 1.0$ (Appendix 1), which, as indicated above, is not realistic (i.e., abundance of fish with a specific coded wire tag cannot increase). One explanation for this is that the same group of fish were sampled repeatedly (fish moved past Chipps Island more than once due to a shift in tide direction). Alternatively, $\hat{s}_{release}$ values are based on a single control release that is likely not representative of each fish from each hatchery released at each site during the entire field season. This suggests that we need to increase replication of control releases in the future to account for differences among hatcheries, rivers, and time of year.

Second, we conduct trawls just after sunrise and, during the VAMP period, just before sunset to maximize CPUE (Brandes & McLain 2001). While this may allow higher recovery rates, it may also inflate mean CPUE. Of greater importance, there is currently no consensus on temporal patterns of juvenile salmon catch and the mechanisms that may drive these patterns. Patterns in catch may be higher during the day than at night (Wickwire and Stevens 1966, Schaffter 1980, Brandes and McLain 2001), lower during the day than at night (Hansen 2004), or vary seasonally (Wilder & Ingram 2006). Recent spring sampling protocols were developed based on 24 hour sampling at Jersey Point conducted in April and May of 1997 (Hanson Environmental, unpublished data, 1997). Further evaluation is needed to better understand patterns in juvenile salmon abundance in our catches to provide the best estimates available of true salmon abundance.

Figure 38 illustrates annual abundance estimates at Chipps Island between April 1 and June 30 from 1978 to 2003 using the trawl recovery rate for each year or, if not available, mean trawl recovery rate from 1980-2003 (excluding 1987). Only April-June estimates were included because these are the only months in which we have sampled consistently since 1978. This graph provides a general index of the absolute production of Chinook salmon passing Chipps Island through time.

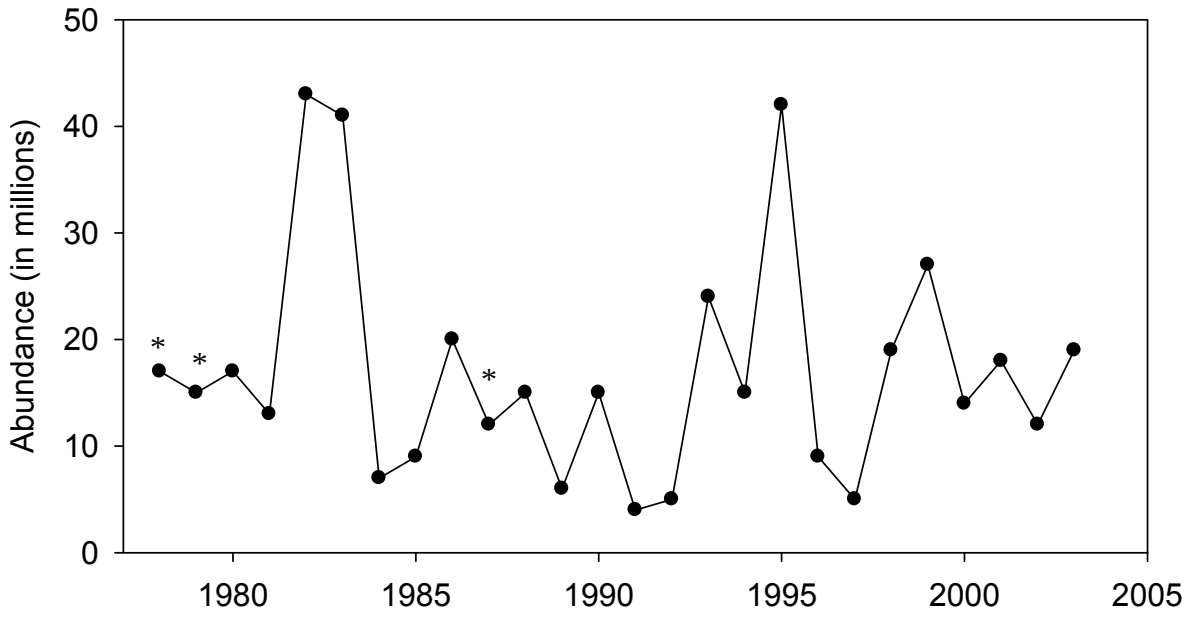

Figure 38. Absolute abundance estimates of all juvenile Chinook salmon between April 1 and June 30 from 1978-2003 using mean annual trawl recovery rates from ocean recoveries. *Indicates that trawl recovery rate was estimated by using average mean annual trawl recovery rate from 1980-2003 (excluding 1987).

Mark and Recapture Experiments

Four mark and recapture experiments were continued during 2001-2005 field seasons to better understand juvenile Chinook salmon survival through the Sacramento/San Joaquin Delta: (1) Delta Action 8 experiment, (2) Sacramento River fall-run survival indexing experiment, (3) Vernalis Adaptive Management Plan (VAMP) experiment and (4) Fall run interior Delta versus mainstem Sacramento survival comparison. In 2001, no Delta Action 8 releases were conducted. Instead, all Delta Action 8 experimental fish were allocated for use in evaluating the effects of the Delta Cross Channel (DCC) on salmon distribution and movement (see Delta Cross Channel section below and Hansen, 2004).

Delta Action 8 Experiment

Delta Action 8 is one of the nine Delta Actions implemented as part of the Anadromous Fish Restoration Program (AFRP). The AFRP is a component of the Central Valley Project Improvement Act. Delta Action 8 originated in October 1996, as an experiment to estimate juvenile salmon survival through the Delta with Central Valley Project (CVP) and State Water Project (SWP) exports at 65% and 35% of Delta inflow. Delta Action 8 was intended to provide the data needed to assess the benefits of Delta Action 9, which

would limit the average combined exports to no greater than 35% of Delta inflow during November through January, similar to the level prescribed in the 1995 Water Quality Control Plan (WQCP) between February and June.

Due to low numbers and the endangered status of winter-run Chinook salmon, late fall-run yearlings from Coleman National Fish Hatchery (CNFH) were used as surrogates for winter-run salmon in the Delta Action 8 experiment. Late fall-run Chinook were used because of their larger size and earlier timing of out-migration relative to fall-run. Fish were coded wire tagged, trucked, and released in Georgiana Slough (interior Delta) and at Ryde or Isleton (main stem Sacramento River). In the early years of implementation of the experiment, it became apparent that Sacramento River flows were unpredictable, making it difficult to test a particular export/inflow ratio. As a result, the experiment evolved into a comparison of relative survival of the two release groups to Chipps Island (and in the ocean fishery) between different export rates. The experiment was conducted previously in December of 1993,1994,1997,1998 and 1999 and January of 1995, 1996, 1998. Since January 1996, additional releases have been made at Port Chicago or Benicia to aid in assessing absolute survival from ocean recoveries.

Starting in December 2002, the addition of a West Sacramento release group was used to evaluate the proportion of fish diverted into Georgiana Slough from the main stem of the Sacramento River. Similar releases were made previously at Miller Park (rm 57) in December 1996 and January 1997. The diversion was inferred by comparing survival from the West Sacramento releases to the Georgiana Slough and Ryde releases. Starting in December 2003, releases began at Sherman Island (just upstream of Chipps Island) to correct for the efficiency of trawls at Chipps Island. Because of the additional releases, the Georgiana Slough/Ryde releases were reduced to one group per year. More information on the Delta Action 8 experiment is available at http://www.delta.dfg.ca.gov/jfmp/patfiles.asp.

Methods

There are two specific goals of the Delta Action 8 experiment: (1) to compare survival of late fall-run juvenile salmon in the interior Delta (areas physically in between the Sacramento and San Joaquin Rivers) relative to the mainstem Sacramento River, and (2) to determine if there is a relationship between relative survival of juvenile late fall salmon in the interior Delta and SWP and CVP water exports out of the Delta. Two hypotheses were tested: (1) survival of late fall juvenile salmon is greater in the mainstem Sacramento River than in the interior Delta, and (2) relative survival of late-fall run juvenile salmon in the interior Delta increases with decreased water exports by the SWP and CVP.

In January 2002 and December 2002-2004, four paired releases were made in Georgiana Slough and at Ryde with corresponding releases at Port Chicago or Benicia (Table 11). For several weeks after the releases, sampling at Chipps Island was conducted daily to increase recovery efforts of these fish (Table 11).

To estimate survival to the delta from upriver two releases were made during each field season of 2002-2004. The first release was at the hatchery on Battle Creek (Table 12) and the second occurred within a week of the Battle Creek release in West Sacramento (Table 13).

Table 11: Release date, tag code and number released of CWT groups released into Georgiana Slough, at Ryde and near Port Chicago or Benicia and dates when daily trawling occurred at Chipps Island for releases made in field seasons 2002-2005.

	Release					
Field season	Site	Date	Tag code	# fish released	Total # fish released	Daily trawling at Chipps Island
2002	Georgiana Slough	01/03/02	5-7-76	77053	77053	01/06/02-02/02/02
	Ryde	01/05/02	5-7-67	52327	52327	
	Port Chicago	01/10/02	5-7-68	47876	47876	
2003	Georgiana Slough	12/05/02	5-11-68	55173	55173	12/05/02-12/28/02
	Ryde	12/06/02	5-11-67	49629	49629	
	Port Chicago	12/09/02	5-11-66	45981	45981	
2004	Georgiana Slough	12/09/03	5-17-71	34972	34972	12/07/03–01/24/04
			5-17-72	33731	68703	
	Ryde	12/10/03	5-17-81	23943		
			5-17-82	22038	45981	
	Benicia	12/11/03	5-17-80	24785	24785	
2005	Georgiana Slough	12/08/04	5-22-92	36009	36009	12/06/04–01/15/05
			5-22-93	36073	72082	
	Ryde	12/09/04	05-22-80	25202		
			05-22-81	25195	50397	
	Port Chicago	12/10/04	05-22-82	25132	25132	

Table 12: Release dates, tag codes and the number released of CWT groups released at Battle Creek in field seasons 2003-2005.

Field season	Release Site	Release Date	Tag code	# fish released	Total # fish released
2003	Battle Creek	12/2/02	5-10-94	59,887	
			5-11-65	59,419	119,306
2004	Battle Creek	11/28/03	5-17-67	65,339	
			5-17-69	71,183	64,547
2005	Battle Creek	11/29/04	5-22-76	69,993	69,993

Table 13: Release dates, tag codes and the number released of CWT groups released at Sacramento in field seasons 2003-2005.

Field season	Release Site	Release Date	Tag code	# fish released	Total # fish released
2003	West Sacramento	12/03/02	5-51-38	69,490	69,490
2004	West Sacramento	12/05/03	5-17-73	30,738	
			5-17-74	33,809	64,547
2005	West Sacramento	12/06/04	5-22-84	25,279	
			5-22-85	25,482	50,761

Additional releases were made at Sherman Island in December 2003 and 2004 (Table 14). A release was also proposed at Sherman Island in December 2002, but was unable to proceed due to high mortality of fish released at Georgiana Slough on 12/04/02 during transit. As a result, a second group was released at Georgiana Slough on 12/05/02. To estimate survival between Sacramento and just upstream of the Delta Cross Channel a release was made at Vorden (just upstream of the Delta Cross Channel) on 12/7/04. The Vorden release was also used to assess the proportion of fish diverted into Georgiana Slough by comparing the survival indices of the fish released at Vorden to those released at Ryde and Georgiana Slough.

Table 14: Release dates, tag codes and the number released of CWT groups released at Sherman Island and at Vorden in field seasons 2004 and 2005.

Field season	Release Site	Release Date	Tag code	# fish released	Total # fish released
2004	Sherman Island	12/11/03	5-17-83	25,956	25,956
2005	Vorden	12/7/04	05-22-90	34,007	
			05-22-91	34,413	68,420
	Sherman Island	12/10/04	05-22-83	25,558	25,558

The Delta Action 8 CWT salmon recovered in each year at the SWP and CVP fish salvage facilities were provided to us. DJFMP processed these fish and recorded the tag code data (Table 15).

A survival index to Chipps Island for each release, $\hat{s}_{Chipps,\ release}$, was calculated as:

$$\hat{s}_{Chipps,\ release} = \frac{N_{release,\ recovered}}{N_{release,\ released} \times p_{time} \times p_{length}} \qquad (12)$$

where, p_{length} is the proportion of the distance across the river at Chipps Island that was sampled.

A paired t-test was used to determine whether a statistical difference existed between survival indices of fish from Georgiana Slough and Isleton/Ryde releases for all years combined (1993-2004, n = 13). We also calculated the ratio of survival index for Georgiana Slough to survival index for Ryde/Isleton.

Water flow rates for the Sacramento River at Freeport were obtained from the CDEC (California Department of Water Resources, 2006 http://cdec.water.ca.gov/) website. Export data is the combined CVP and SWP exports reported by the Dayflow (Interagency Ecological Program, 2006 http://www.iep.ca.gov/dayflow/index.html) website. River flow and exports were calculated by averaging the estimates for the three days after the release at Georgiana Slough.

Results and Discussion

The Delta Cross Channel gates were closed during the four Delta Action 8 Experiments.conducted in field seasons 2002-2005.

Flow and export rates varied during the course of the experiments for these field seasons (Table 15). In January 2002 flows at Freeport were high and started at 51,000 cfs on the day of the release then increased and peaked at 65,500 cfs by the third day after the first release and decreased to 31,000 cfs at two weeks post first release. The average daily flow rate on the Sacramento River at Freeport for the three-day period following the Georgiana Slough release was 62,400 (±2,400) cfs (Table 15a). Exports during January 2002 started at 12,000 cfs on day 1, decreased to a daily average of 5,600 cfs from day 3 to day 7, and increased to a daily average of 11,500 by day 14. Average daily exports for the three days after the Georgiana Slough release were 7,800 ±2,200 cfs (Table 15a).

In contrast, initial flows during the December 2002 were low and made a gradual increase from 10,500 cfs on the first day of the release to 14,500 cfs nine days after the first release. After the ninth day, flow rates drastically increased over a five day period

to peak at the end of the two weeks at 53,200 cfs. The three-day average daily flow rate on the Sacramento River at Freeport after the Georgiana Slough release was 11,000 (±173) cfs (Table 15b). Exports in December 2002 started at 5,700 on the first day of releases, decreased to 4,700 cfs by the eighth day and increased over the next seven days to peak at 11,200 cfs at two weeks post release. Average daily exports for the three days after the Georgiana Slough release were 5,000 ±201 cfs (Table 15b).

In December 2003, flows ranged from 21,500 to 35,000 cfs during the two weeks after the first release. The three-day average daily flow rate on the Sacramento River at Freeport after the Georgiana Slough release was 22,700 ±712 cfs (Table 15c). Exports started at 4,300 cfs then increased to 11,000 cfs by day 7. From day 8 to day 14 exports fluctuated and were 11,500 cfs two weeks after the release date. Average daily exports for the three days after the Georgiana Slough release were 4,000 ±374 cfs (Table 15c).

On the first day of the December 2004 releases, flow rates were 12,500 cfs, increased rapidly and peaked on the third day post release at 28,000 cfs. After the third day, the flow rates decreased drastically to 16,904 cfs at the seventh day, and gradually decreased to 12,600 cfs two weeks after the release. The three-day average daily flow rate on the Sacramento River at Freeport after the Georgiana Slough release was 24,100 ±3,100 cfs (Table 15d). Exports were fairly constant (6,090 ±14 cfs) during the first eight days, fluctuated between 8,500 and 11,500 cfs for the next seven days, and ended at 9300 cfs after two weeks. Average daily exports for the three days after the Georgiana Slough release were 6,100 ±40 cfs (Table 15d).

Table 15: Survival indices, expanded CVP salvage, SWP salvage, and ocean recovery numbers for late fall-run releases made at Ryde, in Georgiana Slough and Port Chicago or Benicia during the (a) 2002, (b) 2003, (c) 2004 and (d) 2005 field seasons. Mean daily flow rates and exports were calculated for the three days after the Georgiana Slough release. Standard errors are reported in parentheses. N/A = Not Available

(a) 2002

Release		# fish	Temperature (C)		Survival		Mean 3 day	Mean 3 day CVP+SWP	Expanded salvage		Expanded ocean
Date	Site	released	Truck	River	Index	Ratio	flow	exports	CVP	SWP	recovery
01/03/02	Georgiana Slough	77053	12.2	12.0	0.225	0.312	62,400 (2400)	7800 (2200)	96	294	250
01/05/02	Ryde	52327	10.0	10.0	0.722	--	--	--	12	6	522
01/10/02	Port Chicago	47876	12.2	12.21	--	--	--	--	0	12	314

(b) 2003

Release		# fish	Temperature (C)		Survival		Mean 3 day	Mean 3 day CVP+SWP	Expanded salvage		Expanded ocean
Date	Site	released	Truck	River	Index	Ratio	flow	exports	CVP	SWP	recovery
12/05/02	Georgiana Slough	55173	12.8	12.8	0.017	0.043	11,000 (173)	5000 (201)	216	348	52
12/06/02	Ryde	49629	13.9	11.1	0.397	--	--	--	24	18	147
12/09/02	Port Chicago	47048	12.8	12.21	--	--	--	--	0	0	458

(c) 2004

Release		# fish	Temperature (C)		Survival		Mean 3 day	Mean 3 day CVP+SWP	Expanded salvage		Expanded ocean
Date	Site	released	Truck	River	Index	Ratio	flow	exports	CVP	SWP	recovery
12/09/03	Georgiana Slough	68703	10.0	12.2	0.081	0.276	22,700 (712)	4000 (374)	132	174	51
12/10/03	Ryde	45981	11.7	11.1	0.293	--	--	--	0	24	127
12/11/03	Benicia	24785	11.7	12.2	--	--	--	--	--	--	157

(d) 2005

Release		# fish	Temperature (C)		Survival		Mean 3 day	Mean 3 day CVP+SWP	Expanded salvage		Expanded ocean
Date	Date	released	Truck	River	Index	Ratio	flow	exports	CVP	SWP	recovery
12/08/04	Georgiana Slough	72082	12.5	9.0	0.187	--	24,100 (3100)	6100 (40)	0	0	N/A
12/09/04	Ryde	50397	15.0	11.0	0.586	0.319	--	--	0	0	N/A
12/10/04	Port Chicago	25132	12.8	12.2	0.074	--	--	--	0	0	N/A

Survival indices from 2002-2005 field seasons were pooled with those of previous years. When pooled, mean survival indices to Chipps Island of late fall-run salmon released at Ryde or Isleton (mean $\hat{s}$ = 0.654) were four times greater than those released into Georgiana Slough (mean $\hat{s}$ = 0.166; t_{13}= 4.86, P = 0.0003).

It appears from figure 39 that relative survival ratios from 1993-2004 may decrease as combined CVP and SWP exports increase. This apparent trend occurs with the Chipps Island trawl data (r^2 = .2571) as well as the ocean recovery data prior to 2000 (r^2 = 0.3548). Having two separate estimates of relative survival that have similar responses to exports increase our confidence that these trends are real. Although there is uncertainty, the hypothesis that decreased export rates increases the survival of juvenile Chinook salmon in the interior Delta is generally supported by these data.

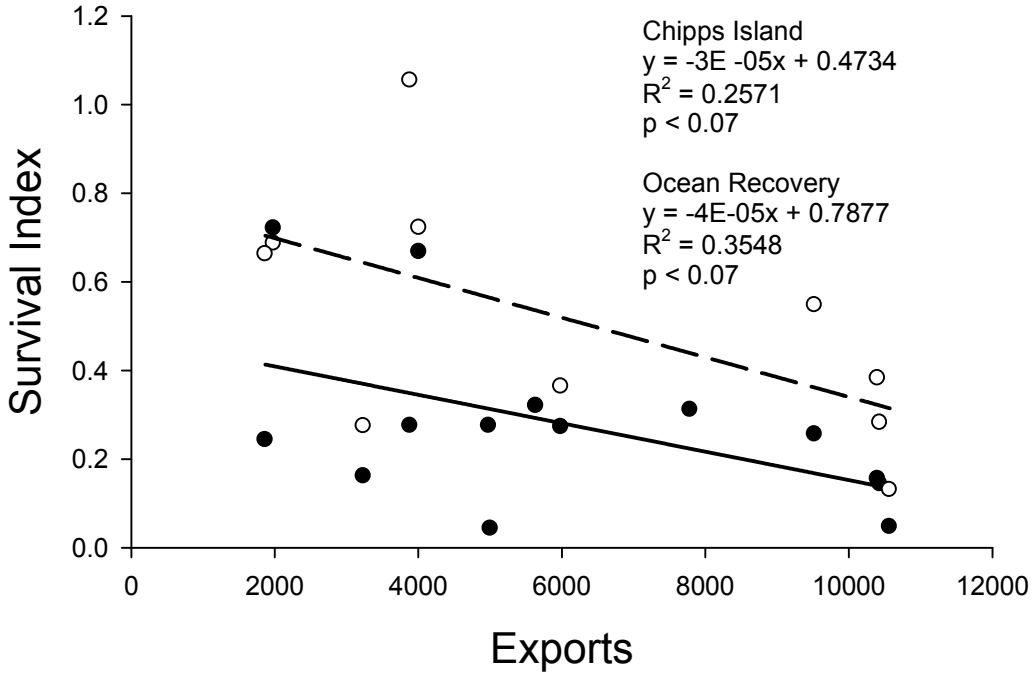

Figure 39: Relative interior Delta survival index versus CVP+SWP exports for the three days after release for 1993-2004. Closed circles and solid line represents Chipps Island data. Open circles and dashed lines represent ocean recovery data and only include data through 1999.

Survival indices indicate that survival is variable between Battle Creek and Sacramento. In December of 2002 the average survival rate for the Battle Creek group (0.70) was higher than the West Sacramento group (0.52), indicating high survival to the Delta. In December of 2003, survival was lower down river to Sacramento; the survival index to Chipps Island for the Battle Creek group was 0.24 and 0.42 for the Sacramento group

(Figure 40). In December of 2004, survival indices were similar between the Battle Creek group (0.42) and the Sacramento group (0.53), again indicating that survival to Sacramento was high (Figure 41).

The survival indices for the West Sacramento and Vorden releases were more similar to the survival indices of the Ryde releases than the Georgiana Slough releases. This may suggest that a relatively small number of smolts were diverted into the interior Delta (Table 16 and Figures 40 and 41).

Table 16: Survival indices, expanded salvage and expanded ocean recoveries of CWT smolts released at various locations in the Delta.

Release		Tag Code	# fish released	Survival Index	Expanded salvage		Expanded Ocean Recovery Numbers
Date	Site				CVP	SWP	
01/03/02	Georgiana Slough	05-07-76	77053	0.225	96	294	250
01/05/02	Ryde	05-07-67	52327	0.722	12	6	522
01/10/02	Port Chicago	05-07-68	47876	--	0	12	316
12/02/02	Battle Creek	05-10-94	59887	0.733	96	158	252
		05-11-65	59419	0.660	204	316	632
12/03/02	West Sacramento	05-51-38	69490	0.515	1922	255	280
12/05/02	Georgiana Slough	05-11-68	55173	0.017	216	348	52
12/06/02	Ryde	05-11-67	49629	0.397	24	18	147
12/09/02	Port Chicago	05-11-66	47048	--	0	0	458
11/28/03	Battle Creek	05-17-67	65339	0.236	60	81	158
		05-17-69	71183	0.243	24	36	146
12/05/03	West Sacramento	05-17-73	30738	0.530	12	12	108
		05-17-74	33809	0.305	12	~~6~~30	83
12/09/03	Georgiana Slough	05-17-71	34972	0.054	96	108	20
		05-17-72	33731	0.010	36	66	51
12/10/03	Ryde	05-17-81	23943	0.171	0	12	61
		05-17-82	22038	0.424	0	12	66
12/11/03	Benicia	05-17-80	24785	--	--	--	157
11/29/04	Battle Creek	05-22-76	69993	0.423	0	0	N/A
11/29/04	West Sacramento	05-22-84	25279	0.665	0	0	N/A
		05-22-85	25482	0.380	0	0	N/A
12/07/04	Vorden	05-22-90	34007	0.641	0	0	N/A
		05-22-91	34413	0.483	0	0	N/A
12/08/04	Georgiana Slough	05-22-92	36009	0.128	0	0	N/A
		05-22-93	36073	0.224	0	0	N/A
12/09/04	Ryde	05-22-80	25202	0.409	0	0	N/A
		05-22-81	25195	0.711	0	0	N/A

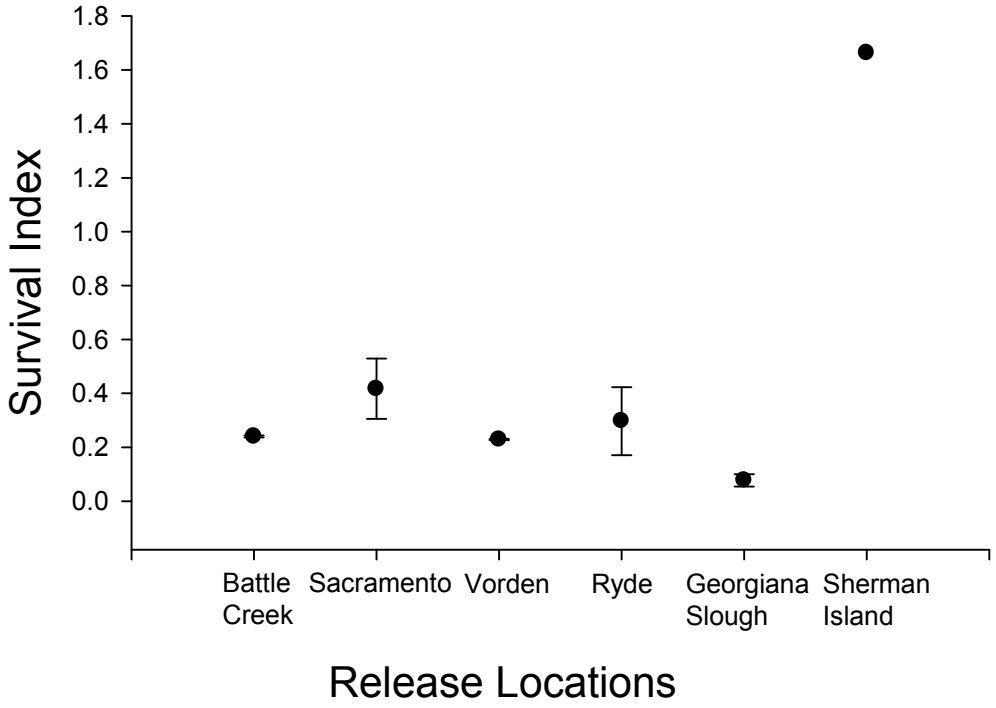

Figure 39: Relative interior Delta survival index versus CVP+SWP exports for the three days after release for 1993-2004. Closed circles and solid line represents Chipps Island data. Open circles and dashed lines represent ocean recovery data and only include data through 1999.

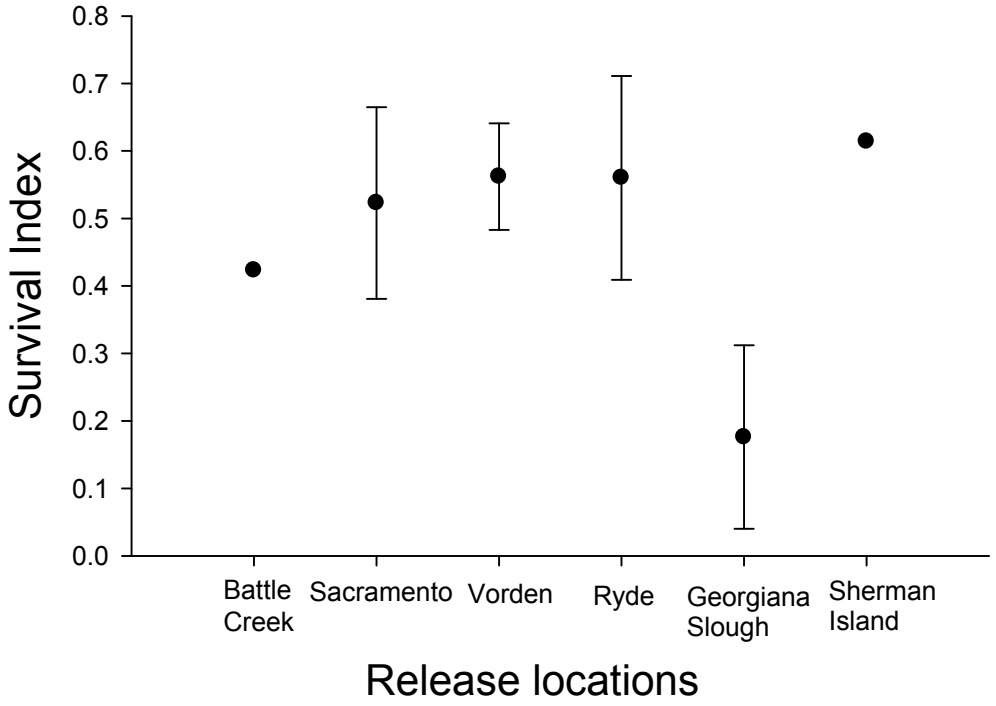

Figure 41: Mean survival indices and standard errors for releases made in December of 2004 at Battle Creek, Sacramento, Vorden, Ryde, Georgiana Slough and Sherman Island.

Sacramento River Fall-run Survival Index

The Sacramento River fall-run survival indexing experiments estimate the survival of juvenile fall-run Chinook salmon in the Delta. During 2001-2005, both fry and smolts were released. However, because calculations for fry survival rely on ocean recovery rates, only return data from 2001-2003 are presented for fry. Future reports ≥3 years after fish were released will include results from 2004 and 2005. Results of smolt survival are reported for 2001-2005 because they rely only on Chipps Island recoveries.

Coded wire tagged (CWT) fry were released on the mainstem Sacramento River at Isleton and in the lower Mokelumne River to index relative fry survival of fish released on the mainstem Sacramento River versus interior Delta. Survival was also indexed for CWT fall-run smolts as they migrate through the Delta from Sacramento to Chipps Island. Indices also provide estimates of baseline survival to help evaluate Delta restoration and operational changes that may occur in the future. Further, data can be used to improve Chinook salmon smolt survival models for the Delta.

Methods

Fry

To estimate relative survival of fall-run salmon fry upstream and at multiple locations in the Delta (north Delta versus central Delta), pairs of marked fall-run fry from Feather River Hatchery (FRH) were released and later recovered in the ocean fishery. An index of survival was calculated for each release group by dividing the number of expanded ocean recoveries by the number released.

To compare relative survival of fall-run fry released in the upper Sacramento River to that of fish released in the Delta, each year during 2001-2003 two replicate groups of fry were released in the Sacramento River, just downstream of the Red Bluff Diversion Dam (RBDD) and paired with release groups in the Delta at Clarksburg.

To compare survival of fall-run fry in the north Delta to survival of fall-run fry in the central Delta in 2001 and 2002, a group of CWT fall-run fry were released at Isleton and paired with a group released on the Lower Mokelumne River at Lighthouse Marina. This pairing was replicated once in 2001 and twice in 2002. In 2003 paired releases were replicated twice, B&W Marina replaced Lighthouse Marina as the central Delta release site and Vieira's Resort replaced Isleton as the north Delta release site due to site accessibility.

Although some fry were recovered at Chipps Island, recoveries were too low to accurately compare survival rates. Therefore, we used ocean recovery rates to compare survival among sites.

Smolts

In the 2001, 2003, 2004, and 2005 field seasons, three groups of CWT smolts from the Feather River Fish Hatchery were released at the Broderick boat ramp in West Sacramento. In 2002, only two releases were made there. An additional release was made in 2005 at Sherman Island. These releases overlapped the peak period of outmigration of natural fall-run Chinook salmon. Additional releases were made at Port Chicago or Benicia to estimate survival from Sacramento to Port Chicago or Benicia using ocean recoveries. In 2001, the downstream release was made on 04/27/01 at Benicia. Releases were made at Port Chicago (Concord Naval Weapons Station) on 4/26/02, 5/1/03, 5/3/04 and 5/19/05. The DCC gates were closed for the entire study period during each year. Fish were recovered at Chipps Island and survival indices were calculated as described in the methods section of the Delta Action 8 experiment (see page 90).

Results and Discussion

Fry

Comparisons of the ocean recovery rate of CWT fall-run fry released in the north Delta at Isleton in 2001 and 2002, and Vieira's in 2003, were consistently higher than those released in the interior Delta at Lighthouse Marina in all years except for the second release in 2003 which was made at B&W Marina (Table 17 and Figure 42). This suggests that there is higher survival of fall-run fry in the north Delta than in the interior Delta.

Table 17. Ocean recovery rate of CWT fall-run fry releases made for (a) 2001, (b) 2002 and (c) 2003 Sacramento River fall-run fry survival index study. N/P = Not provided

(a) 2001

Release			# fish released	Mean fork length (mm)	Truck temp (C)	River temp (C)	Expanded ocean recovery numbers	Ocean recovery rate
Date	Site	Region						
03/02/01	Lighthouse Marina	Central Delta	46,190	60	13.9	13.9	11	0.00024
03/02/01	Isleton	North Delta	46,480	56	13.9	15.0	15	0.00032
02/16/01	RBDD	Upper Sac. River	44,594	46	N/P	N/P	44	0.00099
02/26/01	Clarksburg	Delta	49,447	45	N/P	N/P	27	0.00055
03/05/01	RBDD	Upper Sac. River	46,413	49	N/P	N/P	126	0.00271
030/8/01	Clarksburg	Delta	46,944	46	13.9	11.7	37	0.00079

Table 17 (cont.)

(b) 2002

Release			# fish released	Mean fork length (mm)	Truck temp (C)	River temp (C)	Expanded ocean recovery numbers	Ocean recovery rate
Date	Site	Region						
02/22/02	Lighthouse Marina	Central Delta	51,832	62	8.9	12.8	26	0.00050
02/22/02	Isleton	North Delta	50,738	59	8.9	11.7	76	0.00150
03/13/02	Lighthouse Marina	Central Delta	48,800	73	8.9	12.0	16	0.00066
03/13/02	Isleton	North Delta	48,457	73	8.9	11.7	96	0.00198
02/19/02	RBDD	Upper Sac. River	49,774	57	N/P	N/P	49	0.00098
02/21/02	Clarksburg	Delta	49,714	58	12.5	12.0	29	0.00058
03/11/2002	RBDD	Upper Sac. River	48,956	57	N/P	N/P	128	0.00261
03/12/02	Clarksburg	Delta	50,205	57	13	12.0	86	0.00171

(c) 2003

Release			# fish released	Mean fork length (mm)	Truck temp (C)	River temp (C)	Expanded ocean recovery numbers	Ocean recovery rate
Date	Site	Region						
02/24/03	Lighthouse Marina	Central Delta	49,838	58	8.9	11.1	6	0.00012
02/24/03	Vieira's Resort	North Delta	51,841	58	8.9	11.1	26	0.00050
03/17/03	B&W Marina	Central Delta	50,331	71	12.2	15.0	23	0.00046
03/17/03	Vieira's Resort	North Delta	51,403	71	11.1	13.9	115	0.00224
02/20/03	RBDD	Upper Sac. River	50,147	55	N/P	N/P	222	0.00443
02/21/03	Clarksburg	Delta	49,848	53	11.7	11.7	32	0.00064
03/06/03	RBDD	Upper Sac. River	49,896	60	8.9	11.6	273	0.00547
03/07/03	Clarksburg	Delta	47,176	62	11.1	13.3	94	0.00199

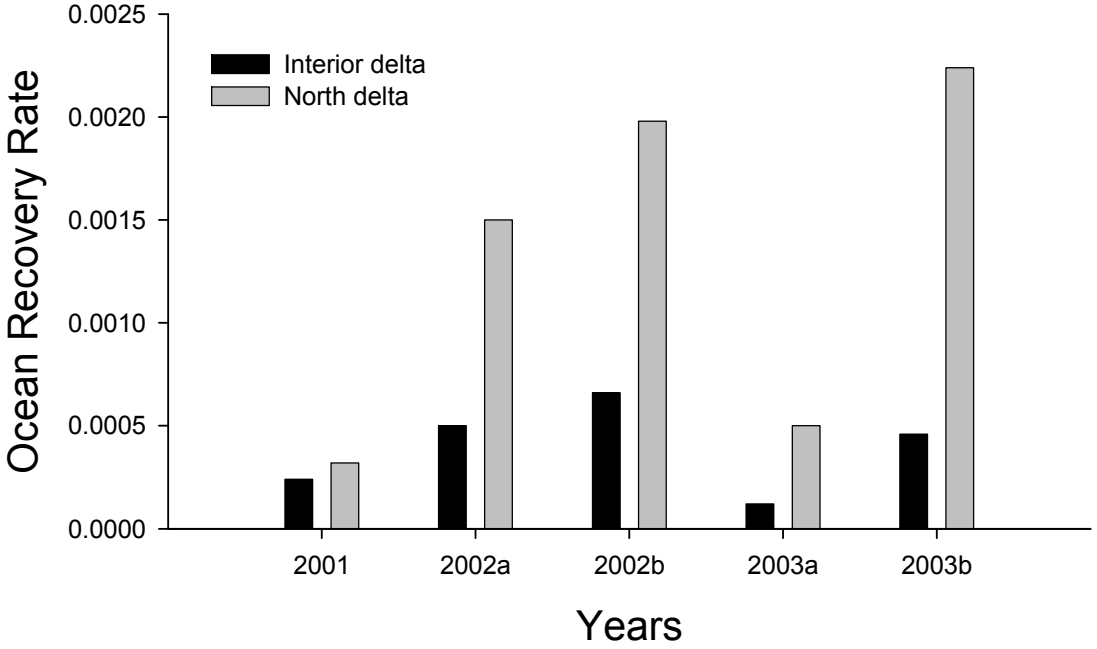

Figure 42. Ocean recovery rates of CWT fall-run fry released between 2001 and 2003 in the interior and north delta.

The ocean recovery rate of CWT fall-run fry released at RBDD was greater than that of fish released at Clarksburg for both pairs of releases in 2001, 2002, and 2003. This indicates that fall-run fry have a higher survival rate when released in the north Delta compared to those released in the interior Delta (Table 17 and Figure 43). The consistency in the results makes us more confident that these trends are real.

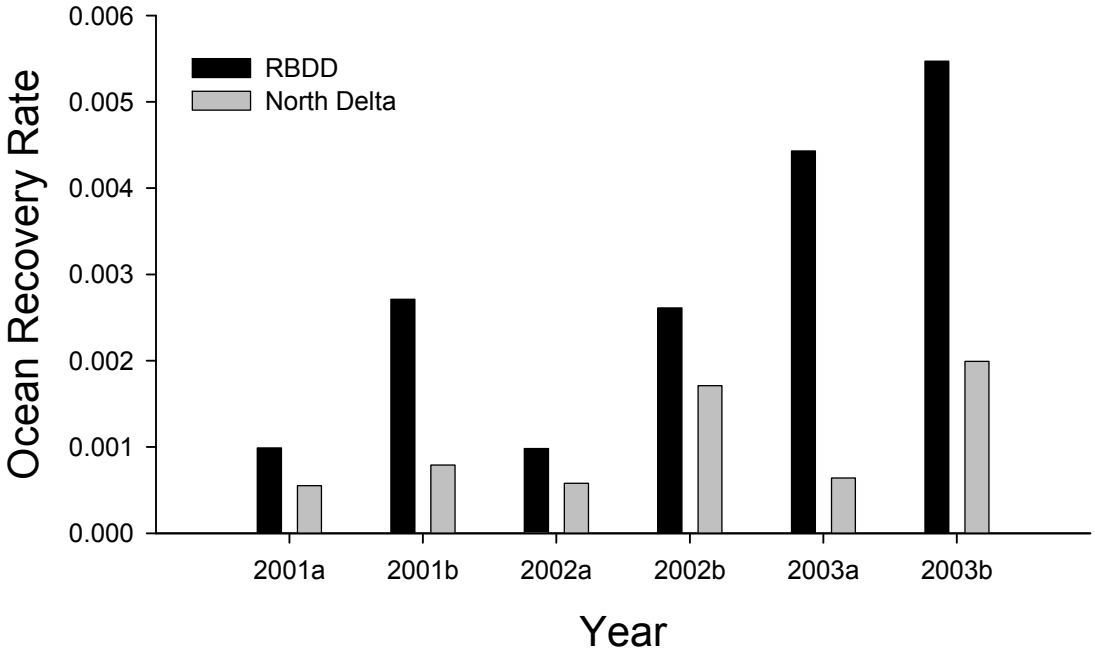

Figure 42. Ocean recovery rates of CWT fall-run fry released between 2001 and 2003 in the interior and north delta.

Smolts

Survival indices during 2001 ranged from 0.018 to 0.716 (Table 18a). In 2002, survival indices were 0.204 and 0.279 (Table 18b). Survival indices in 2003 ranged from 0.436 to 0.692 (Table 18c). In 2004 survival indices ranged from 0.029 to 0.314 (Table 18d). Survival indices in 2005 ranged from 0.189 to 0.634 (Table 18e). Hatchery fish in 2001 originated from the Mokelumne River Hatchery. In all other years fish originated from Feather River Hatchery.

Table 18. Survival index and expanded CVP salvage, SWP salvage, and ocean recovery numbers for CWT fall-run releases made for the Sacramento River fall-run smolt survival index study during the (a) 2001, (b) 2002, (c) 2003, (d) 2004, and (e) 2005 field seasons. Mean daily flow rate was calculated for the 14 days following each release. Standard error of mean daily flow rate is reported in parentheses.

(a) 2001

Release								Expanded salvage		Expanded Ocean Numbers (Recovery rate)
Date	Site	# fish released	Mean fork length (mm)	Truck Temp (C)	River Temp (C)	Survival index	Mean daily flow (cfs)	CVP	SWP	
04/16/01	West Sacramento (Mok)	51,590	81	12. 8	17.8	0.716	11,298 (268)	0	0	597 (0.0116)
04/26/01	West Sacramento (Mok)	51,514	78	12. 8	18.9	0.018	9025 (351)	0	0	721 (0.0140)
05/0901	West Sacramento (Mok)	51,744	85	12. 8	22.2	0.127	8,970 (294)	0	0	169 (0.0033)
04/27/01	Benicia (MOK)	51,520	80	12. 8	17.2	**	**	0	0	313 (0.0061)

(b) 2002

Release								Expanded salvage		Expanded Ocean Numbers (Recovery rate)
Date	Site	# fish released	Mean fork length (mm)	Truck Temp (C)	River Temp (C)	Survival index	Mean daily flow (cfs)	CVP	SWP	
04/02/02	West Sacramento (FRH)	44,563	59	10.0	12. 8	0.204	16,104 (42)	0	6	0
04/17/02	West Sacramento (FRH)	45,972	89	11.0	16.0	0.279	12,546 (405)	0	0	276 (0.0060)
04/26/02	Port Chicago (FRH)	44,789	95	13.0	16.0	**	**	0	0	275 (0.0061)

(c) 2003

Release								Expanded salvage		Expanded Ocean Numbers (Recovery rate)
Date	Site	# fish released	Mean fork length (mm)	Truck Temp (C)	River Temp (C)	Survival index	Mean daily flow (cfs)	CVP	SWP	
04/15/03	West Sacramento (FRH)	49,094	72	12.2	13.9	0.436	24,545 (1774)	0	6	249 (0.0051)
04/30/03	West Sacramento (FRH)	49,837	79	11.0	12.5	0.692	12,546 (405)	0	0	468 (0.0094)
05/15/03	West Sacramento (FRH)	50,284	78	12.8	17.8	0.480	30,572 (887)	0	0	643 (0.0128)
05/01/03	Port Chicago (FRHI)	50,475	79	12.8	18.6	**	**	0	0	415 (0.0082)

Table 18 (cont.)
(d) 2004

Release								Expanded salvage		
Date	Site	# fish released	Mean fork length (mm)	Truck Temp (C)	River Temp (C)	Survival index	Mean daily flow (cfs)	CVP	SWP	Expanded Ocean Numbers (Recovery rate)
04/15/04	West Sacramento (FRH)	49,936	73	12.2	13.8	0.314	19,758 (1899)	24	0	--
04/30/04	West Sacramento (FRH)	49,132	77	12.2	18.8	0.265	12,750 (249)	0	0	--
05/14/04	West Sacramento (FRH)	49,243	89	11.1	20.6	0.029	12096 (97)	0	0	--
05/03/04	Port Chicago (FRH)	49,568	78	15.6	21.1	**	**	0	0	--

(e) 2005

Release								Expanded salvage		
Date	Site	# fish released	Mean fork length (mm)	Truck Temp (C)	River Temp (C)	Survival index	Mean daily flow (cfs)	CVP	SWP	Expanded Ocean Numbers (Recovery rate)
04/15/05	West Sacramento (FRH)	51,257	91	10.0	15.0	0.347	17,837 (654)	0	0	--
4/22/05	Sherman Island (FRH)	52,483	94	10.0	18.0	0.634	15,398 (189)	0	0	--
04/29/05	West Sacramento (FRH)	51,462	115	10.9	18.0	0.189	21,323 (2419)	0	0	--
05/16/05	West Sacramento (FRH)	53,455	97	13.9	18.0	0.467	55,300 (3343)	0	0	--
05/19/05	Port Chicago (FRH)	49,568	78	15.6	21.1	**	**	0	0	--

The average smolt survival index, for 2001-2005 was 0.32. The lowest average was in 2004 (0.20), and the highest was in 2003 (0.54). The average indices for 2001, 2002, and 2005 were 0.29, 0.24, and 0.33 respectively.

Temperature at release has been shown to be important to the survival of fall run juvenile salmon through the Delta (Newman, 2003). We also observed the importance of temperature to survival in the relationship between river temperature and the survival indices from 1988-2005 ($R^2 = 0.26$; $p < 0.0005$; Figure. 44a). The relationship between the temperature differential and the survival indices were significant ($R^2 = 0.22$, $p < 0.002$, Figure. 44b). A mechanism for this relationship may be the affect of the temperature differential (between truck and river temperatures) on the fish at the time of release.

It is possible that the cause of these relationships is the increased physiological stress of a dramatic change in temperature or high temperatures. In recent VAMP studies, there has been an effort to determine the effect of temperature differential between the

truck and river on short term salmon mortality by holding marked fish for 48 hours in net pens. These studies indicate that very few mortalities resulted during this time, suggesting that this instant change in temperature does not cause immediate mortality (San Joaquin River Agreement, 2005). However, there is a possibility that the shock associated with the instantaneous change in temperature may reduce the health of the fish on a longer term or that higher river temperatures in of themselves may cause stress, higher susceptibility to predation and disease, lower dissolved oxygen concentration, and greater energy demands resulting from a higher metabolism.

For releases made in 2001-2005, the variation in temperature differential was low indicating other factors contributed to the differences observed in the survival indices.

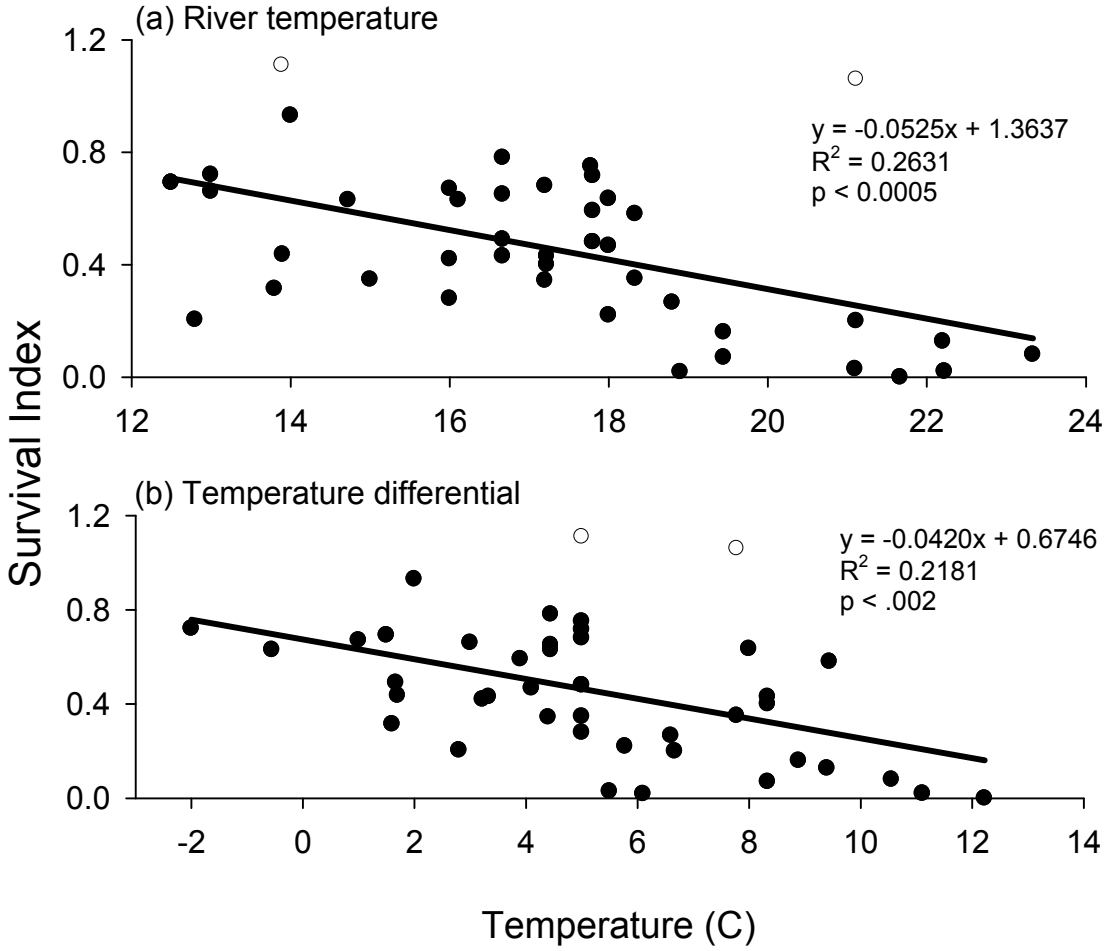

Figure 44: Relationship between survival index and (a) river temperature and (b) temperature differential between truck and river from 1988-2005. The two open circles indicate releases where survival index >1.0.

VAMP

The goal of the VAMP study is to evaluate the effects of river flows and exports by the SWP and the CVP pumping facilities on juvenile Chinook salmon survival through the San Joaquin Delta. VAMP measures survival under specific flow and export rates with a barrier at the head of Old River.

Escapement of fall run Chinook salmon in the San Joaquin River and tributaries has fluctuated dramatically for many years, with peak escapement values near 70,000 fish. Brandes (2000) reported that escapement was related to flows between April-June from 2.5 years prior, which is when juveniles migrate towards the ocean. Results from past smolt survival studies conducted in the South Delta indicate that survival to Chipps Island is very low in some years. In addition, survival of salmon smolts in the mainstem San Joaquin River is generally greater than those in upper Old River (Brandes and McLain, 2001).

A temporary barrier at the head of Old River (HORB) was installed during the experiments in 2001-2004 as in previous years (1992, 1994, 1996, 1997 and 2000) as a way to increase smolt survival by preventing their migration into upper Old River. In 1996, the HORB was installed for a short period, due to high flows it was breached prior to the release of the experimental fish. The barrier in 2001-2004 had six culverts incorporated into the design and all six were operating for all of these years. In 2005, the temporary barrier was not installed because spring flows exceeded 5,000 cfs, which is the maximum flow for safe installation of the barrier.

Methods

The 2001, 2002, 2003, and 2005 VAMP study involved two releases of CWT juvenile Chinook salmon at three locations along the San Joaquin River: Jersey Point, Durham Ferry, and Mossdale. Due to a shortage of fish from the Merced River Hatchery in 2004, only one set of releases at these locations were made. Durham Ferry, which is approximately 10 river miles upstream from Mossdale, was used as a release site for the first time during the 2000 VAMP study. This was done to address the concern that salmon released at Mossdale could disperse into upper Old River at a higher rate than those originating from the San Joaquin River tributaries during years when the Old River Barrier could not be installed. In 2005, a release was made at Dos Reis instead of Mossdale to better assess losses into upper Old River when the barrier was not in place. Fish were recovered at Chipps Island and survival indices were calculated as described for the Delta Action 8 experiment on page 91.

The two sets of releases made at Durham Ferry, Mossdale/Dos Reis, and Jersey Point were considered replicates measuring survival at similar flow and export rates. Target export and flow rates were set for each water year (Table 19).

Table 19: Target flow and export rates for VAMP experiments conducted in 2001-2005.

Water Year	Target Flow Rate (cfs)	Target Export Rate(cfs)
2001	4,450	1,500
2002	3,200	1,500
2003	3,200	1,500
2004	3,200	1,500
2005	>7,000	2,250

Results and Discussion

Survival indices for marked fish released as part of VAMP between 2001 and 2005 are shown in Table 20. Survival was higher at Jersey Point because of its proximity to Chipps Island. The release at Jersey Point was intended to standardize the catches of the upstream groups (Durham Ferry, Mossdale and Dos Reis) to obtain absolute estimates of survival.

Comparisons in survival between years are made by using survival estimates obtained by dividing the survival index of upstream groups (Durham Ferry, Mossdale, or Dos Reis) by that of the downstream group (Jersey Point). Survival estimates in 2003, 2004, and 2005 were extremely low, lower than those observed in 2001 and 2002. For further information about VAMP methods and results see the 2001-2005 VAMP technical reports (San Joaquin River Group Authority, 2002, 2003, 2004, 2005, 2006).

Table 20. Survival index and expanded CVP salvage, SWP salvage, and ocean recovery numbers for fall-run releases made for the VAMP study during (a) 2001, (b) 2002, (c) 2003, (d) 2004, and (e) 2005 field seasons. Mean daily flow rate at Vernalis was calculated for the 14 days following each release. Standard error of mean daily flow is reported in parentheses. N/A = Not available.

(a) 2001

Release								Expanded salvage		Expanded Ocean Numbers (Recovery rate)
Date	Site	# fish released	Mean fork length (mm)	Truck Temp (C)	River Temp (C)	Survival index	Mean daily flow (cfs)	CVP	SWP	
04/30/01	Durham Ferry	68,682	89	14.4	21.7	0.365 (0.34)	4169 (31.5)	84	0	364
050/1/01	Mossdale	45,177	91	15	19.4	0.323 (0.30)	4194 (50.5)	36	12	228
05/0401	Jersey Point	49,435	88	15	20	1.06	8123 162)	0	0	1026
05/07/01	Durham Ferry	72,231	85	14.4	18.9	0.052 (0.13)	8612 (290)	24	15	90
05/08/01	Mossdale	49,186	89	15.6	21.1	0.076 (0.19)	8812 (297)	24	12	52
05/11/01	Jersey Point	51,374	87.5	16.1	22.8	0.401	9159 (274)	0	0	578

(b) 2002

Release								Expanded salvage		Expanded Ocean Numbers (Recovery rate)
Date	Site	# fish released	Mean fork length (mm)	Truck Temp (C)	River Temp (C)	Survival index	Mean daily flow (cfs)	CVP	SWP	
04/18/02	Durham Ferry	97,713	83	12.5	15	0.105 (0.13)	3364 (35.2)	96	111	270
04/19/02	Mossdale	50,785	83	13	14	0.122 (0.15)	3377 (31.1)	96	138	145
04/22/02	Jersey Point	48,928	84	15	18	0.830	3408 (28.6)	24	24	950
04/25/02	Durham Ferry	98,499	80	16	17	0.077 (0.16)	3411 (29.8)	84	91	34
04/26/02	Mossdale	49,340	80	13	17.5	0.051 (0.11)	3265 (32.3)	12	117	40
04/30/02	Jersey Point	46,913	82	11.5	17.5	0.480	3288 (33.2)	0	0	597

Table 20 (cont.)

(c) 2003

Release								Expanded salvage		Expanded Ocean Numbers (Recovery rate)
Date	Site	# fish released	Mean fork length (mm)	Truck Temp (C)	River Temp (C)	Survival index	Mean daily flow (cfs)	CVP	SWP	
04/21/03	Durham Ferry	74,449	86	11	15	0.019 (0.02)	3306 (34.2)	48	3	19
04/22/03	Mossdale	49,683	87.5	13	15	0.048 (0.04)	3297 (32.2)	0	0	8
04/25/03	Jersey Point	24,414	89	13.5	16.5	1.09	3297 (27.5)	0	0	253
04/28/03	Durham Ferry	74,502	87	11.5	16.5	0.000	3329 (20.5)	24	0	10
04/29/03	Mossdale	48,526	86	13	16	0.010 (0.01)	3321 (22.5)	12	0	5
05/02/03	Jersey Point	25,692	88	13.5	16.5	0.739	3177 (79.8)	0	0	415

(d) 2004

Release								Expanded salvage		Expanded Ocean Numbers (Recovery rate)
Date	Site	# fish released	Mean fork length (mm)	Truck Temp (C)	River Temp (C)	Survival index	Mean daily flow (cfs)	CVP	SWP	
04/22/04	Durham Ferry	92,264	82.5	13	16	0.015 (0.03)	3273 (17.9)	84	12	N/A
04/23/04	Mossdale	73,709	80.6	13	17	0.020 (0.04)	3276 (17.0)	24	6	N/A
04/26/04	Jersey Point	22,910	85	14	22	0.511	3295 (15.0)	12	0	N/A

(e) 2005

Release								Expanded salvage		Expanded Ocean Numbers (Recovery rate)
Date	Site	# fish released	Mean fork length (mm)	Truck Temp (C)	River Temp (C)	Survival index	Mean daily flow (cfs)	CVP	SWP	
05/02/05	Durham Ferry	93,833	85.6	11	16	0.058 (0.09)	8692 (125)	1428	27	N/A
05/03/05	Dos Reis	69,125	87	13	17	0.019 (0.03)	8745 (120)	1	6	N/A
05/06/05	Jersey Point	22,767	86.1	11	18	0.634	9025 (320)	0	0	N/A
05/09/05	Durham Ferry	91,563	87.6	11	15	0.028 (0.04)	9755 (320)	517	327	N/A
05/10/05	Dos Reis	68,646	87.2	11	15	0.037 (0.05)	10,034 (378)	0	6	N/A
05/13/05	Jersey Point	23,231	87.5	13	19	0.711	10,898 (489)	0	0	N/A

Fall run interior Delta versus mainstem Sacramento survival comparison

In 1999, 2000 and 2002 groups of fall-run smolts were released to compare the relative survival of fish released in the main stem Sacramento River and in the central Delta both before and during the VAMP experiment with increased San Joaquin flows and an export curtailment. The hypothesis tested was that the relative survival rate of the groups released in the central Delta would be lower with higher exports (prior to VAMP) than with lower exports (during VAMP).

Two groups of fall-run smolts were released at Georgiana Slough and Ryde prior to and during VAMP (Table 21). There were two releases made at Georgiana Slough during the pre-VAMP phase in 2002 due to the high mortality (25%) of the first group at release potentially due to the effects of IHN infection. A second release was made at Georgiana Slough the following day and no immediate mortality was observed.

In 1999, we found that the ratio of salmon survival rates between the Georgiana Slough and Ryde releases was greater before the VAMP period (= 0.83) than during the VAMP period (= 0.51; Table 21). Survival indices of both release groups were greater during VAMP than before VAMP, but survival index on the main stem Sacramento River was disproportionately higher, decreasing the ratio estimated during VAMP.

In 2000, ratios of salmon survival were identical before and after the VAMP period (both = 0.48). Survival rates of both releases were nearly twice as high during the VAMP with export curtailments.

In 2002, the survival rates from the second Georgiana Slough and Ryde pre-VAMP releases (0.042 and 0.087 respectively) were less than during VAMP Georgiana Slough (0.078) and Ryde (0.154). The survival ratios were similar during VAMP (0.51) and before VAMP (0.48). Ratios obtained with ocean recovery rates seemed different from those obtained using Chipps Island survival indices. Using the ocean recovery rates survival ratios appeared similar in 1999 and 2002 prior to and during VAMP. The greatest differences were observed in 2000, where the Chipps Island survival indices indicated similar ratios between the two test cases, whereas the ocean recovery rate information indicated ratios were different, with the pre- VAMP releases having a higher ratio of survival than the during VAMP releases. Unfortunately, the results in 2000 are based on relatively few (less than 100) expanded recoveries in the ocean fishery, preventing us from making any conclusive interpretation of these results when the results of the two estimates are not consistent.

The data did not appear to support our hypothesis that relative central Delta survival for fall run smolts is greater with lower exports. However, it is interesting to note that survival indices were generally higher during the VAMP period for both groups. The paired release design was used to factor out parameters affecting survival common to

both groups. It is unclear why relative survival would not improve with lower exports. Ocean recovery information would provide better estimates of survival due to their larger recovery numbers. Due to budget constraints this study was only conducted for these three years, then discontinued.

Table 21. Georgiana Slough versus Ryde survival comparisons before and during VAMP.

Timing of release	Release Date	Release Site	# Fish Released	Mean fork length (mm)	Truck Temp (C)	River Temp (C)	Survival index	Survival Ratio (GS:Ryde)
Pre-VAMP	03/30/99	Georgiana Slough	52,578	75	13	8	0.261	0.83
	03/31/99	Ryde	51,006	75	12	12	0.316	
During VAMP	04/27/99	Georgiana Slough	49,970	86	12	17	0.355	0.51
	04/28/99	Ryde	52,303	86	13	16	0.698	
Pre-VAMP	03/28/00	Georgiana Slough	49,824	71	11	14	0.071	0.48
	03/29/00	Ryde	46,510	71	10	15	0.149	
During VAMP	04/27/00	Georgiana Slough	39,136	79	14	18	0.116	0.48
	04/28/00	Ryde	42,814	79	13	18	0.244	
Pre-VAMP	04/4/02	Georgiana Slough	69,949	78	11	16	0.020	
	04/5/02	Georgiana Slough	44,565	78	12	16	0.042	0.48
	04/4/02	Ryde	43,789	74	11	16	0.087	
During VAMP	04/18/02	Georgiana Slough	68,114	89	11	16	0.078	0.51
	04/18/02	Ryde	43,676	83	11	18	0.154	

Other CWT recoveries in sampling gears during the 2001-2005 field season

Coded wire tagged Chinook salmon of all races are recovered in all sampling gears throughout the field season. They are summarized here, but specific information on any individual fish is available at IEP's BDAT web site <http://baydelta.ca.gov>. Maps showing recovery numbers and locations of the various coded wire tag groups released in 2001-2005 are available online at <http://www.delta.dfg.ca.gov/jfmp/cwt.asp>.

Fall-run

Numerous CWT fall-run salmon are released throughout the year in the Central Valley.

Many are recovered in trawling efforts at Sacramento (Sherwood Harbor) and Chipps Island and in beach seines in the lower Sacramento and San Joaquin Rivers and the Delta. Others are recovered in the SWP and CVP facilities.

In the 2001 field season, we recovered 1,517 CWT fall-run salmon (Table 17). We recovered 1,056 fish at Chipps Island, 235 at Sherwood Harbor and 52 in beach seines, most of which were on the Sacramento River. The CVP recovered 69 fish and the SWP recovered 105 fish. In the 2002 field season, 2,221 CWT fall-run salmon were recovered. We recovered 1,370 fish at Chipps Island, 410 at Sherwood Harbor, and 62 in beach seines. The SWP recovered 186 fish and the CVP recovered 193 fish. In the 2003 field season, 1,294 CWT fall-run salmon were recovered. We recovered 740 fish at Chipps Island, 254 at Sherwood Harbor, and 89 were captured in beach seines. There were 872 fish recovered at the SWP and 311 at the CVP. In the 2004 field season, we recovered 331 CWT fall-run salmon. Of these, 228 were recovered at Chipps Island, 20 at Sherwood Harbor, and 33 in beach seines. There were 23 fish recovered at the SWP and 27 at the CVP. In the 2005 field season, 1,519 CWT fall-run salmon were recovered. We recovered 465 fish at Chipps Island, 236 at Sherwood Harbor, and 102 in beach seines. There were 307 fish recovered at the SWP and 409 from the CVP. A map of these sites is available at <http://www.delta.dfg.ca.gov/data/rtm2000/sample-sites.asp>.

Many fall-run fish released on the Sacramento River (i.e., Battle Creek, West Sacramento, and Ryde/Isleton) were recovered at Chipps Island. This indicates that the majority of these fish stayed in the main stem of the Sacramento instead of moving into the central Delta via Georgiana Slough or Three Mile Slough.

Late fall-run

In 2001, we recovered the lowest number of CWT late fall-run salmon (344 fish) of the 5 year reporting period (Table 17). The majority of these were captured at Chipps Island (91 fish), CVP (29 fish) and SWP (101 fish). In 2002, we recovered 2,204 CWT late fall-run salmon. The majority of these fish were captured in the Sacramento River (1,203 fish) as a result of trawling efforts conducted to evaluate the Delta Cross Channel (see "Delta Cross Channel" below). We caught 423 fish in Chipps Island trawls, 77 at the CVP, and 256 at the SWP facilities. In 2003, a total of 1,723 late fall salmon were captured. Of these, 310 fish were recovered at Chipps Island and 183 fish were captured in Sacramento trawls at Sherwood Harbor. The SWP recovered 872 fish, whereas the CVP recovered 311 fish. In 2004, 1,433 late fall-run salmon were recovered. The largest number of recoveries were at the SWP (667 fish), whereas Chipps Island trawls recovered 454 fish. Recoveries during 2005 were also low (632 fish). Of these, 458 fish were recovered in Chipps Island trawls and 183 fish at the SWP facility. As expected, the majority of CWT late fall-run salmon recoveries occurred in either trawl or salvage efforts and were largely from Battle Creek releases.

Winter-run

Approximately 162,000 winter-run salmon from Livingston Stone National Fish Hatchery (LSNFH) were released in the upper Sacramento River at Caldwell Park on 2/1/01.

Only 14 of these fish were recovered, 9 in our trawling efforts (Chipps Island: 8, Sherwood Harbor: 1), 3 in our beach seines (Verona: 2 and Wards Landing: 1) and 2 were recovered at the State Facility. On 1/30/02, LSNFH released approximately 245,000 winter-run salmon at Caldwell Park. Only 37 of these fish were recovered: 24 in trawls at Chipps Island, 2 in trawls at Sherwood Harbor, 7 in beach seines, and 2 each at the CVP and SWP facilities. Approximately 222,000 winter-run salmon were released by LSNFH at Caldwell Park on 1/30/2003. A total of 96 of these fish were recovered, 34 at Chipps Island, 16 at Sherwood Harbor, and 7 from various beach seine sites along the main stem of the Sacramento River. The SWP recovered 26 fish, while the CVP recovered 12. On 2/05/04, LSNFH released approximately 217,000 winter-run salmon at Caldwell Park. A total of 86 of these fish were recovered, a total of 32 from the facilities and 22 from trawls (Chipps Island: 21 and Sherwood Harbor: 1). The remaining 33 fish were recovered in beach seines, 19 along the main stem of the Sacramento River and 14 at Terminous in the Delta. On 2/3/2005 approximately 170,000 winter-run from LSNFH were released at Caldwell Park. A total of 64 of these fish were recovered: 47 were captured in trawls, (26 at Sherwood Harbor and 21 at Chipps Island), and 15 were captured in beach seines along the main stem of the Sacramento River (Table 17). Only 2 of the total 64 fish recovered were from the State (1 fish) and Federal (1 fish) facilities.

Spring-run

In 2001, the Feather River hatchery released an approximate total of 448,000 wild spring-run salmon at two locations, Butte Creek (167,000 fish) and San Pablo Bay (281,000 fish). We recovered 17 of these fish, 13 were recovered at Chipps Island and four at Sherwood Harbor. In 2002, the Feather River hatchery released an approximate total of 575,000 wild spring-run salmon at three locations, Butte Creek (155,000 fish), Live Oak (254,000 fish) and San Pablo Bay (166,000 fish). We recovered 95 of these fish, 80 were captured in the Chipps Island trawls, 14 were captured in Sherwood Harbor trawls and 1 was recovered in a beach seine at Verona on the Lower Sacramento River. In 2003 the Feather River hatchery released an approximate total of 1,436,000 spring-run salmon. 758,000 were released at Benicia, 40,000 at Butte Creek, and 638,000 at Live Oak. We recovered 296 of these fish, 269 in Chipps Island trawls and 27 in Sherwood Harbor trawls. In 2004 the Feather River hatchery released an approximate total of 1,114,000 spring-run salmon at three locations Butte Creek (199,000 fish), Feather River (459,000 fish) and San Pablo Bay (456,000 fish). We recovered 25 of these fish, 20 at Chipps Island and 5 at Sherwood Harbor. The SWP recovered one fish released at Butte Creek. In 2005, the Feather River Hatchery released an approximate total of 2,095,000 spring-run salmon at four locations Butte Creek (400,000 fish), Live Oak (756,000 fish), Shore Terminal (705,000 fish) and Verona (234,000 fish). We recovered 630 of these fish, 458 at Chipps Island, 132 at Sherwood Harbor and 39 were captured in beach seines along or adjacent to the main stem or of the Sacramento river. The SWP captured two spring-run salmon, one released at Butte Creek and one form the Live oak release (Table 17).

There were multiple releases of wild Chinook salmon in 2005 at Yuba River. Because they were wild, their true race is unknown. As a result, we have classified them as

spring-/fall-run. We caught 10 of these fish in 2005, 8 at Chipps Island and 2 at Sherwood Harbor (Table 18).

Table 17. Recoveries of coded wire tagged juvenile Chinook salmon released at hatcheries during the 2001-2005 field seasons. Blank cells indicate that no fish were recovered.

2001	**Recovery Location**																								
Release Location	B&W Marina	Benicia	Brannan Island	Chipps Island	Clarksburg	Discovery Park	Dos Reis	Elkhorn	Federal Fish Facility	Franks Tract	Garcia Bend	Isleton	Koket	Miller Park	Mossdale	Rio Vista	Sand Cove	Sherwood Harbor	State Fish Facility	Steamboat Sl. (mouth)	Stump Beach	Verona	Wards Landing	Weatherbee	Total
(a) Fall																									
Battle Creek				403					1									198	2						604
Benicia				30																					30
Clarksburg			1	2	1					1									9		1				15
Durham Ferry				62			1		9										2					3	77
Elkhorn				4		1		4					1					2	1						13
Feather River				27																					27
Grayson				1																					1
Hatfield State Park				37					2						1				10					1	51
Head of Old River Barrier				4					33										43						80
Isleton				3												1			1		1				6
Jersey Point				243															2						245
Knight's Ferry									5																5
La Grange				8					1																9
Lighthouse Marina																			2						2
Live Oak				9	2			22			2							20	9		2	2			68
Mossdale				39					5										4						48
New Hope Landing				18					10										15						43
North Fork Mokelumne				28																					28
Old Fisherman's Club				25			1		2										2						30
Red Bluff Diversion Dam				8														2	1						11

2001 (cont.)

Release Location	B&W Marina	Benicia	Brannan Island	Chipps Island	Clarksburg	Discovery Park	Dos Reis	Elkhorn	Federal Fish Facility	Franks Tract	Garcia Bend	Isleton	Koket	Miller Park	Mossdale	Rio Vista	Sand Cove	Sherwood Harbor	State Fish Facility	Steamboat Sl. (mouth)	Stump Beach	Verona	Wards Landing	Weatherbee	Total
	Recovery Location																								
San Pablo Bay				9																					9
South Fork Mokelumne				16																					16
Thermalito Bypass				5																					5
Two Rivers									1																1
Upper Merced @ MRFF				11															2						13
West Sacramento				64							3							13							80
Fall Total			1	1056	3	1	2	26	69	1	5		1		1	1		235	105		4	2		4	1517
(b) Late fall																									
Battle Creek	2	39	1	70	1			5	25		2			4		1	1	51	66		1				269
Old River									1										3						4
Steamboat Slough		3	2	1												1			3						10
Sutter Slough		1	1	4															4						10
Vorden Road				8	1				1			3				1			15						29
Vorden Road East (RM 30)			1	8					2										10	1					22
LateFall Total	2	43	5	91	2			5	29		2	3		4		3	1	51	101	1	1				344
(c) Spring																									
Butte Creek				2														4							6
San Pablo Bay				11																					11
Spring Total				13														4							17
(d) Winter																									
Caldwell Park				8														1	2			2	1		14
Winter Total				8														1	2			2	1		14

2002	Recovery Location																																
Release Location	Brannan Island	Chipps Island	Clarksburg	Colusa St. Park	Delta Cross Channel	Discovery Park	Dos Reis	Durham Site	Eddo's	Elkhorn	Federal Fish Facility	Garcia Bend	Georgiana Slough	Isleton	Knights Landing	Koket	Medford Island	Miller Park	Mossdale	Reels Beach	Rio Vista	Sac. R. Push 1 / DCC Study	Sand Cove	Sherwood Harbor	State Fish Facility	Steamboat Sl. (mouth)	Stump Beach	Terminous	Verona	Walnut Grove / DCC Study	Weatherbee	Wimpy's	Total
(a) Fall																																	
Battle Creek		708																						363	2		1				1		1075
Clarksburg	2	13									2		1	1		3					3				9	1							35
Durham Ferry		36						2			15								1						43						1		98
Elkhorn		16				2						1		1		2								24				1					47
Georgiana Slough		18																							3								21
Grayson		1									1																						2
Hatfield State Park		9									137														28								174
Isleton	9	11									2			6		1					5			1									35
Jersey Point		313							1		10														26								350
Knight's Ferry		4									1														1								6
La Grange		8									2														7								17
Lighthouse Marina	1	3									2						10								8								24
Mossdale		18					1				9														37								65
New Hope Landing		43									5														6							1	55
North Fork Mokelumne		17									4														6								27
Old Fisherman's Club		9									1														4						1		15

2002 (cont.)

Release Location	Brannan Island	Chipps Island	Clarksburg	Colusa St. Park	Delta Cross Channel	Discovery Park	Dos Reis	Durham Site	Eddo's	Elkhorn	Federal Fish Facility	Garcia Bend	Georgiana Slough	Isleton	Knights Landing	Koket	Medford Island	Miller Park	Mossdale	Reels Beach	Rio Vista	Sac. R. Push 1 / DCC Study	Sand Cove	Sherwood Harbor	State Fish Facility	Steamboat Sl. (mouth)	Stump Beach	Terminous	Verona	Walnut Grove / DCC Study	Weatherbee	Wimpy's	Total
	Recovery Location																																
Port Chicago		14																															14
Red Bluff Diversion Dam		14									1													4	1								20
Ryde		22														1																	23
San Pablo Bay		39																							3								42
Thermalito Bypass																								1									1
Two Rivers		1																															1
Upper Merced @ MRFF		1									1														1								3
West Sacramento		46																						17	1								64
Yolo Bypass	1	6																															7
Fall Total	13	1370				2	1	2	1		193	1	1	8		7	10		1		8			410	186	1	1	1			3	1	2221
(b) Late Fall																																	
Battle Creek		358	2			1				11	66	6				2		8			2		1	91	197				2				747
Delta Cross Channel		2																															2
Georgiana Slough		18									9														54								81
Port Chicago		2																							2								4
Ryde		34									1			1											1								37

2002 (cont.)	Recovery Location																																
Release Location	Brannan Island	Chipps Island	Clarksburg	Colusa St. Park	Delta Cross Channel	Discovery Park	Dos Reis	Durham Site	Eddo's	Elkhorn	Federal Fish Facility	Garcia Bend	Georgiana Slough	Isleton	Knights Landing	Koket	Medford Island	Miller Park	Mossdale	Reels Beach	Rio Vista	Sac. R. Push 1 / DCC Study	Sand Cove	Sherwood Harbor	State Fish Facility	Steamboat Sl. (mouth)	Stump Beach	Terminous	Verona	Walnut Grove / DCC Study	Weatherbee	Wimpy's	Total
Vorden Road East		9			105						1		4	1		3					3	470			2		2			733			1333
LateFall Total		423	2		105	1				11	77	6	4	2		5		8			5	470	1	91	256		2		2	733			2204
(c) Spring																																	
Butte Creek		5																						2									7
Live Oak		74																						12					1				87
San Pablo Bay		1																															1
Spring Total		80																						14					1				95
(d) Winter																																	
Caldwell Park		24		1							2				2					3				2	2	1							37
Winter Total		24		1							2				2					3				2	2	1							37

2003	Recovery Location																												
ReleaseLocation	American River	B&W Marina	Brannan Island	Chipps Island	Clarksburg	Colusa St. Park	Discovery Park	Dos Reis	Durham Site	Eddo's	Elkhorn	Federal Fish Facility	Garcia Bend	Isleton	Koket	Liberty Island East #1	Liberty Island East #2	Liberty Island East #4	Medford Island	Reels Beach	Rio Vista	Sherwood Harbor	State Fish Facility	Steamboat Sl. (mouth)	Stump Beach	Terminous	Union Island	Verona	Wards Landing	Total
(a) Fall																														
B&W Marina		27		1								3							1				17				1			50
Clarksburg			1	2	2							3											17							25
Durham Ferry				3				2	1			6											7							19
Elkhorn				10	2						9	1						1				30	9	2						64
Hatfield State Park				14								4											8							26
Jersey Point				169								4																		173
Knight's Ferry				1																			3							4
Lighthouse Marina				3						1		1											5							10
Live Oak				173													1					27			1			1		203
Mokelumne River (Bean Farm)		1		16								37											10			1				65
Mokelumne River FH				29																										29
Mossdale				6				1				1											2							10
New Hope Landing				22								5											7							34
North Fork Mokelumne (Eagle Tree)		3		38								10											3							54
Port Chicago				16																										16
Red Bluff Diversion Dam				23								1								1		4	4							33
South Fork Mokelumne (Beaver Slough)				25								15																		40
Upper Merced @ MRFF				7								6											6							19

2003 (cont.)	Recovery Location																													
ReleaseLocation	American River	B&W Marina	Brannan Island	Chipps Island	Clarksburg	Colusa St. Park	Discovery Park	Dos Reis	Durham Site	Eddo's	Elkhorn	Federal Fish Facility	Garcia Bend	Isleton	Koket	Liberty Island East #1	Liberty Island East #2	Liberty Island East #4	Medford Island	Reels Beach	Rio Vista	Sherwood Harbor	State Fish Facility	Steamboat Sl. (mouth)	Stump Beach	Terminous	Union Island	Verona	Wards Landing	Total
Vieira's Resort			13	13								4				1					3		9							43
West Sacramento				163	2									2	1	2	1					193	1	3						368
Woodbridge Dam				1																										1
Yolo Bypass				5									1										2							8
Fall Total		31	14	740	6			3	1	1	9	101	1	2	1	3	2	1	1	1	3	254	110	5	1	1	1	1		1294
(b) Late fall																														
Battle Creek		1	1	250	1	1	2				6	268	1	2	1							61	788							1383
Georgiana Slough		3		1								23							1				53							81
Port Chicago				6																										6
Ryde			1	18								2											2		1					24
West Sacramento				35	2							18	23									122	29							229
LateFall Total		4	2	310	3	1	2				6	311	24	2	1				1			183	872		1					1723
(c) Spring																														
Benicia				24																										24
Butte Creek				5																		1								6
Live Oak				240																		26								266
Spring Total				269																		27								296
(d) Winter																														
Caldwell Park	1			34							2	12			1					3		16	26						1	96
Winter Total	1			34							2	12			1					3		16	26						1	96

2004	Recovery Location																											
Release Location	B&W Marina	Brannan Island	Chipps Island	Clarksburg	Colusa St. Park	Discovery Park	Dos Reis	Elkhorn	Federal Fish Facility	Garcia Bend	Isleton	King's Island	Knights Landing	Koket	Liberty Island East #5	Miller Park	Mossdale	Reels Beach	Sherwood Harbor	State Fish Facility	Steamboat Sl. (mouth)	Stump Beach	Terminous	Verona	Wards Landing	Weatherbee	Wimpy's	Total
(a) Fall																												
Battle Creek			58																9									67
Clarksburg			1	9																3								13
Durham Ferry			3						8											2						1		14
Elkhorn			2					11											1	1								15
Hatfield State Park			5						8											6								19
Isleton		1	2						1											2								6
Jersey Point			25						1																			26
Lighthouse Marina			4						2											6								12
Live Oak			1																									1
Mokelumne River FH			1																								2	3
Mossdale			3				3		2								1			1								10
New Hope Landing																											2	2
Port Chicago			38																									38
Red Bluff Diversion Dam			11	1																1								13
San Pablo Bay			9																									9
Shaffer Bridge			1																									1
Upper Merced @ MRFF									3											1								4
West Sacramento		1	59						2										10									72
Yolo Bypass @ Fremont Weir			1																									1

2004 (cont.)	Recovery Location																											
Release Location	B&W Marina	Brannan Island	Chipps Island	Clarksburg	Colusa St. Park	Discovery Park	Dos Reis	Elkhorn	Federal Fish Facility	Garcia Bend	Isleton	King's Island	Knights Landing	Koket	Liberty Island East #5	Miller Park	Mossdale	Reels Beach	Sherwood Harbor	State Fish Facility	Steamboat Sl. (mouth)	Stump Beach	Terminous	Verona	Wards Landing	Weatherbee	Wimpy's	Total
Yolo Bypass near I-5			1												1													2
Yuba River			3																									3
Fall Total		2	228	10			3	11	27						1		1		20	23						1	4	331
(b) Late fall																												
Battle Creek		2	344	2		1		11	160	5	1		1			4			35	604			1		1			1172
Georgiana Slough	3		5						11			1								28		1						49
Ryde			13											1						4								18
Sac River RM206										1																		1
Sherman Island			53						2																			55
Vorden Road		1	10						12					1						24								48
West Sacramento		1	29	4					2	11						5			30	7	1							90
LateFall Total	3	4	454	6		1		11	187	17	1	1	1	2		9			65	667	1	1	1		1			1433
(c) Spring																												
Butte Creek			3																1	1								5
Feather River			3																4									7
San Pablo Bay			14																									14
Spring Total			20																5	1								26
(d) Winter																												
Caldwell Park			21		3				6	2			1					1	1	26				14	11			86
Winter Total			21		3				6	2			1					1	1	26				14	11			86

2005	Recovery Location																																			
Release Location	American River	Antioch Dunes	B&W Marina	Brannan Island	Chipps Island	Clarksburg	Colusa St. Park	Discovery Park	Dos Reis	Durham Site	Eddo's	Elkhorn	Federal Fish Facility	Garcia Bend	Georgiana Slough	Isleton	Knights Landing	Koket	Lost Isle	Miller Park	Mossdale	Rio Vista	Route 132	Sand Cove	Sherman Island	Sherwood Harbor	State Fish Facility	Steamboat Sl. (mouth)	Sturgeon Bend	Terminous	Union Island	Verona	Wards Landing	Weatherbee	Wimpy's	Total
(a) Fall																																				
Clarksburg					2	1										2																				5
Dos Reis					9				1				2														3									15
Durham Ferry					18				2	1			172														87				5			1		286
Elkhorn Park				1	12							29			1			3								38									1	85
Hatfield					15								90														42		1							148
Isleton				4	10						1				1	7		3				5			1		2									34
Jersey Point					70																															70
La Grange					7								33														50									90
Lighthouse Marina			12	2	1																						1			3						19
Live Oak					11																					5										16
Merced Hatchery					13								75														93									181
Mokelumne River FH					59																															59
Old Fisherman's Club					4				1				37						1		1		1				29		5							79
Port Chicago					3																															3
Red Bluff Diversion Dam	1				11																					6										18
Sherman Island		1		1	68																															70
Shore Terminal					2																															2
West Sacramento					144																	2				187										333

2005 (cont.)	Recovery Location																																			
Release Location	American River	Antioch Dunes	B&W Marina	Brannan Island	Chipps Island	Clarksburg	Colusa St. Park	Discovery Park	Dos Reis	Durham Site	Eddo's	Elkhorn	Federal Fish Facility	Garcia Bend	Georgiana Slough	Isleton	Knights Landing	Koket	Lost Isle	Miller Park	Mossdale	Rio Vista	Route 132	Sand Cove	Sherman Island	Sherwood Harbor	State Fish Facility	Steamboat Sl. (mouth)	Sturgeon Bend	Terminous	Union Island	Verona	Wards Landing	Weatherbee	Wimpy's	Total
Yolo Bypass					6																															6
Fall Total	1	1	12	8	465	1			4	1	1	29	409		2	9		6	1		1	7	1		1	236	307		6	3	5			1	1	1519
(b) Late fall																																				
Battle Creek			1		263		1					6	24	10			1	1		2				2	1	56	151									518
Georgiana Slough					10								4														19									33
Port Chicago					2																															2
Ryde					28											1																				29
Sac River RM206					10									1						1						1	5									18
Sherman Island					15						1														1											17
Vorden Road					37								1														2									40
West Sacramento					21	2							2	8												52	6	1								92
Late fall Total			1		386	2	1				1	6	30	19		1	1	1		3				2	2	109	183	1								749
(c) Spring																																				
Butte Creek					4																					1	1									6
Live Oak			1		435							1		1												42	1									481
Shore Terminal					4																															4
Verona	1			1	15	8		1				4		5				2				1				89						14				141
Spring Total	1		1	1	458	8		1				5		6				2				1				132	2					14				632
(d) Spring/ Fall																																				
Yuba River					8																					2										10

2005 (cont.)				Recovery Location																															
Release Location	American River	Antioch Dunes	B&W Marina	Brannan Island	Chipps Island	Clarksburg	Colusa St. Park	Discovery Park	Dos Reis	Durham Site	Eddo's	Elkhorn	Federal Fish Facility	Garcia Bend	Georgiana Slough	Isleton	Knights Landing	Koket	Lost Isle	Miller Park	Mossdale	Rio Vista	Route 132	Sand Cove	Sherman Island	Sherwood Harbor	State Fish Facility	Steamboat Sl. (mouth)	Sturgeon Bend	Terminous	Union Island	Verona	Wards Landing	Weatherbee	Wimpy's	Total
Spring/Fall Total					8																					2										10
(e) Winter																																				
Caldwell Park					21		2						1				1									26	1					1	11			64
Winter Total					21		2						1				1									26	1					1	11			64

Delta Cross Channel

The Delta Cross Channel (DCC) is located on the Sacramento River north of Walnut Grove. This channel was constructed in 1951 to divert freshwater from the Sacramento River into the interior Delta to meet water quality requirements. The diversion of water is controlled by two gates located at the entrance to the DCC on the Sacramento River. When the gates are open, water is diverted into the interior Delta. Out migrating juvenile salmon can also be diverted into the interior Delta where their survival is significantly less than those that migrate down the Sacramento River (Brandes and McLain 2001, "Delta Action 8" section above).

In Fall 2001, a multi-agency (USGS, CDFG, Natural Resource Scientists, Inc. [NRSI], and USFWS) study was designed and implemented to evaluate the effects of time of day and tidal phase on the downstream movement of juvenile salmon into the DCC when the gates are open (Hansen 2004). The DJFMP conducted the CWT salmon recovery component of this study. The objective of the CWT recovery experiment was to estimate the proportion of fish that moved into the DCC and to determine whether any relationship exists between movement and tidal phase, flow, and time of day.

Methods

The CWT recovery experiment was conducted from 10/28/2001 to 11/2/2001 with two replicates of approximately 36 hours of trawling per replicate. Approximately 121,000 CWT late fall-run salmon from CNFH were released for this study. The fish were divided into four groups of approximately 29,000 to 33,000 fish each. Each group was tagged with a unique CWT code and their adipose fins were removed for ease of identification. Two of these groups were used for each replicate. Fish were delivered to the release site the day before the release and placed into net pens anchored in the river adjacent to the bank approximately 4 km (2.5 miles) upstream of the DCC. Each group was separated into three more sub-groups ranging from approximately 7,000 to 15,000 fish providing six releases for each replicate. The fish in each group were transferred to portable pens that were towed to the middle of the river and released by inverting the pen in the water. Fish releases were timed with tidal stage to obtain similar river conditions for each replicate.

Fish recovery was conducted by two simultaneous trawls, one downstream of the DCC in the Sacramento River (rm 27) and one in the DCC. Trawls were typically 15 minutes and were nearly continuous for 36 hours. All fish captured in each tow were identified to species and their fork length was measured. All adipose clipped salmon were kept and examined for a CWT. If CWT were present, it was later removed and read.

Replicate I

Approximately 57,512 fish were released on 10/29/2001. The average sub-group size was 9,585 fish. The first sub-group was released at 0529 h and the last sub-group was released at 2222 h. On 10/29/2001 trawling began at 0702 h at the Sacramento River site and 0721 h at the DCC site. Trawling concluded on 10/30/2001 at 1202 h on the

Sacramento river and 1159 h at the DCC. Sixty-nine tows were completed at the Sacramento River site and 68 tows were completed at the DCC site.

Replicate II
Approximately 54,364 fish was released in five releases on 11/01/2001. There were 8924 fish were released in the sixth release on 11/02/2001, for a total of 63,288 fish released in replicate II. The average group size was 10,548, the first group was released at 0707 and the last group was released at 0105. On 11/01/2001 trawling began at 0714 at the Sacramento river site and 0734 at the DCC site. Trawling concluded on 11/02/2001 at 1110 on the Sacramento River and 1036 at the DCC. Sixty-eight tows were completed at the Sacramento River site and 66 tows completed at the DCC site.

Results
Replicate I
At the Sacramento trawl site, the majority of the 402 CWT salmon captured occurred between ~2.5 hours after sunset to sunrise (Figure 40a). At the DCC trawl site, 75 CWT salmon were captured, none were captured until ~2 hours after sunset and only a few were captured after sunrise (Figure 40b). It is important to note there were no captures of either CWT code at the Sacramento River until after a group of each CWT code was released, and no captures of either CWT code at the DCC until after two groups of each CWT code were released (Hansen 2004).

Replicate II
At the Sacramento trawl site, we recovered only one CWT before sunset (Figure 41a). The majority of the 812 CWT salmon captured occurred between sunset and ~2 hours before sunrise. Only 34 CWT salmon were recovered at the DCC site (Figure 41b). Recoveries began ~2 hours after sunset and ended at sunrise. It is important to note, that somewhat similar to the captures observed in Replicate I, there were no captures of either CWT code at the Sacramento River until after three groups were released, and almost no captures of either CWT code at the DCC until after two groups of each CWT code were released (Hansen 2004).

Significantly, more CWT juvenile salmon were recovered at night during both replicates at both stations. Nearly 99% of the CWT juvenile salmon were captured at night. Daytime captures were insufficient to estimate the proportion of juvenile Chinook salmon which moved into the DCC during the daytime. Differences between catch in the Sacramento River and the DCC were significantly different (Mann-Whitney U test, $p < 0.0001$). No clear relationships occurred between catch of the tagged fish and the tidal cycle. In addition, there were no clear relationships between fish release and capture times (Figures 40, 41; Hansen 2004). There did, however, appear to be a relationship between the cumulative number of juvenile salmon released and the temporal patterns of recoveries. Although significant differences in a number of recovery patterns of CWT juvenile Chinook salmon were identified, given the low recoveries and large variance in recoveries of CWTs, caution must be exercised in evaluating and applying these findings (Hansen 2004).

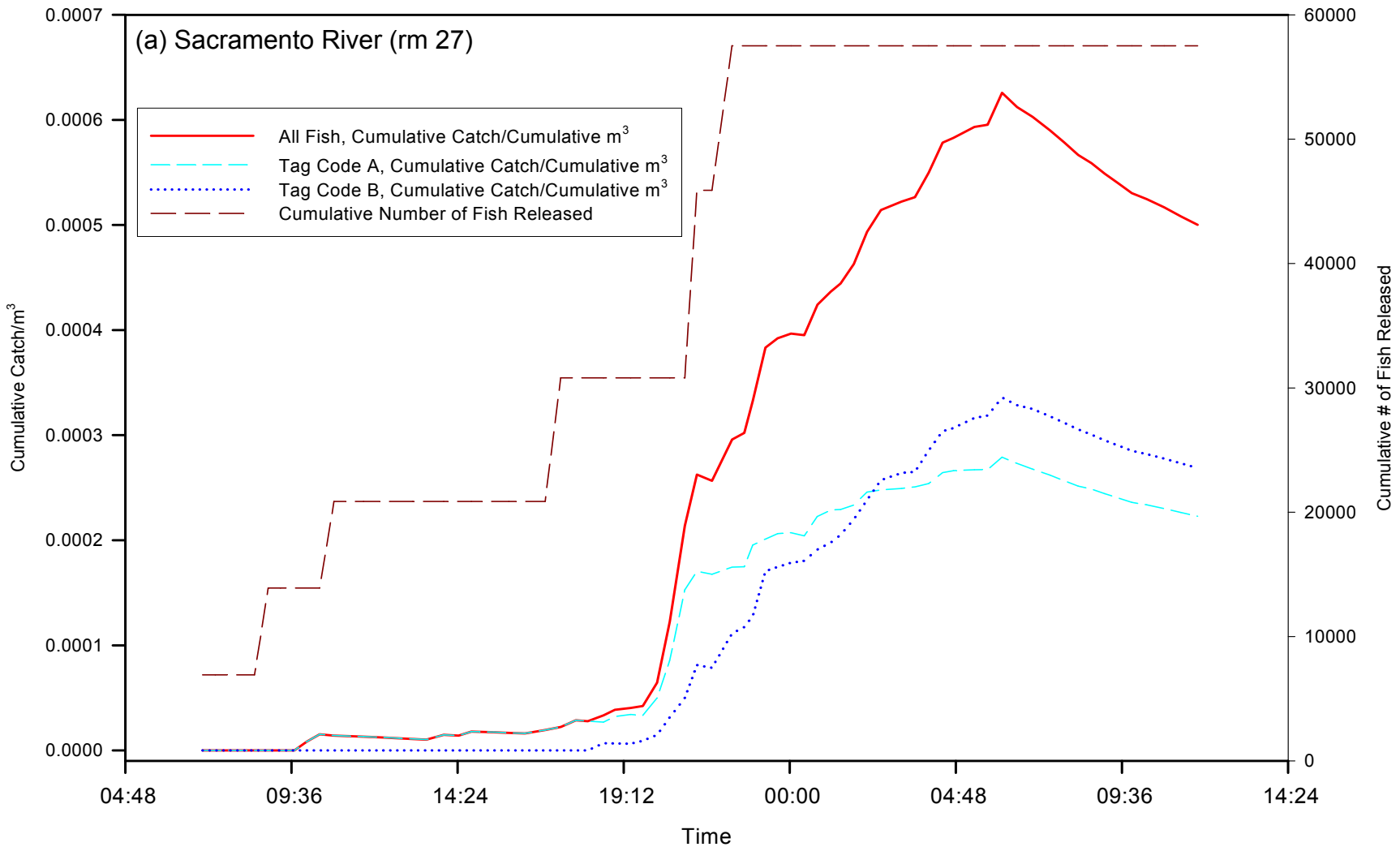

Figure 40. Cumulative distribution of catch/m^3 of all marked and wire tagged (CWT) juvenile Chinook salmon, CWT code A fish, and CWT code B fish captured by tow, and number of marked and CWT fish released during Replicate 1 at (a) Sacramento River (rm 27), and (b) DCC. Note declines in catch/m^3 result because it was calculated as the cumulative catch/cumulative m^3 sampled (taken from Hansen 2004).

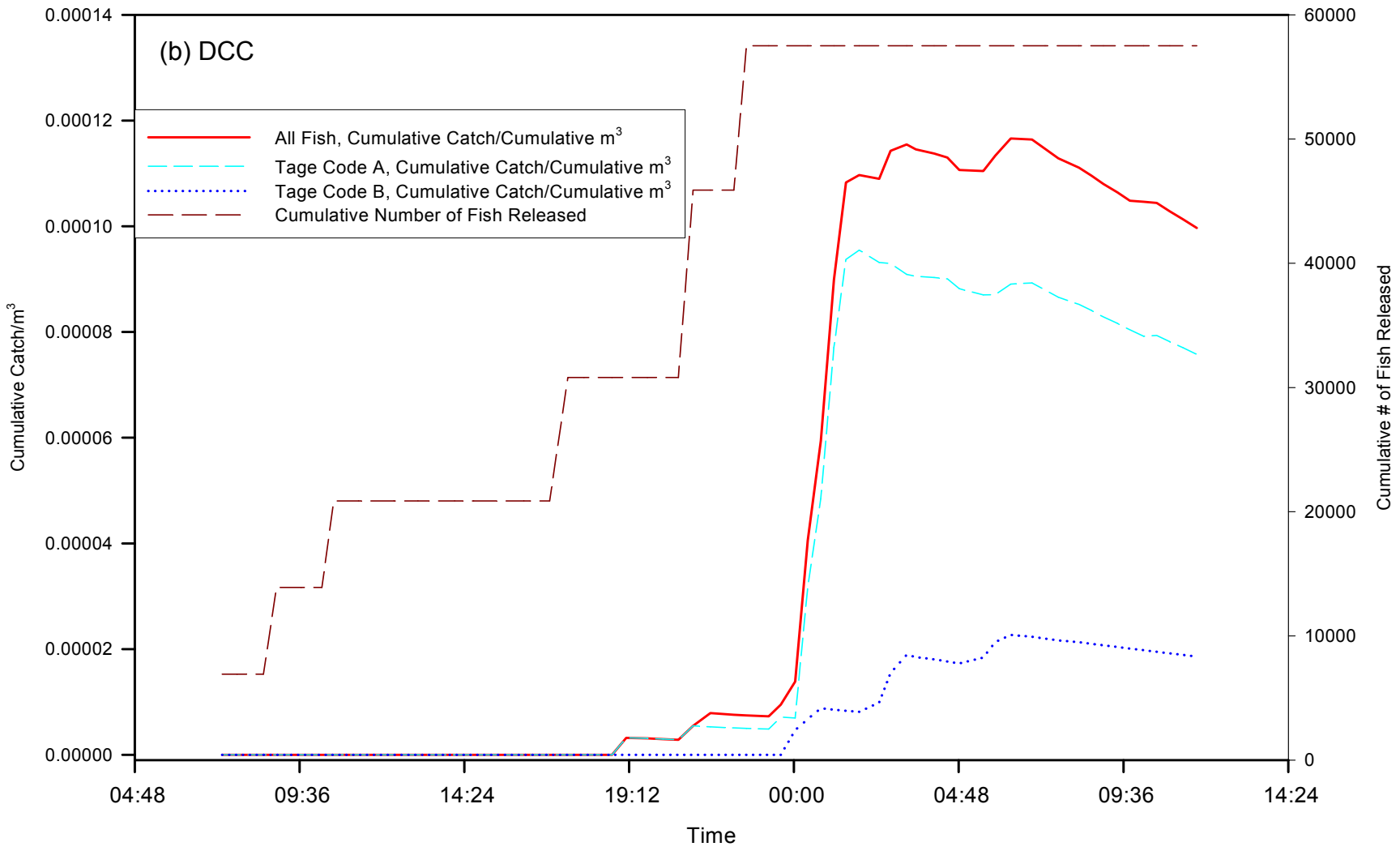

Figure 40 (cont.)

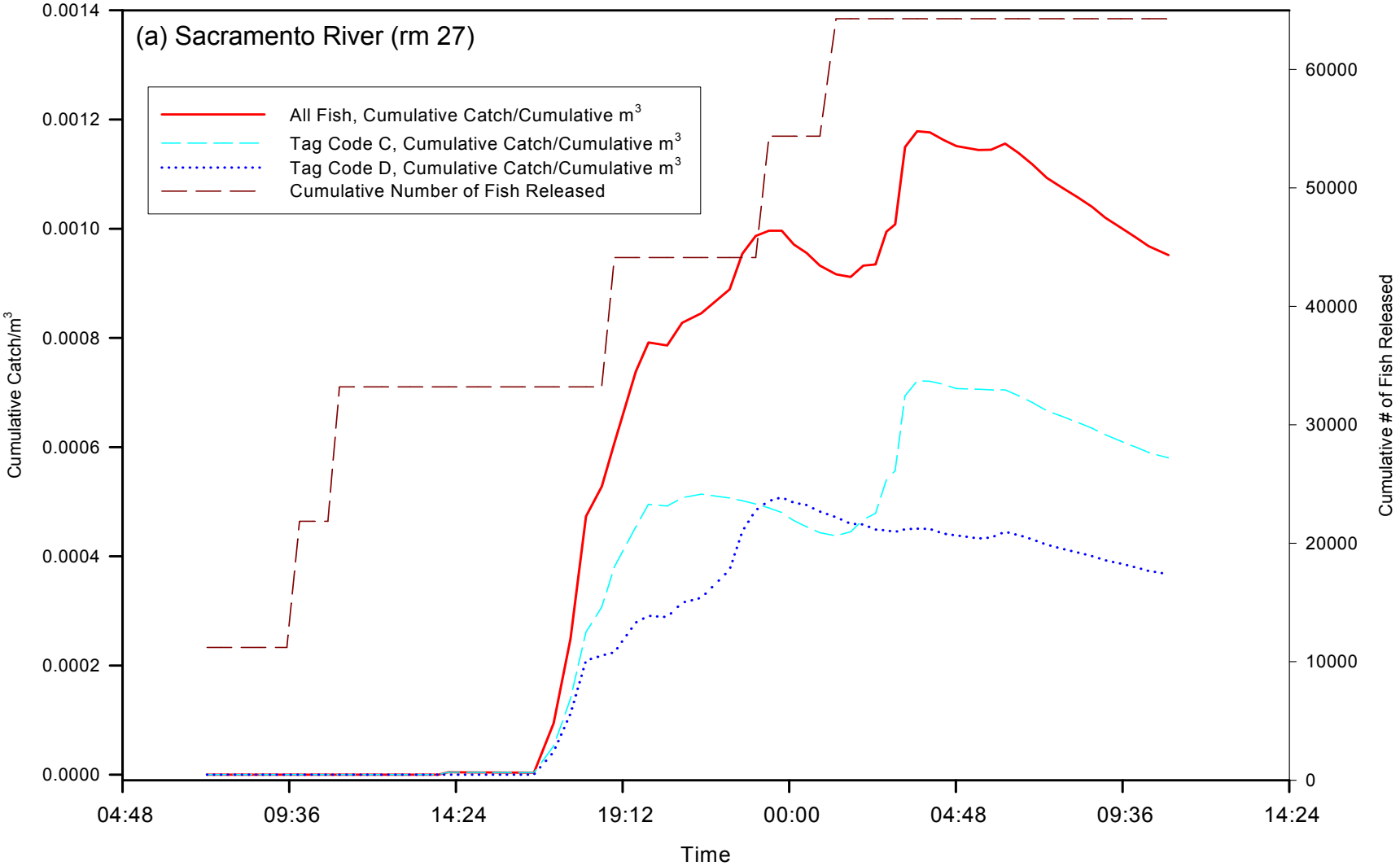

Figure 41. Cumulative distribution of catch/m^3 of all marked and wire tagged (CWT) juvenile Chinook salmon, CWT code C fish, and CWT code D fish captured by tow, and the number of marked and CWT fish released during Replicate 2 at (a) Sacramento River (rm 27), and (b) DCC. Note the declines in catch/m^3 result because it was calculated as cumulative catch/cumulative m^3 sampled (taken from Hansen 2004).

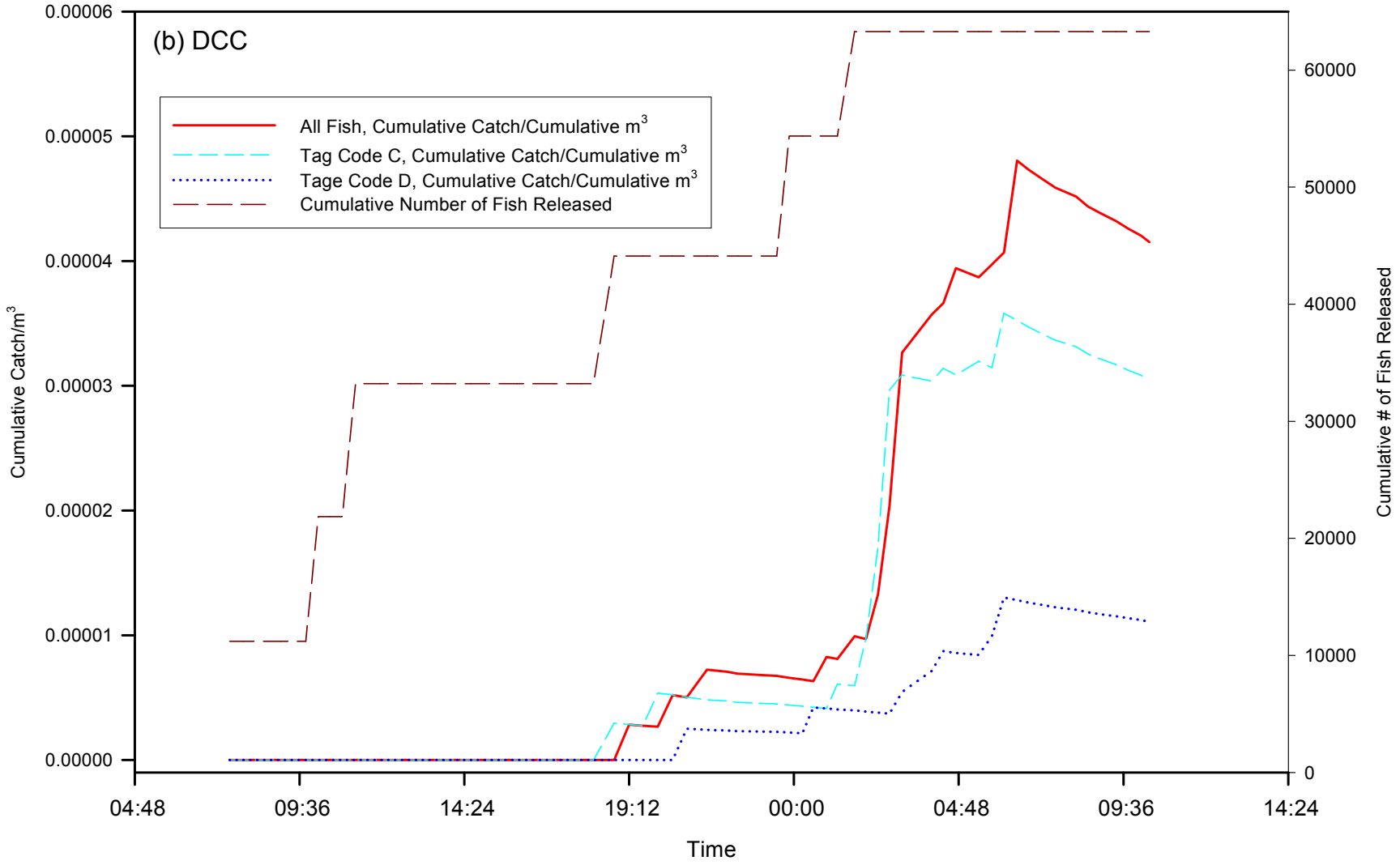

Figure 41 (cont.)

24-Hour Net Efficiency Study

One of the primary purposes of the DJFMP is to provide estimates of relative abundance and patterns in distribution of migrating juvenile salmon in the Sacramento and San Joaquin Rivers, Delta and Bays to water managers that allow them to make informed decisions for water operations. To obtain this information, DJFMP employs midwater and Kodiak trawls. By evaluating the efficiency of these sampling methods, we can ensure that the best information possible is provided to water managers. To determine catch efficiencies of midwater and Kodiak trawls, we timed our sampling efforts with hatchery releases of tagged juvenile salmon in the Sacramento River. We then calculated the proportion of released salmon available for capture that were caught in the midwater and Kodiak trawls (Wilder & Ingram, 2006).

Methods

Study site

Sampling was conducted along a 3.2 km stretch of the Sacramento River near Sherwood Harbor (rm 55). River width in this stretch ranges from 142-182 m. Sampling was also conducted within a 3 km section of river upstream of the western tip of Chipps Island in Suisun Bay.

Sampling

Fish were captured in spring using a midwater trawl net and in late fall using a Kodiak trawl net near Sherwood Harbor. Fish were captured in late fall using a midwater trawl net near Chipps Island. Net dimension were the same as previously detailed on page 16 in the general methods section of this report. Twenty minute trawls were conducted on a near 24 hour continuous basis, for each efficiency test, during six periods near Sherwood Harbor, three in spring (05/15/03-05/16/03, 04/15/05-04/16/05, and 04/29/05-04/30/05) and three in late fall (12/03/02-12/04/02, 12/05/03-12/06/03, and 12/06/04-12/07/04). All trawls were conducted in the center of the river in an upstream direction. At Chipps Island, twenty-minute trawls were conducted on a near continuous basis from 12/11/03-12/12/03. Trawls were conducted in both directions (upstream and downstream) regardless of tide in three channel locations: north, south, and middle. Water temperature was recorded at the beginning of each trawl. Water turbidity was measured using a Secchi disk at the beginning of daytime trawls only. River flow data for the Sacramento River at Freeport was obtained from the CDEC (CDWR, 2006); flow data for Chipps Island was obtained from the Dayflow spreadsheet labeled “OUT” (iep.ca.gov/dayflow/). Trawling at Sherwood Harbor was timed in coordination with hatchery releases of coded wire tagged (CWT) juvenile Chinook salmon at the Broderick boat ramp in West Sacramento. The Chipps Island trawls were timed in coordination with hatchery releases of coded wire tagged (CWT) juvenile Chinook salmon at Sherman Island. Sampling began near the time of each release and continued for approximately 24 hours.

After each trawl, all Chinook salmon were counted by race. We measured the fork length, to the nearest mm, of up to 50 individuals per race and plus counted

any remaining salmon in each race category. All salmon with a clipped adipose fin were returned to the laboratory and examined for presence of a CWT. If present, the CWT was extracted and the tag code was read and recorded. All other fish caught were released after being identified and measured to the neares forklength. Catch per unit effort (in fish/m^3), CPUE, of each trawl was calculated as before for CPUE of trawls in the general methods section.

Net Efficiency

We calculated net efficiency for each release, $NE_{release}$, as:

$$NE_{release} = \frac{N_{recovered}}{N_{released}} \qquad (13)$$

where $N_{recovered}$ = number of salmon captured in the trawl net, $N_{released}$ = number of salmon released upstream.

These calculations were based on two assumptions: (1) all released salmon moved downstream from the release site to the sample site; and (2) fish were uniformly distributed through time and space during sampling. Although it is probable that neither of these assumptions were met completely, this calculation provides the best estimate of net efficiency currently available.

Results

Mean efficiency of the midwater trawl net at Sherwood Harbor was 0.00105 ±0.00038 and values ranged from 0.00045-0.00176 (Table 18a). Mean efficiency of the Kodiak trawl net was 0.00232 ±0.00096 and values ranged from 0.00039-0.00336. There was no statistically significant difference between gear types (t_4 =1.22, p = 0.29), although the trend indicates that the Kodiak trawl net was much more efficient than the midwater trawl net. A power analysis indicates that the statistical power was 0.15 and that, given the variances we found, at α = 0.05, we must conduct efficiency sampling a minimum of 19 times using each trawl type to obtain the generally accepted statistical power of 0.80.

Mean efficiency of the midwater trawl net at Chipps Island was 0.00127 (Table 18b).

Table 18. Efficiency ($NE_{release}$) of trawl nets used at (a) Sherwood Harbor and (b) Chipps Island.

(a) Sherwood Harbor

Midwater trawl (Spring)		Kodiak trawl (Late fall)	
Sample dates	$NE_{release}$	Sample dates	$NE_{release}$
12/3-12/4/02	0.00176	5/15-5/16/03	0.00336
12/5-12/6/03	0.00045	4/15-4/16/05	0.00320
12/6-12/7/04	0.00095	4/29-4/30/05	0.00039
Mean	0.00105	Mean	0.00232
(SE)	(0.00038)	(SE)	(0.00096)

(b) Chipps Island

Midwater trawl (Late fall)	
Sample dates	$NE_{release}$
12/11-12/12/03	0.00127

Liberty Island

Introduction

From 1917-1997, Liberty Island, in the lower Yolo Bypass, was a highly prosperous artificial agricultural island. However, in 1998, after an extreme rain event, the island flooded and the levees were never repaired. Since then, the island has undergone passive restoration back to a more natural state. In 1999, the island was acquired by the Trust for Public Lands with CALFED funds awarded to the USFWS. In 2000, another CALFED grant was awarded to the Stone Lakes National Wildlife Refuge (SLNWR). One purpose of this funding was to implement a monitoring program of the physical and biological resources of Liberty Island. The DJFMP was tasked by the SLNWR with assessing the fisheries resources of the island. During the 2003-2005 field seasons, the DJFMP conducted fish monitoring at Liberty Island focusing on use of the flooded island by three life stages (larvae, juveniles, and adults) of all fish species.

With the flooding of Liberty Island came the return of one of very few tidally influenced marshes in the Delta. This habitat is reminiscent of the Delta region before humans started manipulating waterways. It is thought that tidally influenced marshes provide good habitat for the native fish species that were present before waterway manipulations and the introduction of multiple non-native species into the Delta. As a result, we predicted that native fish species would prosper at Liberty Island relative to non-native fish.

Methods

Fish monitoring was conducted at Liberty Island from August 2002 until July 2005. We attempted to monitor fish in the entire island, although most northern sites were not sampled until the 2004 or 2005 field seasons.

Larvae
We employed two techniques for field sampling of larval fish. First, we deployed two sets of 16 acrylic light traps (28 x 28 x 28 cm) equipped with a high-powered flashlight to attract photo tactic larvae. Traps were attached to a buoy and floated at the surface of the water for approximately one hour at night. After one hour, the collection container at the bottom of the trap was removed and all contents were transferred into 10% formalin. Samples were later sorted and identified to species under magnification in the laboratory. Light traps were used to sample during 2003 and 2004 field seasons only. In the 2003 field season, larvae sampling occurred once per week during 3/11/03-5/20/03. In the 2004 field season, sampling occurred once per week during 2/11/03-6/25/04.

Second, we used egg and larval nets that were towed on the side of a small boat. The net was made of 500 micron nylon mesh, had a 45.7 cm mouth diameter, and a 5:1 mouth width to net length ratio. Trawling was conducted during 2004 and 2005 field seasons only. During the 2004 field season, one net was towed along side the boat at night for ten, five-minute tows once per week from 3/27/04 to 6/25/04. During the 2005 field season, two nets were towed simultaneously on either side of the boat for ten, five minutes tows, during daylight hours only once per week from 3/16/05 to 6/28/05. After each trawl the contents of the cod end of the net was emptied into a sample jar containing 10% formalin. Samples were later sorted and identified to species under magnification in the lab.

Juveniles and small adults
To assess the use of Liberty Island by juveniles and smaller adult fishes, we used 15-meter beach seine methods identical to the standard DJFMP monitoring (see page 14) at ten fixed locations, five on the west side of the island and five on the east side of the island. These seines were used once a week in the 2003 (8/1/02-7/31/03) and 2004 (8/7/03-7/21/04) field seasons and in the beginning of the 2005 field season (8/5/04-2/4/05). Because many sampling sites were shallow mudflats, we sampled only very small volumes of water. As a result, from 2/8/05 until the end of our sampling on 7/28/05, we used a larger (60 m) net. Sampling with the larger net occurred weekly at five random sites. Because this larger net had a larger mesh size (5 mm compared to 3 mm mesh for 15 m beach seines), caution should be taken in comparing these data to those from which 15 m seines were used.

Larger adults
We used gill nets to determine the use of Liberty Island by larger adults. Nets were 35 x 3 m and consisted of multiple panes of variable sized mesh (from ½”-3 ½”). Three Nets were set for one hour, after which fish were removed, identified to species, and their fork lengths were measured. In the 2003 field season, gill netting was conducted once per week during 3/4/03-7/30/03. In the 2004 field season, sampling was conducted once per week during 8/5/03-7/20/04. In the

2005 field season, sampling was conducted once per week during 8/3/04-7/28/05.

Analysis

For each gear type, catches were converted to CPUE. For light traps and gill nets, CPUE was calculated as the number of fish caught per trap hour. For larval trawls, revolutions of a flow meter (General Oceanics; model #2030) were converted to linear distance traveled and multiplied by net mouth area to determine volume of water sampled. Fish catches were then divided by this volume to determine CPUE as fish caught per m^3. The CPUE for 15 m beach seines was calculated as for other beach seines (see "General Methods" page 14). For larger beach seines, if the sampling area was a square, volume was calculated as with 15 m beach seines. If the sampling area was a circle or oval, diameter of the circle or dimensions the oval were converted to area and ultimately volume of water sampled.

The island was split into four quadrants for spatial analyses (Figure 42). The east-west line divides the area that goes dry at low tide (to the North) from the area that remains underwater throughout the entire tidal cycle (to the South). The line north-south divides the area that is exposed to higher wind and wave action (east) from the more protected area (west).

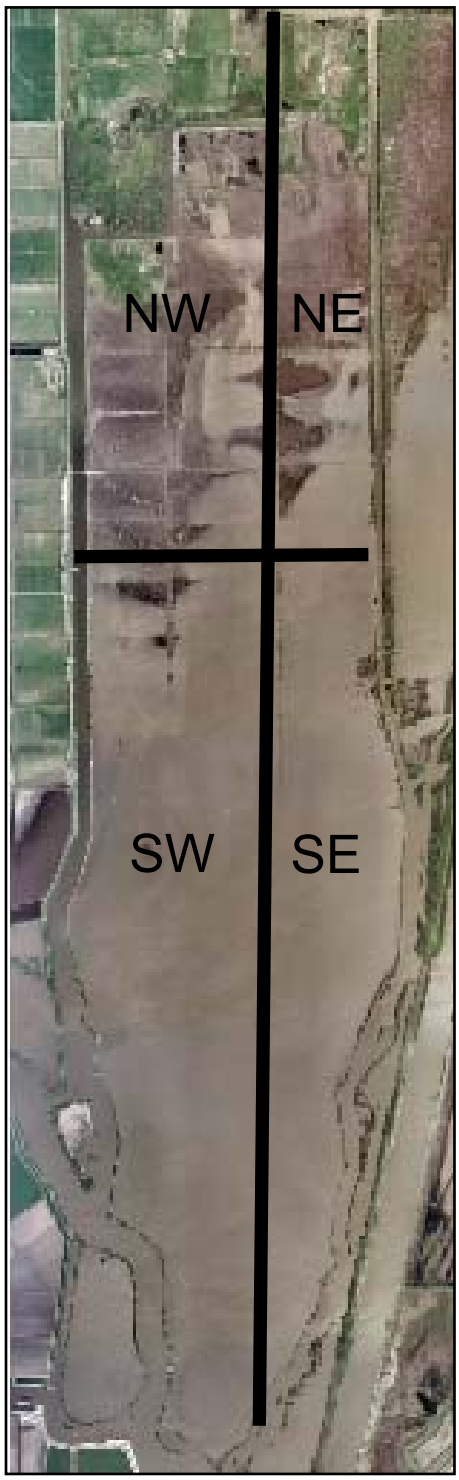

Figure 42. Map of Liberty Island indicating the division of quadrants for spatial analyses. NW = northwest, NE = northeast, SW = southwest, SE = southeast.

Results

Larvae

We caught a total of 24,057 larval fish from 26 species during the 2003-2005 field seasons. We caught 9,543 fish from 23 species during the 2003 and 2004 field seasons in all light traps: 4,413 fish were natives from nine species, 4,761 fish were non-natives from 13 species, and 369 fish were unidentifiable. In trawls, we caught 14,514 fish from 24 species during the 2004 and 2005 field seasons: 4,428 fish were natives from nine species, 9,924 fish were non-natives from 15 species, and 162 fish were unidentifiable.

The top five most abundant species caught in light traps were: prickly sculpin (3,846 fish, 40% of total catch in light traps), inland silversides (3492 fish, 37%), log perch (416 fish, 4%), threadfin shad (348 fish, 4%), and striped bass (309 fish, 3%). The top 5 most abundant species in trawls were: threadfin shad (5,941 fish, 41% of total catch in trawls), prickly sculpin (4,098 fish, 28%), inland silversides (1571 fish, 11%), striped bass (1,080 fish, 7%), and common carp (578 fish, 4%).

We found that intra-annual temporal patterns in CPUE were fairly consistent among years and among gear types, although there was high inter-annual variation in magnitude of CPUE (Figure 43). Natives peaked earlier than non-natives in all years and in both gear types.

Spatial patterns are highly variable among years and between trawl types (Figure 44). There does, however, appear to be evidence that CPUE is greater on the western, more protected side of the island.

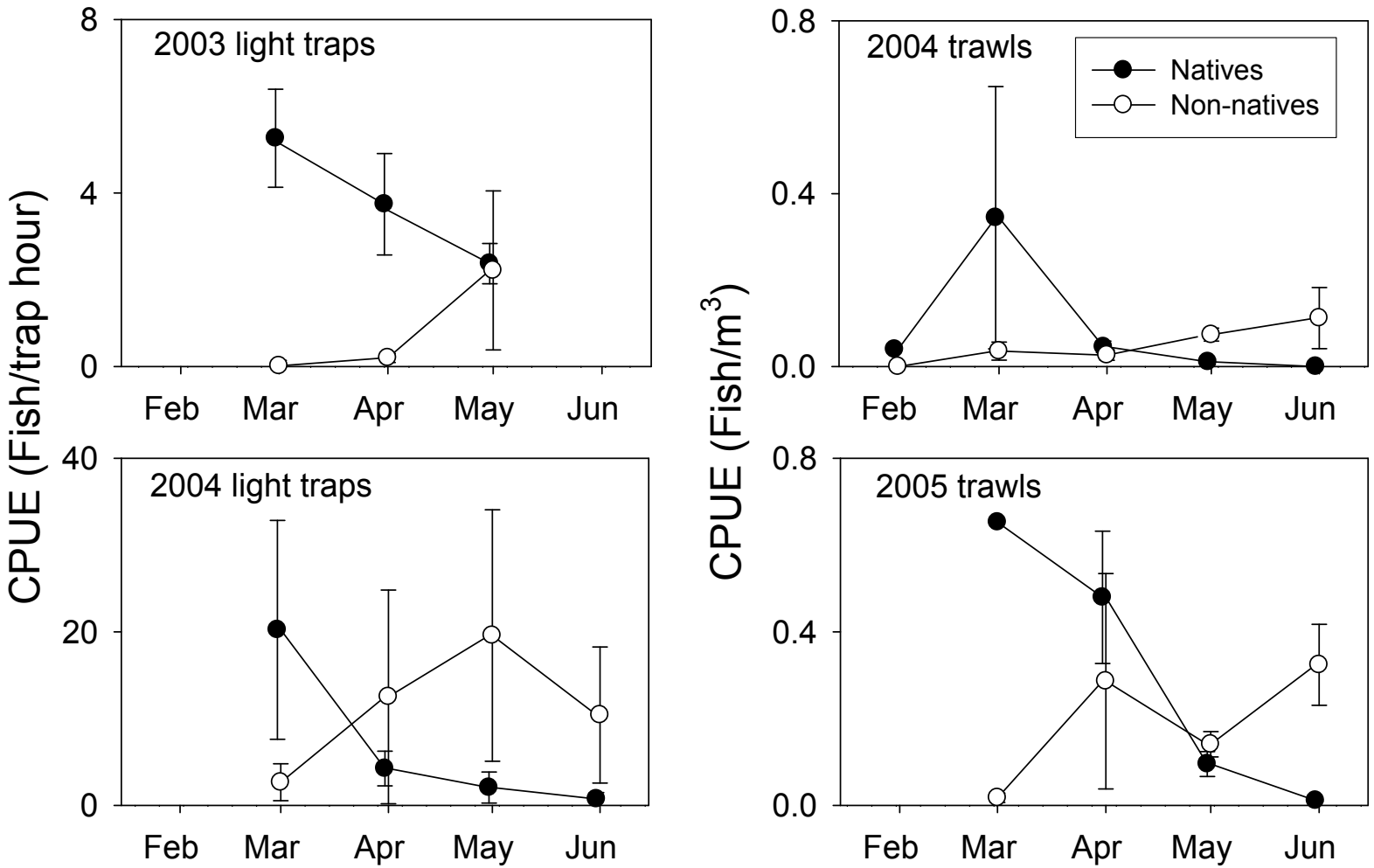

Figure 43. Temporal patterns in catch per unit effort of native and non-native larval fish caught in light traps and trawls at Liberty Island during the 2003-2005 field seasons. Note the change in scale among panels.

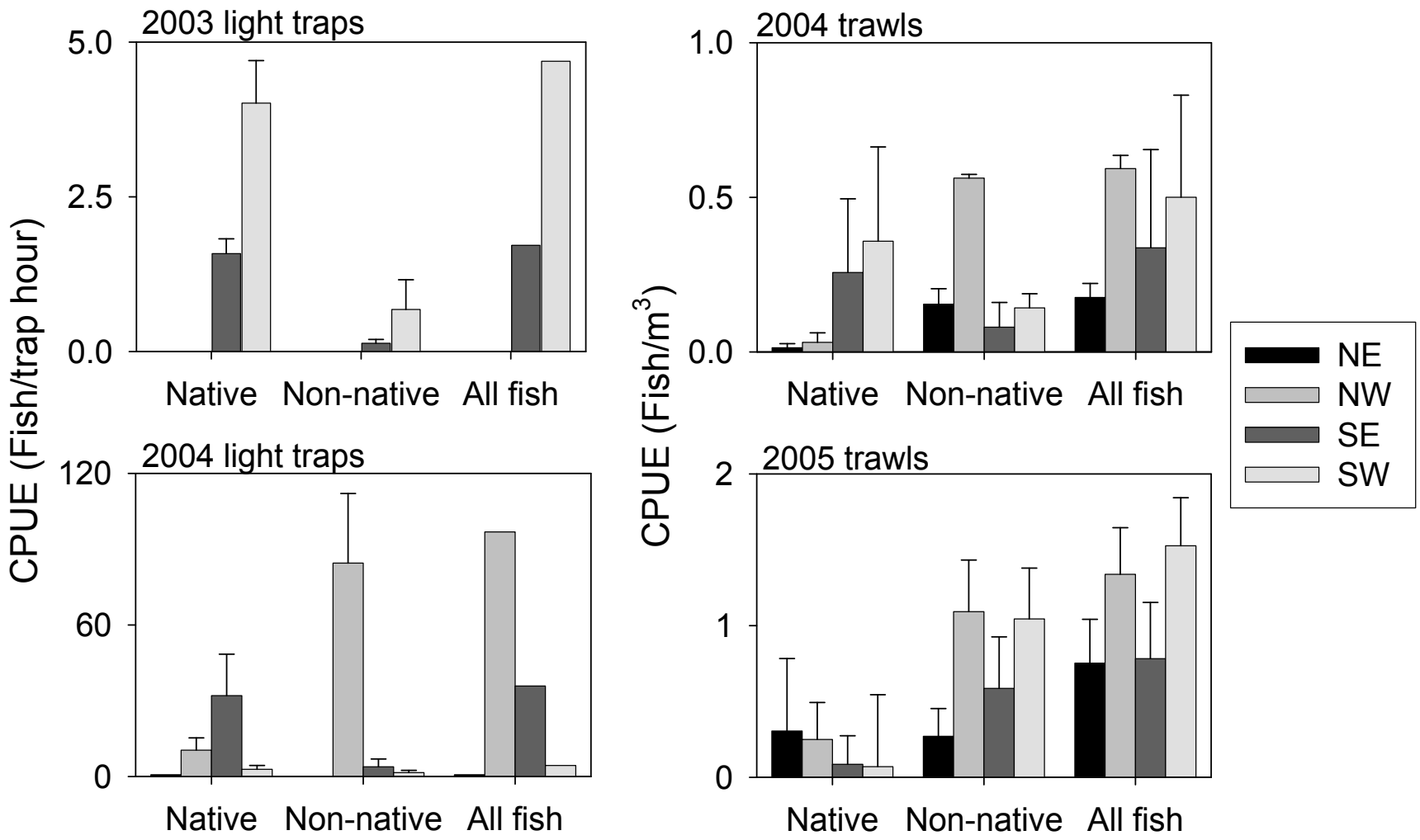

Figure 44. Spatial patterns in catch per unit effort of native, non-native, and all larval fish caught in light traps and trawls at Liberty Island during the 2003-2005 field seasons. Note change in scale among panels.

Juveniles and small adults
During the 2003-2005 field seasons, we caught a total of 26,320 fish from 37 species in beach seines: 7,823 were natives from 15 species, 18,491 fish were non-natives from 22 species, and six fish were unidentifiable to species. In 2003, we caught 6,423 fish from 28 species: 1,385 fish were natives from 13 species, 5,037 non-natives from 15 species, and there was one unidentifiable fish. In 2004, we caught 10,198 fish from 26 species: 2,796 fish were natives from 10 species and 7,402 fish were non-natives from 16 species. In 2005, we caught 9699 fish from 36 species: 3,642 were natives from 14 species, 6,052 were non-natives from 22 species, and 5 were unidentifiable. The increase in species richness from 2003-2004 to 2005 may have been a result of the larger nets (60 m vs. 15 m nets used in 2003 and 2004) and, therefore, greater volumes of water sampled.

The top five most abundant species caught in beach seines throughout the sampling period were: inland silverside (11,938 fish, accounting for 45% of all fish caught in beach seines), Sacramento splittail (5,606 fish, 21%), threadfin shad (2,618 individuals, 10%), yellow fin goby (1981 individuals, 8%), and Chinook salmon (1,059 individuals, 4%).

Temporal patterns in CPUE of both natives and non-natives were remarkably consistent among field seasons (Figure 45). Native abundance peaked in May or June each year, whereas non-native abundance peaked later in July. This pattern is consistent with larval abundance patterns (Figure 43), but delayed by 2-3 months. This likely reflects the ability of beach seines to capture larval fish when they grow to a large enough size.

During all three field seasons, both natives and non-natives were most abundant in the southwest quadrant of Liberty Island compared to the southeast quadrant (Figure 46). In 2005, when the entire island was sampled, native fish were more abundant in the southern half of the island compared the northern half. Although non-natives were abundant in the northeast quadrant, they were still more abundant in the southern half of the island compared to the northern half overall.

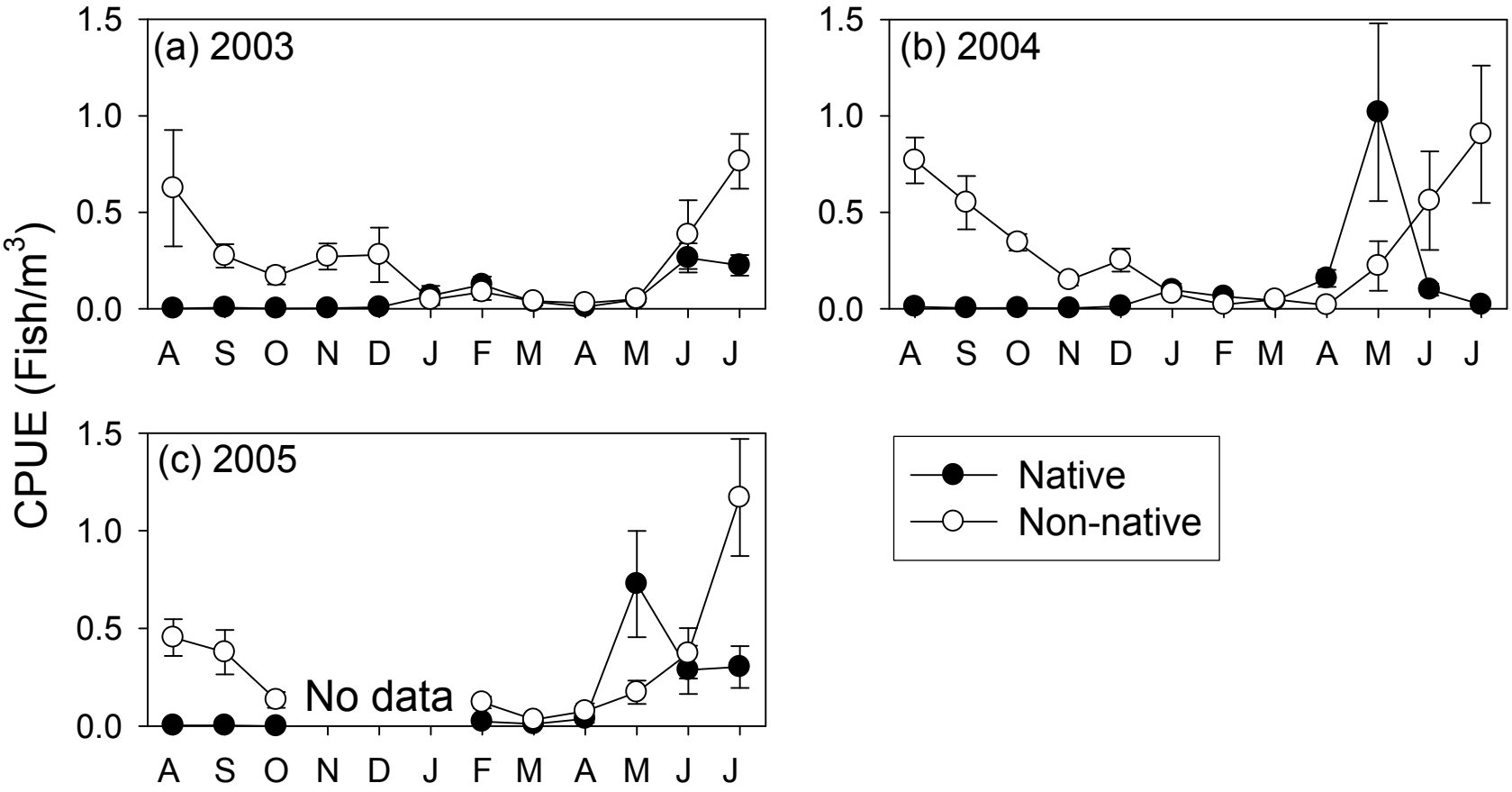

Figure 45. Temporal patterns in CPUE of native and non-native fish recovered in beach seines at Liberty Island during the (a) 2003, (b) 2004, and (c) 2005 field seasons. No sampling was conducted in the northern half of the island before 2005.

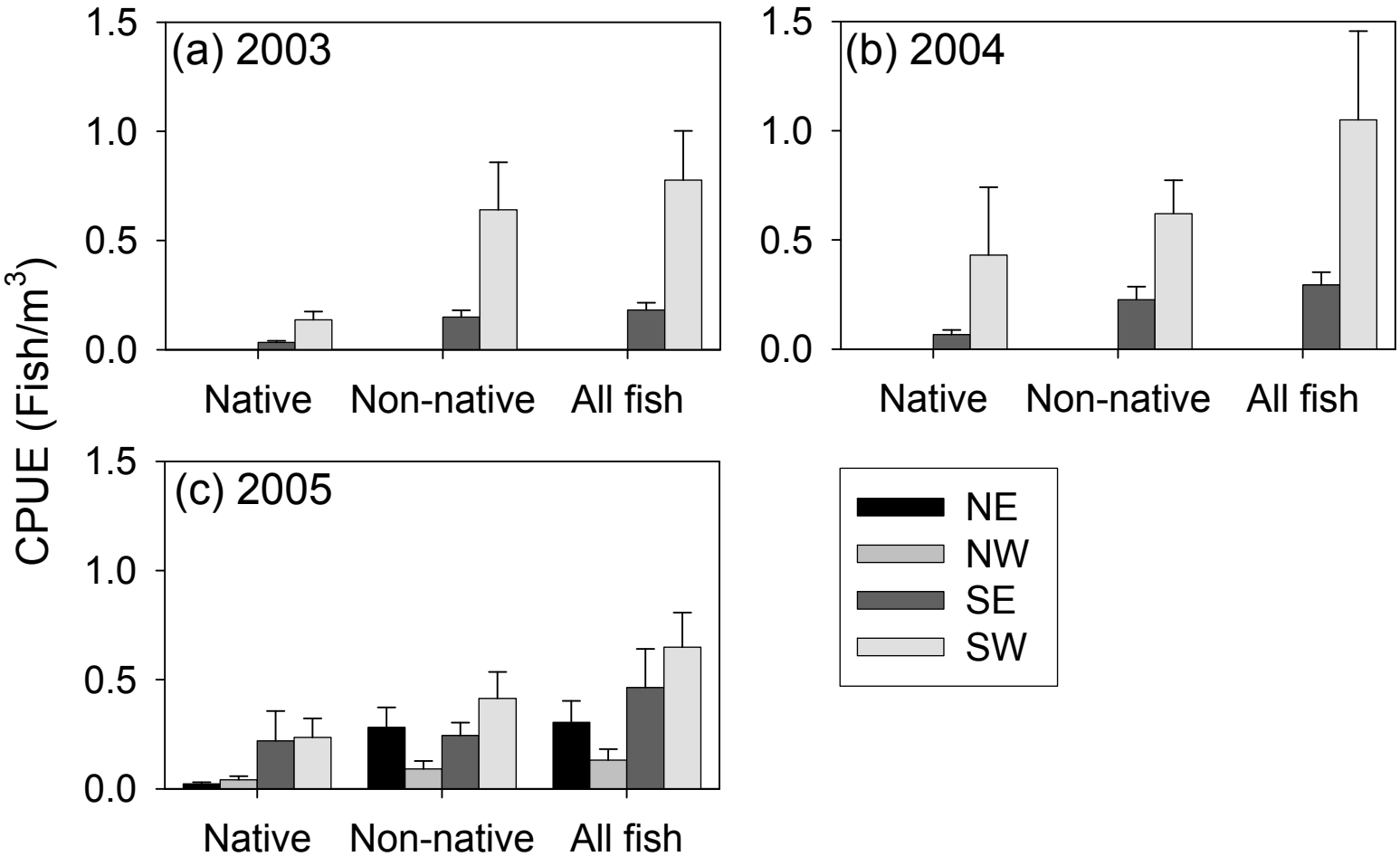

Figure 46. Spatial patterns in CPUE of native and non-native fish recovered in beach seines at Liberty Island during the (a) 2003, (b) 2004, and (c) 2005 field seasons. No sampling was conducted in the northern half of the island before 2005.

Larger adults
During the 2003-2005 field seasons, we captured 1,720 total individual fish from 24 species in gill nets: 183 fish were natives from 10 species and 1537 fish were non-natives from 14 species. In 2003, 604 fish from 12 species were recovered: 46 fish were natives from six species and 558 were non-natives from six species. In 2004, we recovered 644 fish from 15 species: 46 were natives from eight species and 598 were non-native fish from seven species. In 2005, we recovered 472 fish from 22 species: 91 were natives from nine species and 381 were non-natives from 13 species.

The top five species of fish caught from 2003-2005 in gill nets were: white catfish (580 individuals, 34% of total catch in gill nets), striped bass (395 individuals, 23%), common carp (258 individuals, 15%), channel catfish (124 individuals, 7%), and threadfin shad (114 individuals, 7%). The large number of non-natives caught in gill nets likely reflects the nature of introduced species. Many of these non-native fish were intentionally introduced for freshwater sport fishing because of their size and activity levels (Moyle, 2002). These two traits, larger size and higher activity level, promote capture in gill nets.

Temporal patterns in CPUE of native and non-native species of fish were consistent among years (Figure 47). Although there were no intra-annual peaks in native CPUE, there were two peaks in non-native CPUE. One was identified in September-October during 2004, the only year during which we sampled at this time of year. The second peak occurred in spring. This peak may be due to the accumulation of fish during the spawning season, or may be a response to increased food availability during the time of year when many larvae and juveniles are present (Figures 43, 45).

In 2003-2004, there were no obvious differences in CPUE of natives or non-natives between the southeast and southwest quadrants (Figure 48). In 2005, when the entire island was sampled, CPUE of natives was greatest in the northeast quadrant and CPUE of non-natives was greatest in both the northeast and northwest quadrants of the island.

Conclusion
These data indicate that, after just five years of existence, Liberty Island can support a diverse assemblage of fish. However, as seen at other DJFMP monitoring sites, non-native fish species were numerically dominant over native fish species. Analyses will be conducted in the near future to determine how fish assemblages at Liberty Island compare to other nearby DJFMP monitoring sites.

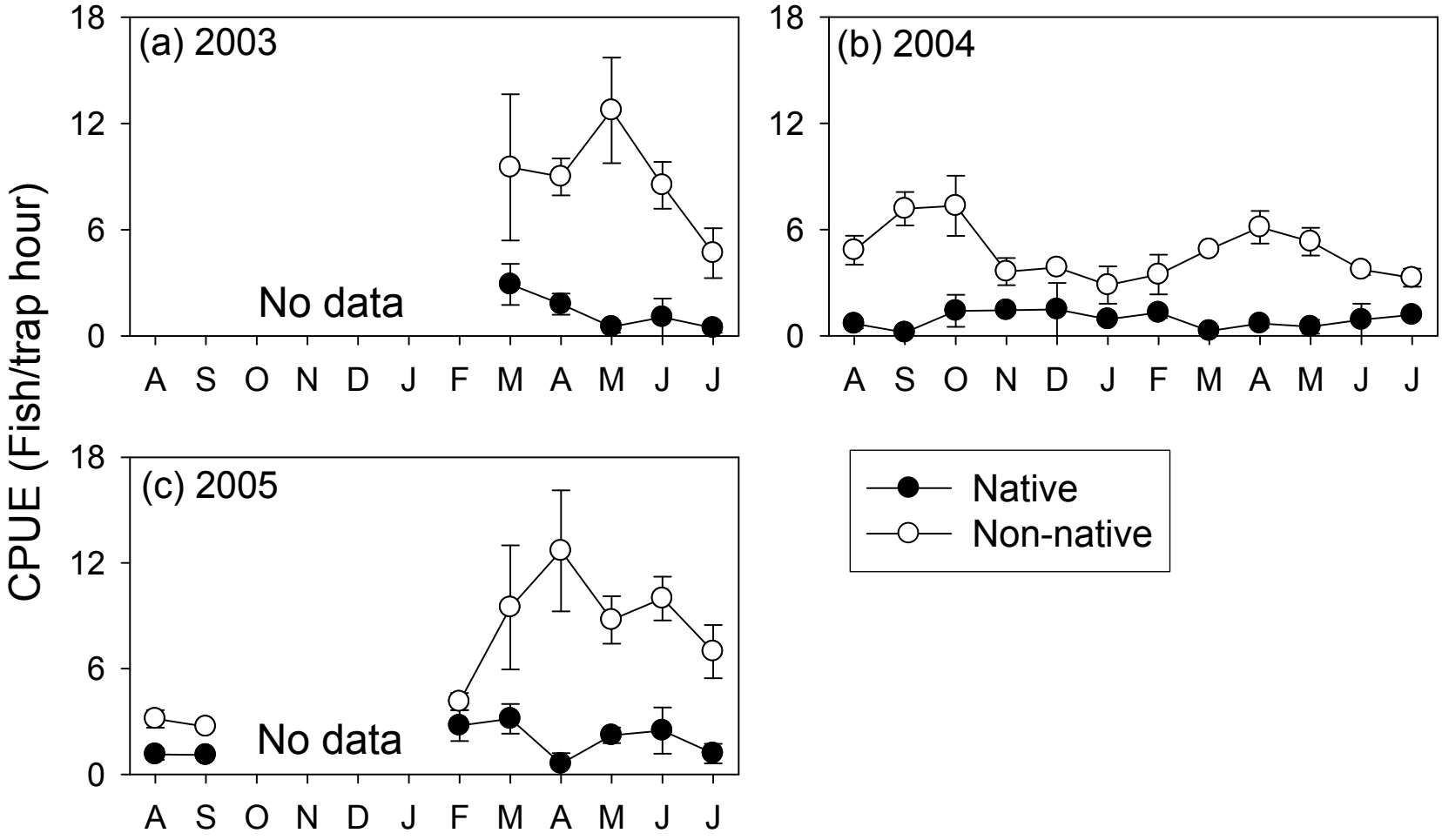

Figure 47. Temporal patterns in CPUE of native and non-native fish recovered in gill nets at Liberty Island during the (a) 2003, (b) 2004, and (c) 2005 field seasons. No sampling was conducted in the northern half of the island before the 2005 field season.

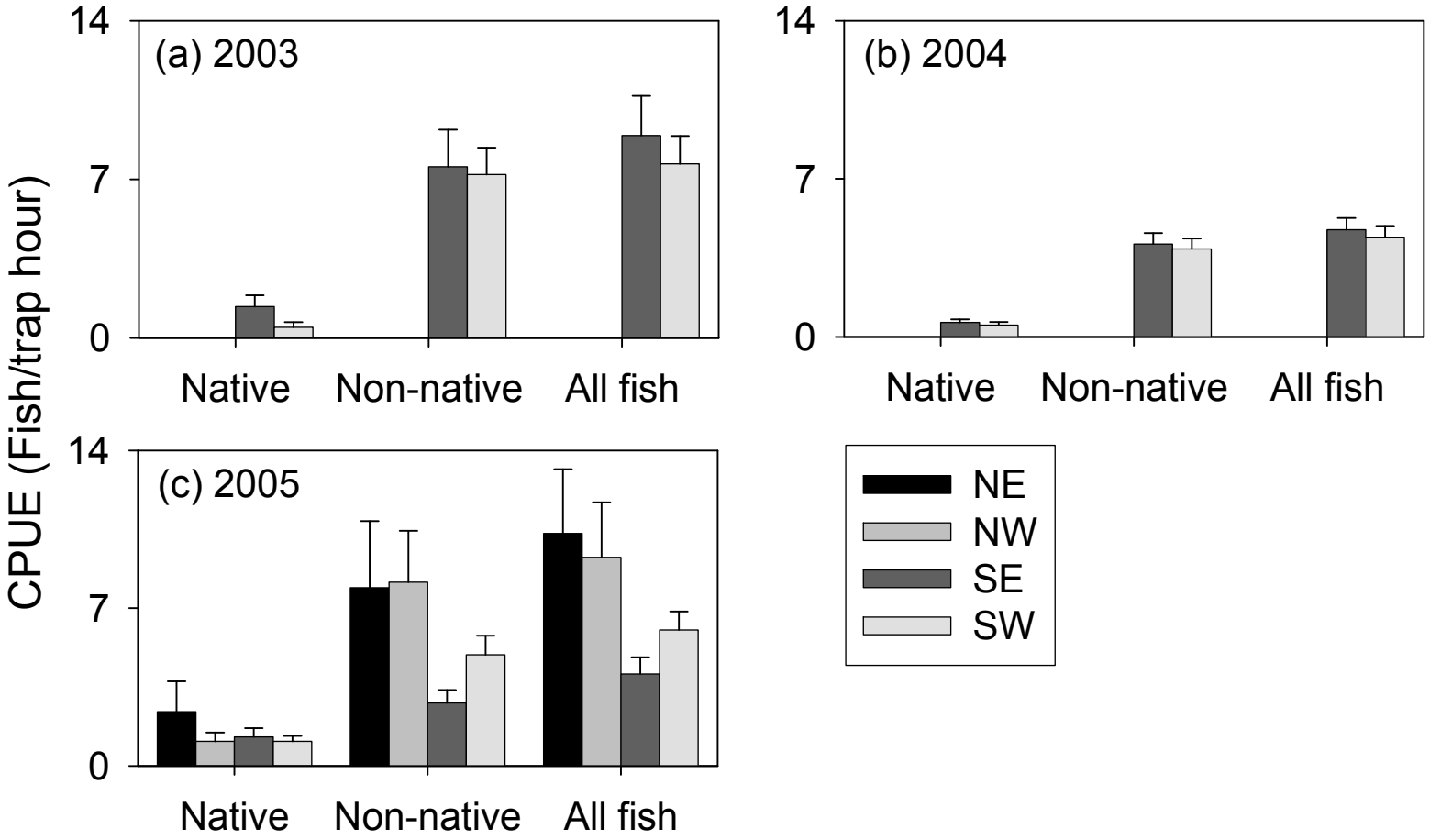

Figure 48. Spatial patterns in CPUE of native and non-native fish recovered in gill nets at Liberty Island during the (a) 2003, (b) 2004, and (c) 2005 field seasons. No sampling was conducted in the northern half of the island before the 2005 field season.

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