Juvenile Fish Monitoring and Abundance and Survival of Chinook Salmon in the Sacramento-San Joaquin Estuary

2006 ANNUAL PROGRESS REPORT
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Cover photo: DJFMP field staff conduct a Kodiak trawl at Chipps Island in Suisun Bay (Credit: Jackie Hagen)

Acknowledgments

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

Table of Acronyms

The following acronyms have been used in the following report:

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
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 goals have evolved since its inception 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 other areas where fish may reside (lower Sacramento and San Joaquin Rivers, Delta, and Bay). Although DJFMP has historically identified and measured all juvenile fishes, it was in 2001 that the programs name changed from Juvenile Salmon Monitoring Program to its current name to reflect the broadened focus of the program. Annual reports have been written each year to document sampling effort and summarize findings and are available from the STFWO.

The DJFMP historically monitors populations of juveniles from all fish species. This report will focus on Chinook salmon and five other juvenile fish species of concern: delta smelt *Hypomesus transpacificus*, longfin smelt *Spirinchus thaleichthys*, rainbow trout *Oncorhynchus mykiss*, striped bass *Morone saxatilis*, and threadfin shad *Dorosoma petenense.*

Work in 2006 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.

Three objectives of the 2006 field season were:

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

2. Determine relative survival (using fall and late-fall hatchery smolts) of juvenile salmon released in the Sacramento-San Joaquin River and Delta, and relate survival to different flows.

3. Determine catch- per- unit effort and distribution of all juvenile fishes in the Sacramento and San Joaquin Rivers, the Delta, and portions of San Pablo and San Francisco Bays.

General Methods

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. Size criterion was developed by Frank Fisher (Fisher 1992), of California Department of Fish and Game (CDFG) in 1992 as a weekly model of Chinook salmon growth and later modified to a daily criterion by California Department of Water Resources. At this time, it is the only tool used by DJFMP to determine race of juvenile salmon in the field. However, several problems exist regarding the validity of the size at date criterion (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 the two races. 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: the presence or absence of an external yolk sac, visible parr marks, or deciduous scales. However, for this report, we used fork length (FL) as a rough estimate of life stage as a simplified classification scheme. We defined fry as ≤70 mm fork length FL. Juveniles >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, FL does not always define life stage. Therefore, life-stage designation in this report should be interpreted only as a rough approximation.

Escapement

Methods

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 Coleman National Fish Hatchery (CNFH), Feather River, American River, and the combination of Stanislaus, Tuolumne, and Merced Rivers. 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. Stanislaus, Tuolumne, and Merced Rivers were chosen because, when combined, they represent the major tributaries of the lower San Joaquin River.

Gates used to maximize RBDD diversion capabilities must be in the closed position to obtain accurate escapement estimate. Since 1993, this has not occurred during late fall upstream migration (October-April). 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. Returns to CNFH were used as late fall escapement estimates between 1993 and 1998 to account for the lack of closure during upstream migration. Since 1998, carcass surveys have been used to estimate late-fall escapement.

Results

Estimates of winter-run salmon returns for 2006 were greater than the previous 24 years (Figure 1a). In 2006, an estimated 17,000 winter-run salmon returned. There was no spring run data. Fall-run salmon returns were estimated to be 45,000 in 2006 (Figure 1b). Late fall-salmon returns were the sixth highest since 1978 (n = 14,000 salmon; Figure 1c).

Fall-run escapements on the Feather River were up from the previous two years (n= 93,000 salmon, Figure 2a). The fall-run escapements in the American river declined for the third straight year to the fourth lowest since 1978 (n= 29,000 salmon; Figure 2b). Combined spawner population estimates from the Stanislaus, Tuolumne and Merced Rivers have been decreasing for the past six years and estimates in 2006 were the lowest since 2000 (Figure 2c).

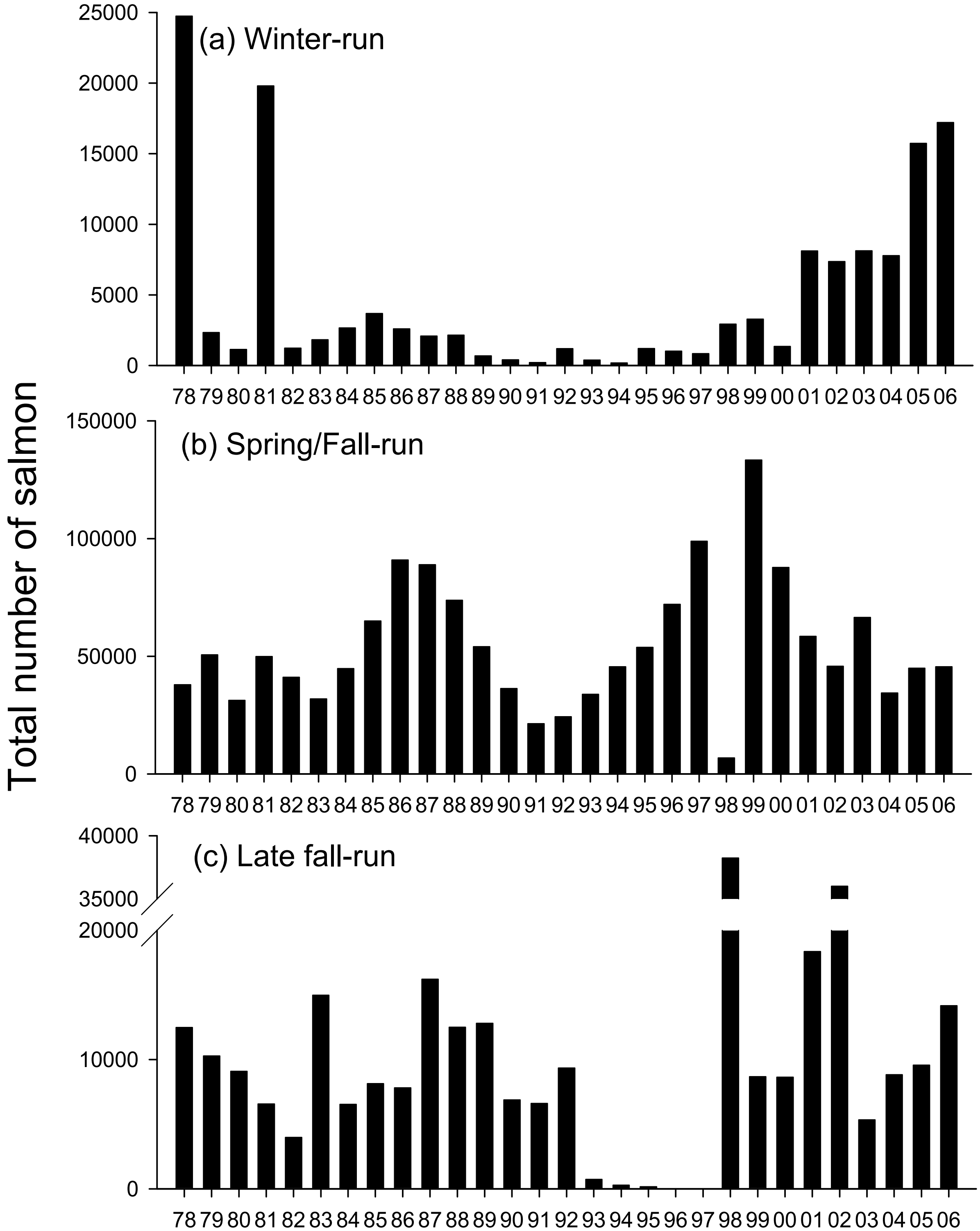

Figure 1. Yearly escapement estimates of adult (a) winter, (b) fall-/spring-, and (c) late fall-run Chinook salmon at the RBDD. Values are the sum of both in-river and hatchery totals. No Spring-run data for 1999-2000 and 2006. No late-fall data for 1997. Late-fall 1997 n = 48. Source: Grand Tab, CDFG, Inland Fisheries Division, Red Bluff.

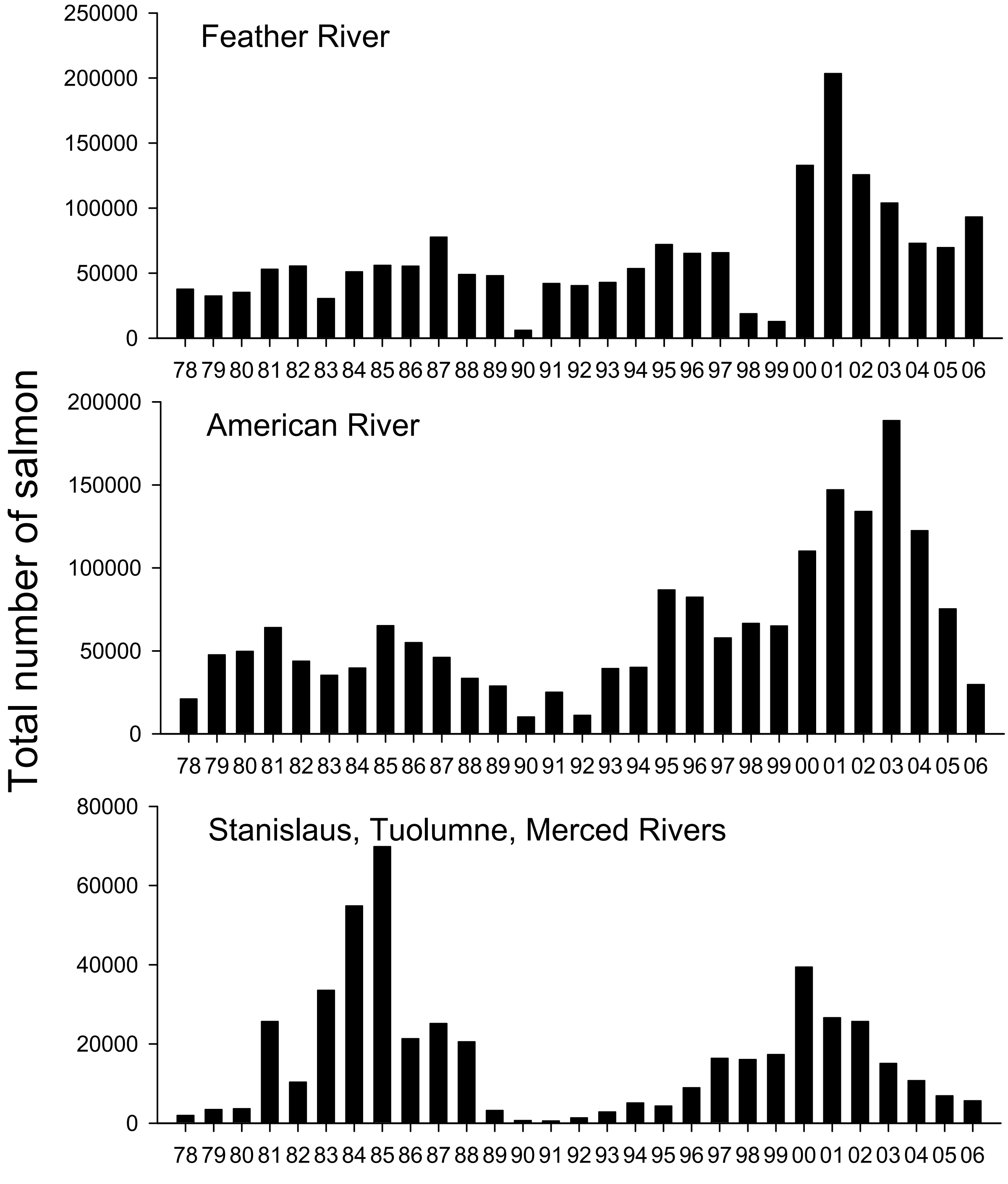

Figure 2. Population estimates of fall-run Chinook salmon spawners between 1978 and 2006 on the (a) Feather and (b) American Rivers, and (c) a combination of the Stanislaus, Tuolumne, and Merced Rivers. Values are the sum of both in-river and hatchery totals. Hatchery only 1998-1999. Source: Grand Tab, CDFG, Inland Fisheries Division, Red Bluff.

Water Conditions

Methods

Discharge 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 discharge 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. 3a, b, and c). Further, we obtained net Delta outflow estimates as calculated by Dayflow to estimate discharge past Chipps Island towards San Francisco Bay (Figure. 3d). The 2006 water year (October 2005 through September 2006) was classified as a wet year in both Sacramento and San Joaquin Valleys (CDEC, 2006).

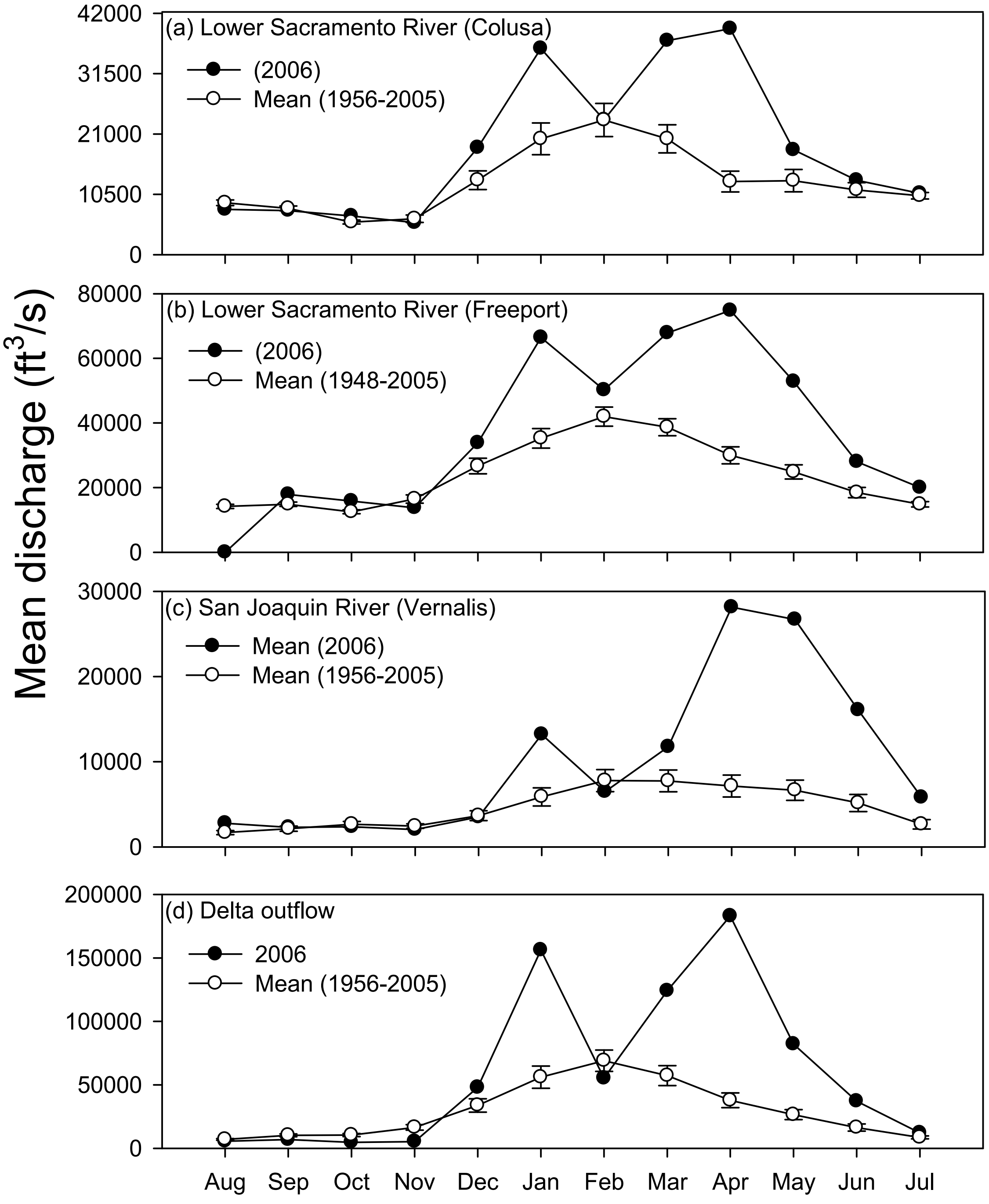

Figure 3. Mean daily discharge (ft^3/s) by month for the 2006 field season on the lower Sacramento River at (a) Colusa and (b) Freeport, (c) on the San Joaquin River at Vernalis, and (d) total calculated Delta outflow near Chipps Island. Historical means for each site are included for comparative purposes. Error bars are ±1 SE.

Fish Sampling

Different sized juvenile fish have distinct spatial and temporal distributions making them vulnerable to capture by different gear types. Midwater trawling, Kodiak trawling, and beach seining were used at varying times and locations in the Delta, lower Sacramento and San Joaquin Rivers, and parts of San Pablo and San Francisco Bays for fish collection.

Monitoring Locations

The majority of sites on the Sacramento River and Delta has been sampled since the mid-1970s by the DJFMP to document the relative abundance of juvenile Chinook salmon and other juvenile fishes 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 analyses 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 bypasses 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 January 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.

All of our sites are influenced by either the Sacramento or San Joaquin Valley via the Sacramento and San Joaquin Rivers, respectively. Different watershed have different drainage patterns resulting in discharge conditions specific to locality. Therefore it was necessary to define site-specific discharge 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 discharge data available on CDEC and Dayflow web sites.

Table 1. Sites sampled by the DJFMP during 2006 field season 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	Site	Station Code
Region 1. Lower Sacramento River		**Region 4. South Delta**	
Colusa State Park	SR144W	Cruiser Haven	OR014W
Elkhorn*	SR071E	Dad's Point	SJ041N
Knight's Landing	SR090W	Dos Reis	SJ051E
Reels Beach	SR094E	Frank's Tract	OR003W
South Meridian	SR130E	Lost Isle	SJ032S
Verona*	SR080E	Old River	OR019E
Ward's Landing	SR138E	Union Island	OR023E
		Veale Tract	WD002W
Region 2. North Delta		Venice Island	SJ026N
American River*	AM001S	Woodward Island	MR010W
Clarksburg	SR043W		
Discovery Park*	SR060E	**Region 5. San Joaquin River**	
Garcia Bend*	SR049E	Big Beach	SJ063W
Isleton	SR017E	Durham Site	SJ068W
Koket	SR024E	Mossdale	SJ056E
Rio Vista	SR014W	N. of Tuolumne River	SJ083W
Sherman Island	MS001N	Route 132	SJ077E
Steamboat Slough (mouth)	SS011N	Sturgeon Bend	SJ074W
Stump Beach	SR012E	Wetherbee	SJ058W
Region 3. Central Delta		**Region 6. Bay**	
Antioch Dunes	SJ001S	Berkeley Frontage Rd	SA007E
B&W Marina	MK004W	China Camp	SP001W
Brannan Island	TM001N	Keller Beach	SA009E
Delta Cross Channel	XC001N	McNear's Beach	SP000W
Eddo's	SJ005N	Paradise Beach	SA008W
Georgiana Slough	GS010E	Point Pinole East	SP003E
King's Island	DS002S	San Quentin Beach	SA010W
Terminous	LP003E	Tiburon Beach	SA004W
Wimpy's	SF014E	Treasure Island	SA001M
Sacramento Seine (additional sites)		**Trawls**	
Sherwood Harbor	SR055E	Chipps Island	SB018M,N,& S
Sand Cove	SR062E	Mossdale	SJ054M
Miller Park	SR057E	Sacramento	SR055M

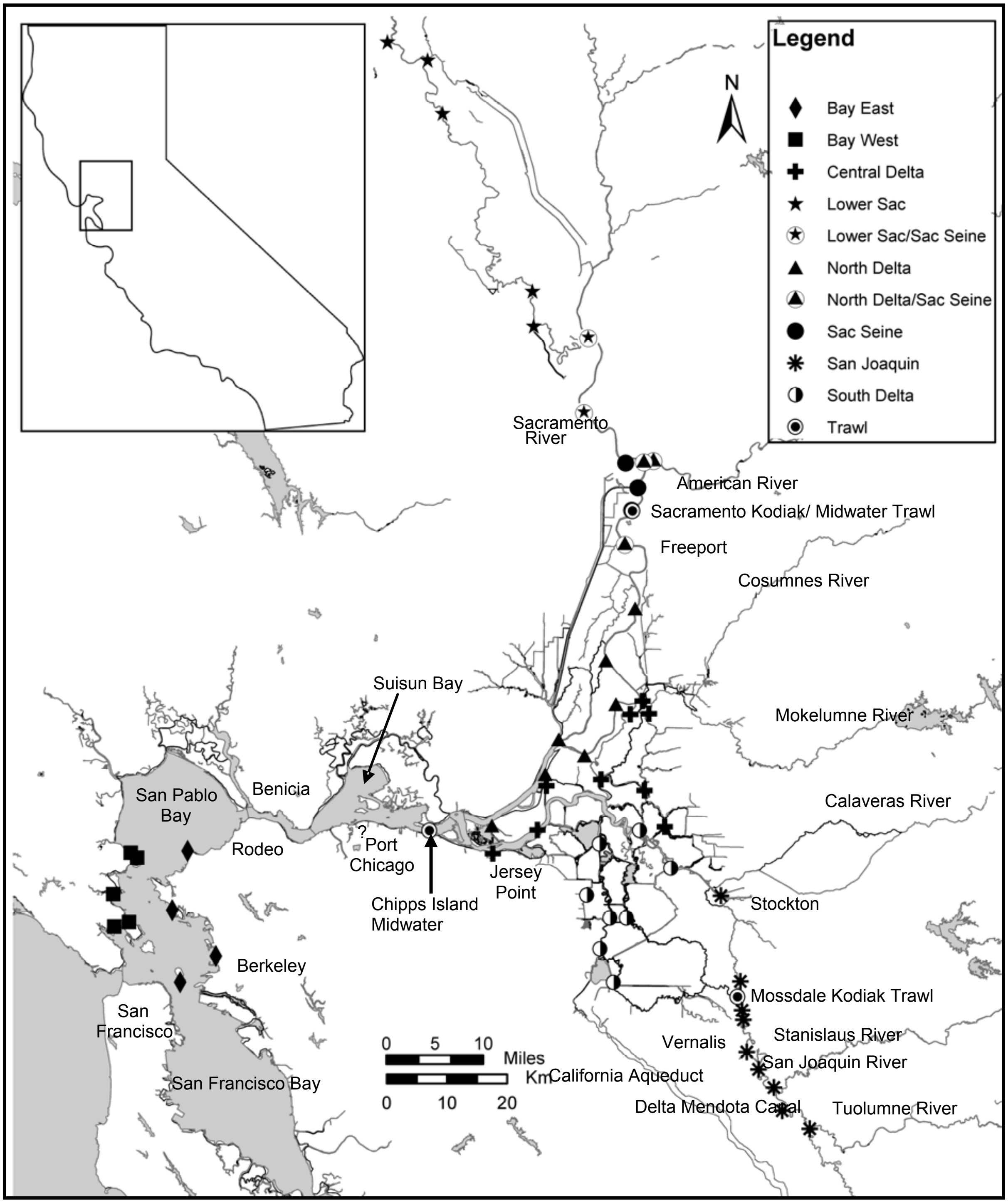

Figure 4. Trawl and beach seine sites for the 2006 field season. Regions are designated as: (1) lower Sacramento, (2) North Delta, (3) Central Delta, (4) South Delta, (5) lower San Joaquin River, and (6) San Francisco/San Pablo Bay.

Beach Seine

Methods

Beach seining is conducted to estimate the relative abundance of shallow, near-shore benthic and pelagic juvenile fish populations. 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 is used for all beach seining. One seine haul is conducted at each site. Seine site substrata are classified as: pavement, sand, mud, or vegetation. Sites are accessed by vehicle or small vessel.

To allow for annual site-specific 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.

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 deepest corners (Figure 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 by taking ½ x depth in calculations.

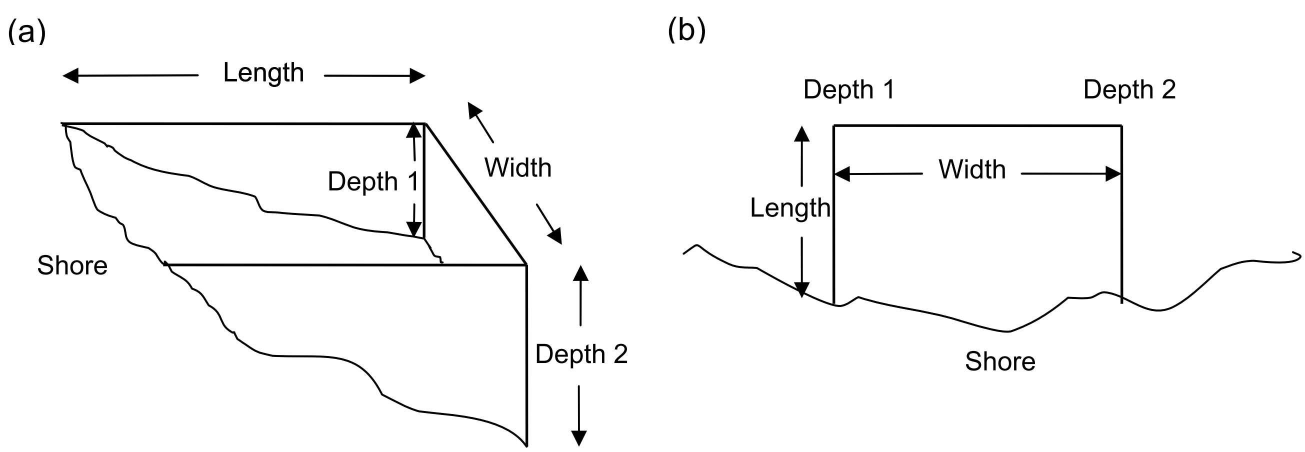

Figure 5. Schematic diagram of beach seine measurements: (a) three-dimensional view, (b) overhead view.

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 sub-samples . 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. This technique diminishes temporal pseudo replication caused by taking multiple sample during a short period of time.

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.

Region 1. Lower Sacramento River

Methods

Beach seining was conducted at five to eight sites per week from 8/1/2005-7/31/2006 to estimate densities of juvenile Chinook salmon and other juvenile fish in the lower Sacramento River. Sites were sampled one to two times per week, with more extensive sampling occurring between 10/31/05-1/31/06, 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 were: sandy and muddy beaches and paved boat ramps.

Results

During the 2006 field season, 272 winter-run sized juvenile salmon were captured in Region 1 beach seines (Figure 6a). All winter-run salmon were captured between October and February. Peak weekly CPUE was observed the week of November 27. Mean monthly CPUE peaked in December and was the third highest since 1993 (Table 2a).

In 2006 spring/fall-run sized salmon were the most abundant race captured in Region 1 beach seines (n = 2,229 fish, Figure 6b). Individuals were caught between November and June. Peak weekly CPUE occurred the week of January 8, coinciding with a period of high discharge in the Sacramento River. Peak monthly mean CPUE was observed in January and is consistent with the previous two years (Table 2b).

Late fall-run size salmon were the least abundant race captured in Region 1 (n = 14 fish, Figure 6c). Seven yearlings from the 2005 brood year were captured from October to December and seven fry from the 2006 brood year were captured from April to June. Peak weekly CPUE was observed the week of April 16 when 6 late fall-run salmon were captured. Peak monthly CPUE occurred in April, a month earlier than the previous year (Table 2c).

We captured one hatchery-reared rainbow trout (Figure 7a) in lower Sacramento River beach seines during the 2006 field season. The rainbow trout was captured on January 26 two weeks after peak discharge in the Sacramento River. There were no wild trout, delta smelt or longfin smelt captured in lower Sacramento River beach seines in 2006.

There were 1430 splittail captured in 2006 lower Sacramento River beach seines (Figure 7b). Most splittail were captured from May 12 to July 27 during a period of decreasing dischage in the Sacramento River. Peak weekly CPUE was observed the week of May 28 when 642 splittail were captured.

Only three stripped bass were captured in the lower Sacramento River beach seines, one on August 1, and two on July 27 (Figure 7c). All three were captured at Ward’s Landing (rm 138). Peak weekly CPUE occurred in July after peak discharge on the Sacramento River.

Threadfin shad were captured regularly throughout the 2006 field season. There were 744 shad captured (Figure 7d), 93% were captured at Knight’s Landing (rm 90). Peak weekly CPUE occurred the week of July 9 when 72 shad were caught during decreasing discharge in the Sacramento River.

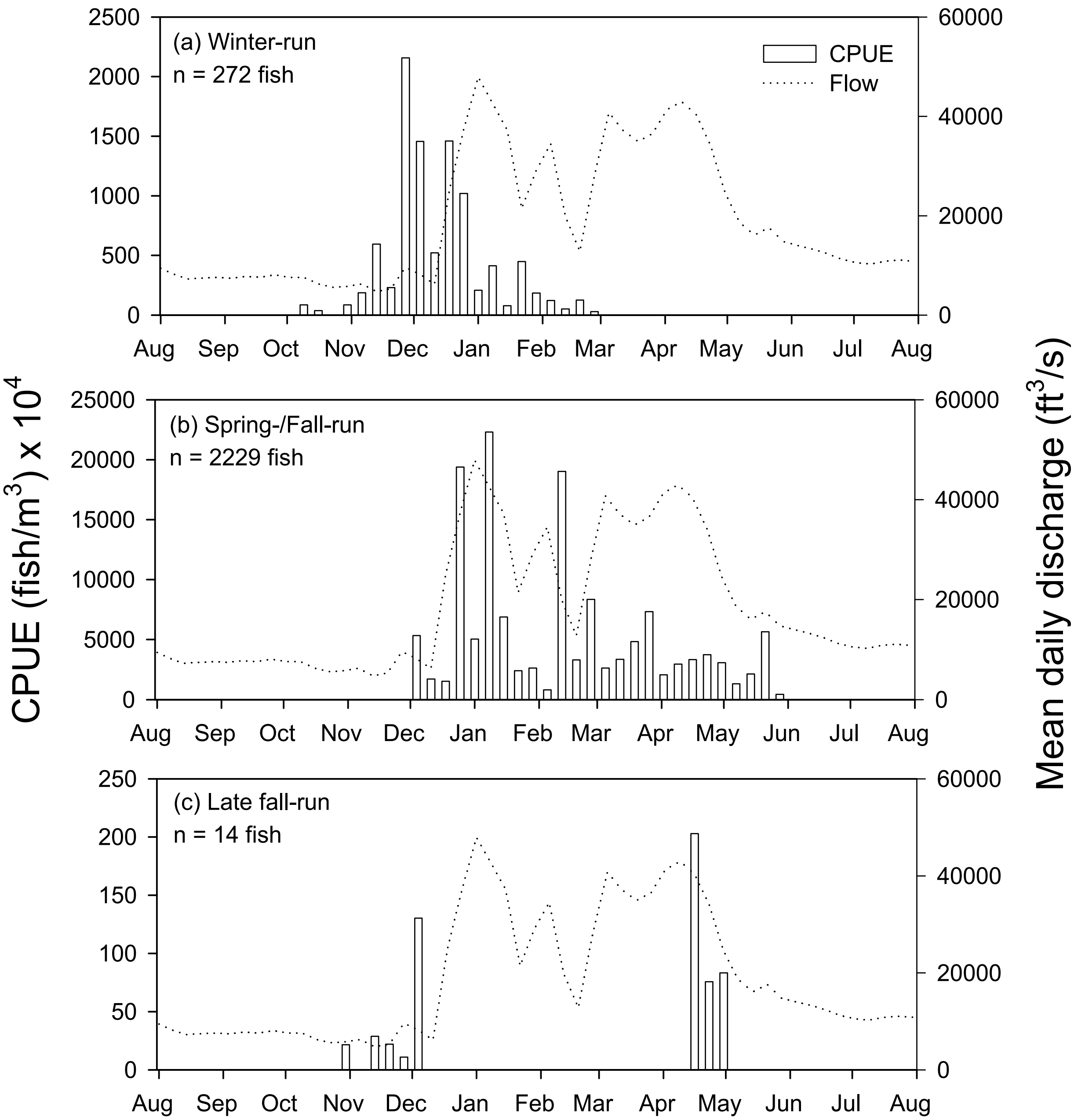

Figure 6. Catch-per-unit effort (x 10^4) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in beach seines and mean daily discharge in lower Sacramento River region (Region 1) during the 2006 field season. All data were averaged by week. Sample size (n) corresponds to total number of fish caught. Fall- and spring-run salmon were combined because of difficulties in distinguishing between them at this size.

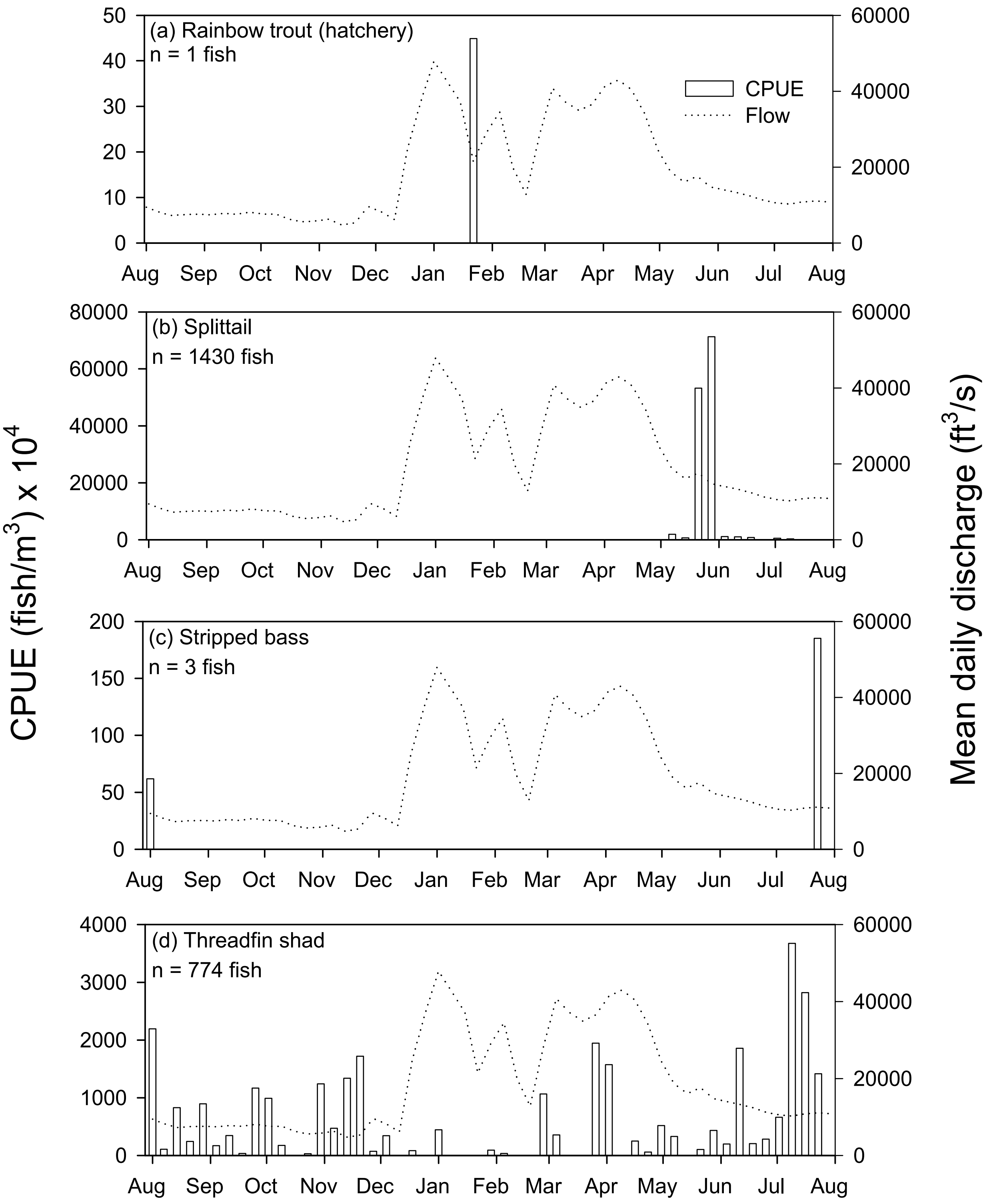

Figure 7. Catch-per-unit effort (x 10^4) of (a) rainbow trout (hatchery), (b) spilttail, (c) stripped bass, and (d) threadfin shad in beach seines and mean daily discharge in lower Sacramento River region (Region 1) during the 2006 field season. All data were averaged by week. Sample size (n) corresponds to total number of fish caught.

Table 2. Summary table of CPUE (fish/m^3) x 10^4 of (a) winter-, (b) fall-/spring-run, and (c) late fall-run Chinook salmon in lower Sacramento River region (Region 1) by month and year. Yearly mean and standard error (SE) values were calculated using years as replicates (n = 12-13). 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; 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	--	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)
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)
Yearly mean 1993-2005 (SE)		0 (0)	5.33 (1.48)	0.973 (0.270)	281 (78.0)	494 (137)	295 (81.8)	81.5 (22.6)	8.95 (2.48)	0.19 (0.053)	0 (0)	0 (0)	0 (0)	105 (29.1)
2006	W	0	0	23.3	279	1467	163	66.8	4.45	0	0	0	0	182 (59.6)

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)
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)
Yearly mean 1993-2005 (SE)		1.40 (0.740)	0 (0)	0.054 (0.054)	5.42 (4.45)	1504 (465)	8526 (1867)	10515 (1815)	8899 (1909)	2401 (466)	684 (222)	48.7 (20.0)	4.26 (2.14)	16352 (5522)
2006	W	0	0	0	15.2	3611	7582	4055	3595	2183	1905	95.3	0	2726 (681)

Table 2. (cont.)

(c) Late fall-run

		Previous field season's brood year								Current field season's brood year				
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)
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)
Yearly mean 1993-2005 (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)
2006	W	0	0	0	17.4	23.7	0	0	0	43.5	13.0	0	0	11.1(5.00)

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 Region 3 (Central Delta), and 10 sites in Region 4 (South Delta) between 8/1/2005-7/31/2006 during the 2006 field season. Three sites from Region 2 (Garcia Bend, American River, and Discovery Park) were sampled up to three times per week during October-January as part of our Sacramento seine sampling (see below for Sacramento area beach seine).

Results

In beach seine regions 2-4, 262 winter-run sized salmon were captured during the 2006 field season. Peak weekly CPUE of winter-run sized salmon occurred in early December before the onset of increasing discharge (Figure 8a). Peak monthly CPUE also occurred in December and was the highest on record since year-round sampling began in 1993 (Table 3a).

Spring/fall-run salmon were first captured in late November and continued to be captured regularly through May (Figure 8b). There were 9,818 spring/fall-run salmon captured in regions 2-4 in 2006. Peak weekly CPUE occurred in April after the second peak in discharge for the sample year. Highest mean monthly CPUE was observed in April, later than previous years of sampling. (Table 3b).

In regions 2-4 beach seines, 103 late fall-run sized salmon were captured (Figure 8c). Seven yearlings from the 2005 brood year were captured between November and December. The remaining 96 salmon were 2006 brood year fry captured between April and July. Peek monthly CPUE was observed in April and was the highest on record (Table 3c).

There were 37 hatchery-reared rainbow trout captured from February 12 through March 26 in regions 2-4 beach seins (Figure 9a). Peak weekly CPUE was observed the week of February 19 when 27 trout were captured during a period of decreased discharge. Only four wild rainbow trout were caught, one in both February and April from the Sacramento River and two in May from the American River (Figure 9b). Weekly CPUE peaked in April as the highest since 1993.

Regions 2-4 were the only regions where delta smelt were captured in our beach seines. From November 8 to June 27, 77 delta smelt were captured (Figure 9c). Weekly CPUE peaked at the end of April when 10 delta smelt were caught during decreasing delta discharge. There were no longfin smelt captured in regions 2-4 beach seines in 2006.

In the 2006 field season, 6,734 splittail were captured in regions 2-4 beach seines (Figure 9d). Nearly all were captured from mid May to mid July as discharge was decreasing. Weekly CPUE for splittail peaked the week of May 28.

We captured 49 stripped bass in our beach seines in regions 2-4 (Figure 9e). Nearly all were captured during periods of low or decreasing discharge. Weekly CPUE peaked in August when 22 fish were captured.

Threadfin shad were the most abundant non-salmonid species captured (n = 7,550 fish; Figure 9f), in regions 2-4 beach seines. Although they were not captured in large numbers in every month, they were regularly captured throughout the 2006 field season. Peak weekly CPUE of threadfin shad occurred in November during a period of low discharge.

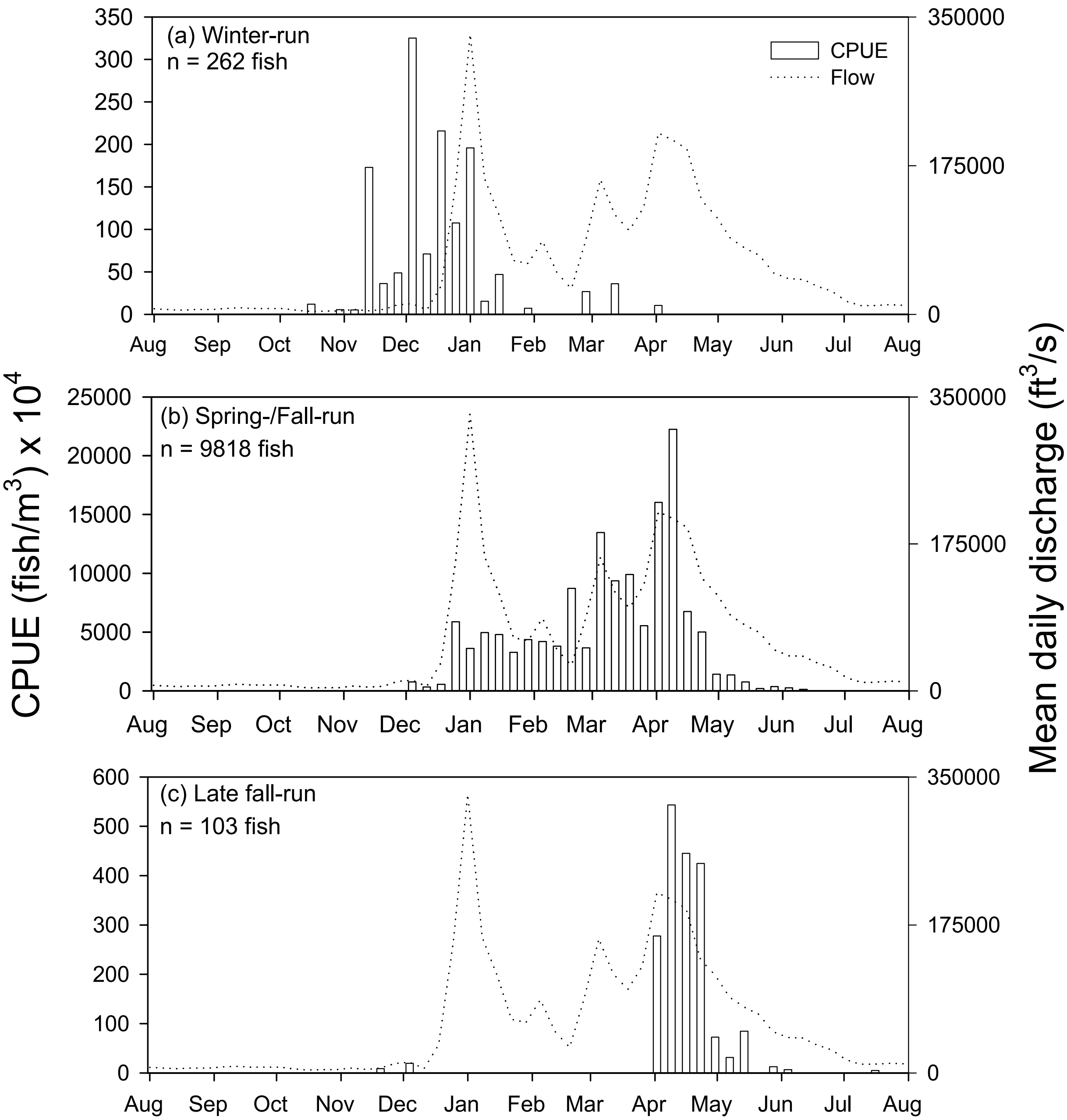

Figure 8. Catch-per-unit effort (x 10^4) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in beach seines and concurrent mean daily discharge in interior Delta (North, Central, and South; Regions 2-4) during the 2006 field season. All data were averaged by week. Sample size (n) corresponds to total number of fish caught. Fall- and spring-run salmon were combined because of difficulties in distinguishing between them at this size.

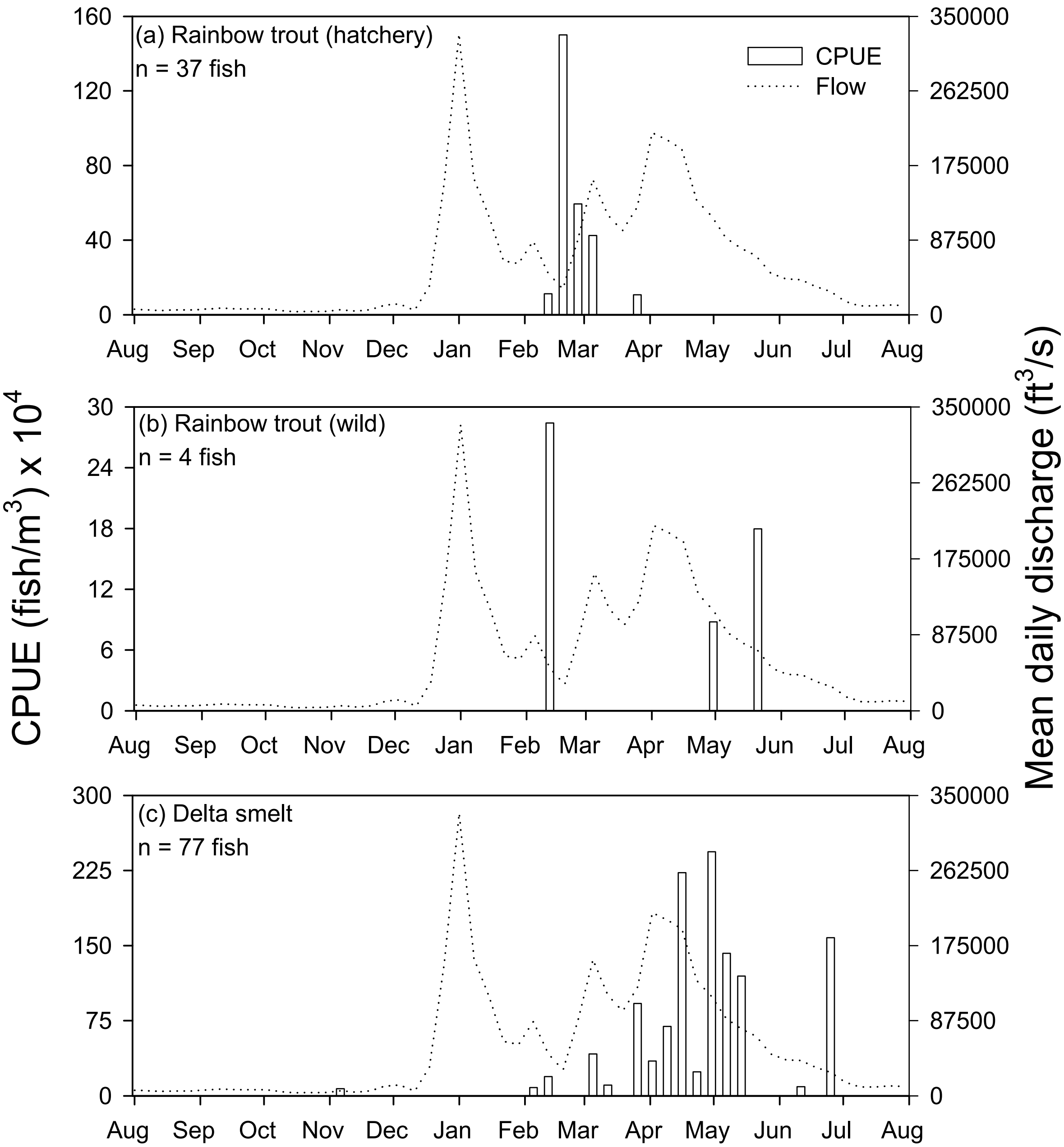

Figure 9. Catch-per-unit effort (x 10^4) of (a) rainbow trout (hatchery), (b) rainbow trout (wild), (c) delta smelt, (d) spilttail, (e) stripped bass, and (f) threadfin shad in beach seines and mean daily discharge in interior Delta (North, Central, and South; Regions 2-4) during the 2006 field season. All data were averaged by week. Sample size (n) corresponds to total number of fish caught.

Figure 9 cont.

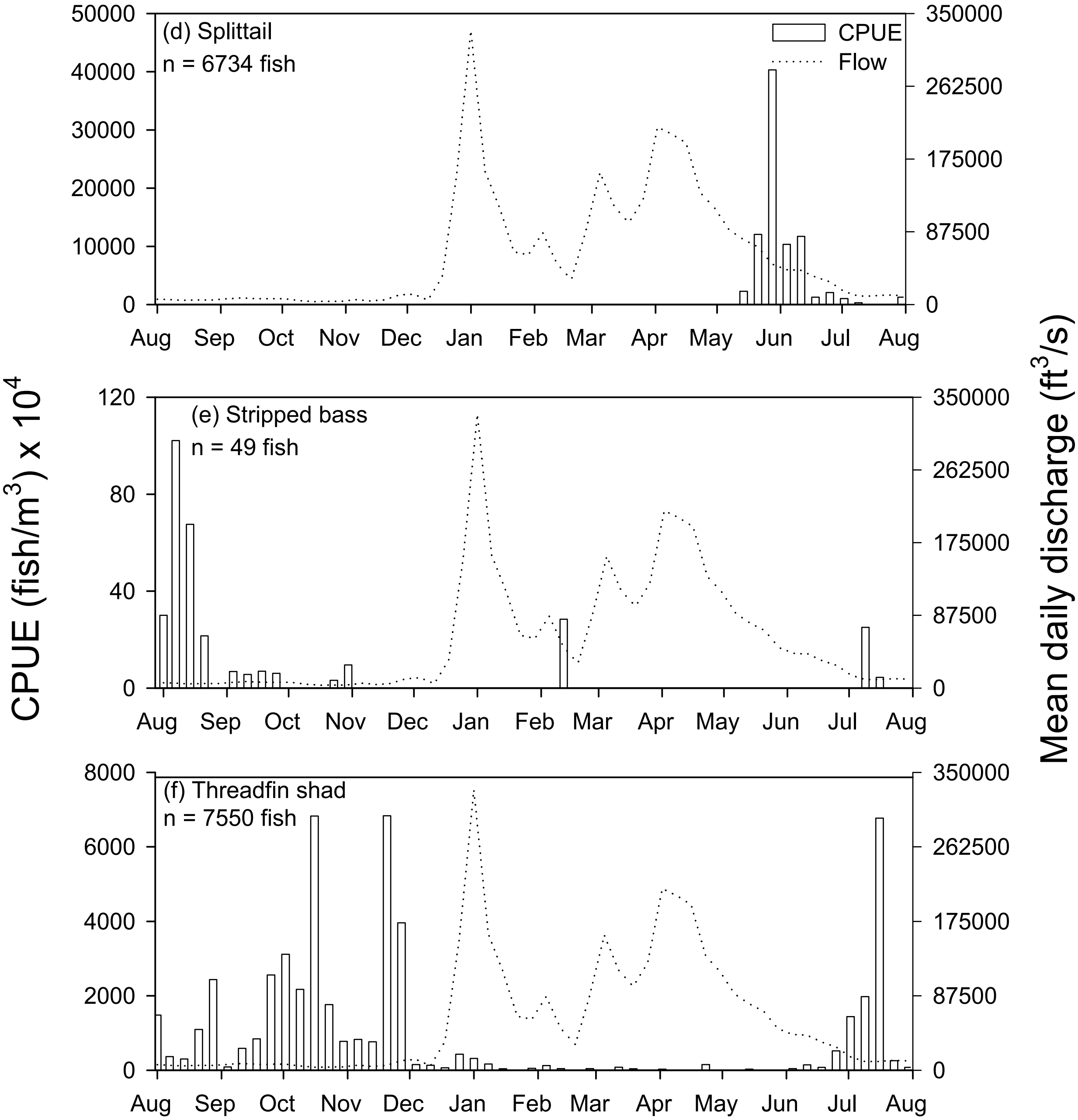

Table 3. Summary table of CPUE (fish/m^3 x 10^4) of (a) winter-, (b) fall-/spring-run, and (c) late fall-run Chinook salmon in interior Delta (North, Central, and South; Regions 2-4) combined by month and year. Yearly mean and standard error (SE) values were calculated using years as replicates (n = 11-13). 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; 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	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)
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)
Yearly mean 1993-2005 (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)
2006	W	0	0	2.97	45.2	151	31.2	5.42	6.41	1.53	0	0	0	25.8 (8.9)

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)
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)
Yearly mean 1993-2005 (SE)		0.142 (0.142)	1.74 (1.19)	0.954 (0.954)	2.42 (1.34)	361 (111)	3634 (678)	7476 (2342)	7709 (2835)	1804 (314)	374 (62.0)	44.2 (13.1)	1.60 (0.684)	2026 (459)
2006	W	0	0	0	0.51	1077	2711	3856	6636	6931	585	92.3	0	2724 (640)

Table 3. cont.

(c) Late fall-run

	Previous field season's brood year									Current field season's Brood year				
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)
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)
Yearly mean 1993-2005(SE)		0 (0)	0 (0)	0.076 (0.076)	1.94 (0.881)	5.84 (1.50)	2.64 (1.12)	0.553 (0.338)	0 (0)	19.0 (7.06)	14.9 (8.76)	3.09 (1.44)	0.268 (0.182)	53.9 (22.8)
2006	W	0	0	0	1.49	4.22	0	0	0	226	25.9	1.54	1.09	37.1 (16.2)

Region 5. San Joaquin River Beach Seine

Methods

San Joaquin River beach seine sampling began in 1994 to document the distribution and abundance of Chinook salmon in the San Joaquin River. Prior to 2000, sampling on the San Joaquin River was typically conducted from January to June of each year. Starting in 2000, sampling was conducted year-round. In 2006, sampling at the majority of sites was conducted once per week annually.

During the 2006 field seasons, we sampled 1-7 sites from Mossdale (rm 56) to north of the Tuolumne River (rm 83; Figure. 4).

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: 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.

Results

We captured 119 fall-run salmon in Region 5 during the 2006 field season (Figure 10). Salmon ranged in size from 31-87 mm (FL). Salmon were caught between late December and mid April. The 2006 field season was the first year since year-round sampling began where salmon were captured in December (Table 4). Peak weekly and monthly CPUE occurred in March during a period of increasing discharge in the San Joaquin River.

There were no delta smelt, longfin smelt, hatchery rainbow trout or wild rainbow trout captured in Region 5 beach seines in the 2006 field season. There were 1298 splittail captured between May 18 and July 20 (Figure 11a). Consistent with previous regions, weekly CPUE for splittail peaked in May as river discharge decreased.

Only two stripped bass were caught in region 5 beach seines, one in October, and one in July (Figure 11b). Weekly CPUE peaked in October during a period of decreased discharge.

There were 720 threadfin shad caught in region 5 during the 2006 field season (Figure 11c). Peak weekly CPUE occurred the week of November 6 when 57 threadfin were captured at Mossdale boat ramp (rm 56). Nearly all threadfin shad were caught before and after peak discharge in the San Joaquin River.

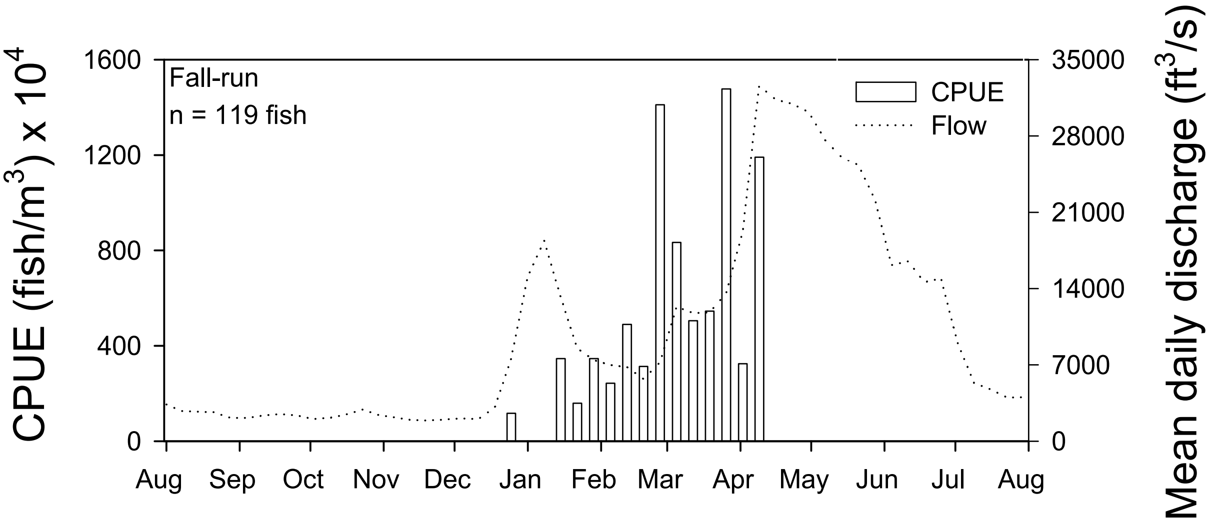

Figure 10. Catch-per-unit effort (x 10^4) of fall-run Chinook salmon in beach seines and mean daily discharge in the San Joaquin River region (Region 5) during the 2006 field season. All data were averaged by week. Sample size (n) corresponds to total number of fish caught. Unsampled weeks have no points on the graph.

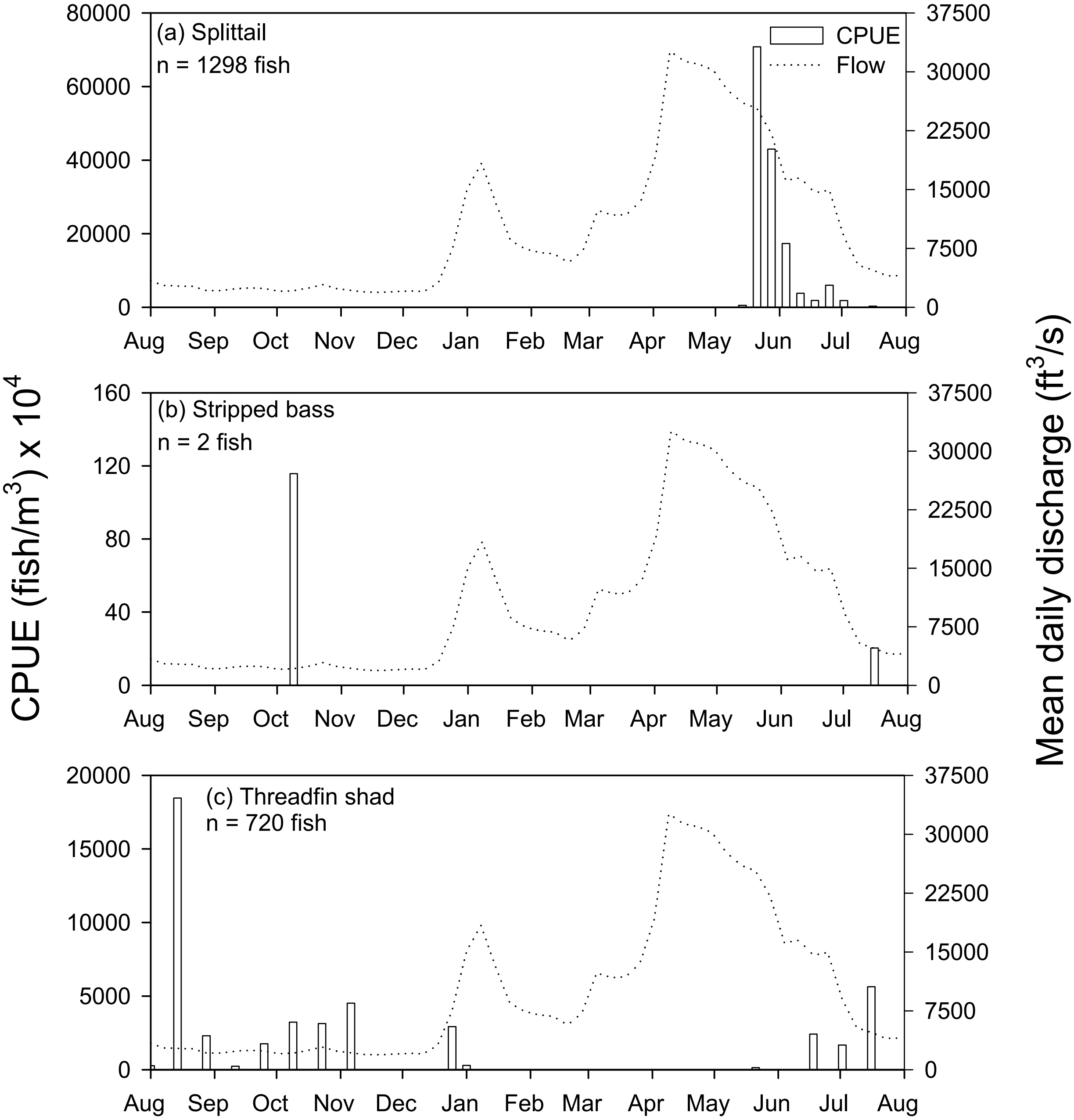

Figure 11. Catch-per-unit effort (x 10^4) of (a) spilttail, (b) stripped bass, (c) threadfin shad, in beach seines and mean daily discharge in the San Joaquin River region (Region 5) during the 2006 field season. All data were averaged by week. Sample size (n) corresponds to total number of fish caught. Unsampled weeks have no points on the graph.

Table 4. Summary table of CPUE (fish/$m^3 \times 10^4$) 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)
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)
Yearly mean 1994-2005 (SE)		0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	260 (178)	1063 (640)	441 (201)	189 (70.0)	21.4 (9.67)	14.5 (12.8)	0 (0)	491(214)
2006	W	0	0	0	0	50.1	101	314	859	65.7	0	0	0	202 (60.2)

Region 6. San Francisco/San Pablo Bays Beach Seines

Methods

Beach seining in San Francisco and San Pablo Bays was originally conducted by DJFMP 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 2006 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 2006 were a subset of those sampled by CDFG in the 1980s (Orsi 1999).

Results

We captured 57 spring/fall-run sized salmon in the 2006 field season in Region 6 (Figure 12). All but four of the 57 salmon captured were in the fry size range. Weekly CPUE peaked in early January coinciding with the highest delta discharge for 2006. Monthly CPUE peaked in January and was an order of magnitude higher than the overall January average for 1997-2005 (Table 5).

Consistent with Region, 5 there were no delta smelt, longfin smelt, hatchery rainbow trout or wild rainbow trout captured in the Region 6 beach seines. There were only 5 splittail captured, one on March 12 at China Camp and four on May 21 at Pt. Pinole East (Figure 13a). Peak weekly CPUE occurred the week of May 21 during a period of decreased delta discharge.

Only three stripped bass were captured in Region 6 (Figure 13b). All three were caught at Pt. Pinole East, one in April and two in July. Weekly CPUE peaked during the week of April 9 coinciding with the second peak in total delta discharge. In addition, twelve threadfin shad were caught in Region 6 between December 20 and January 1 (Figure 13c). Peak weekly CPUE was observed the week of November 20 when 10 threadfin were captured at McNear's Beach.

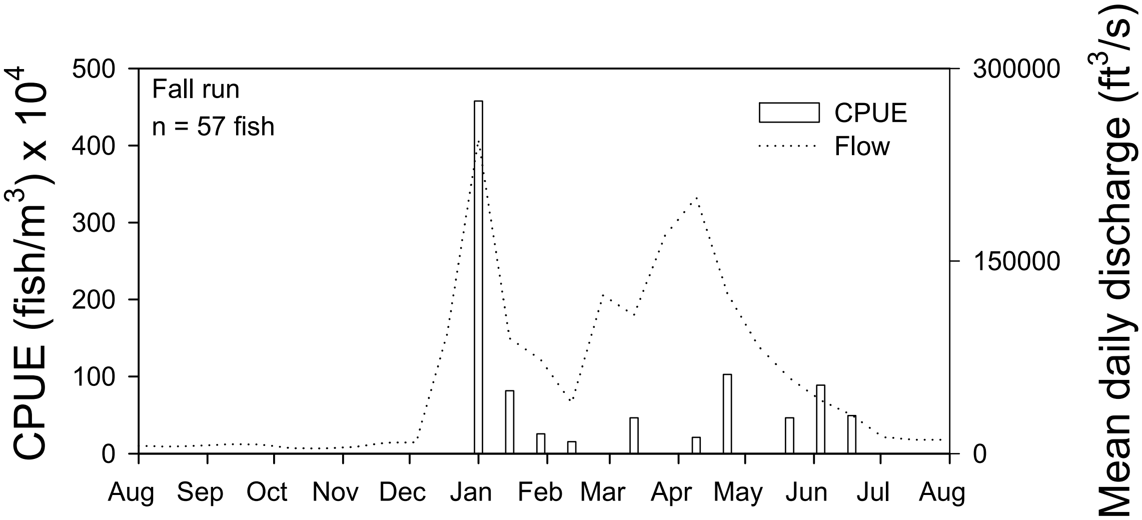

Figure 12. Catch-per-unit effort (x 10^4) of spring-/fall-run Chinook salmon in beach seines in San Francisco/San Pablo Bays (Region 6) and Delta discharge during the 2006 field season. Data were averaged biweekly because each site was sampled every other week. Fall and Spring-run salmon were combined because of the close overlap in size and emigration timing of these two races. No other races of salmon were collected in bay seines. No other races of salmon were collected in bay seines. Sample size (n) corresponds to total number of fish caught during 2006 field season.

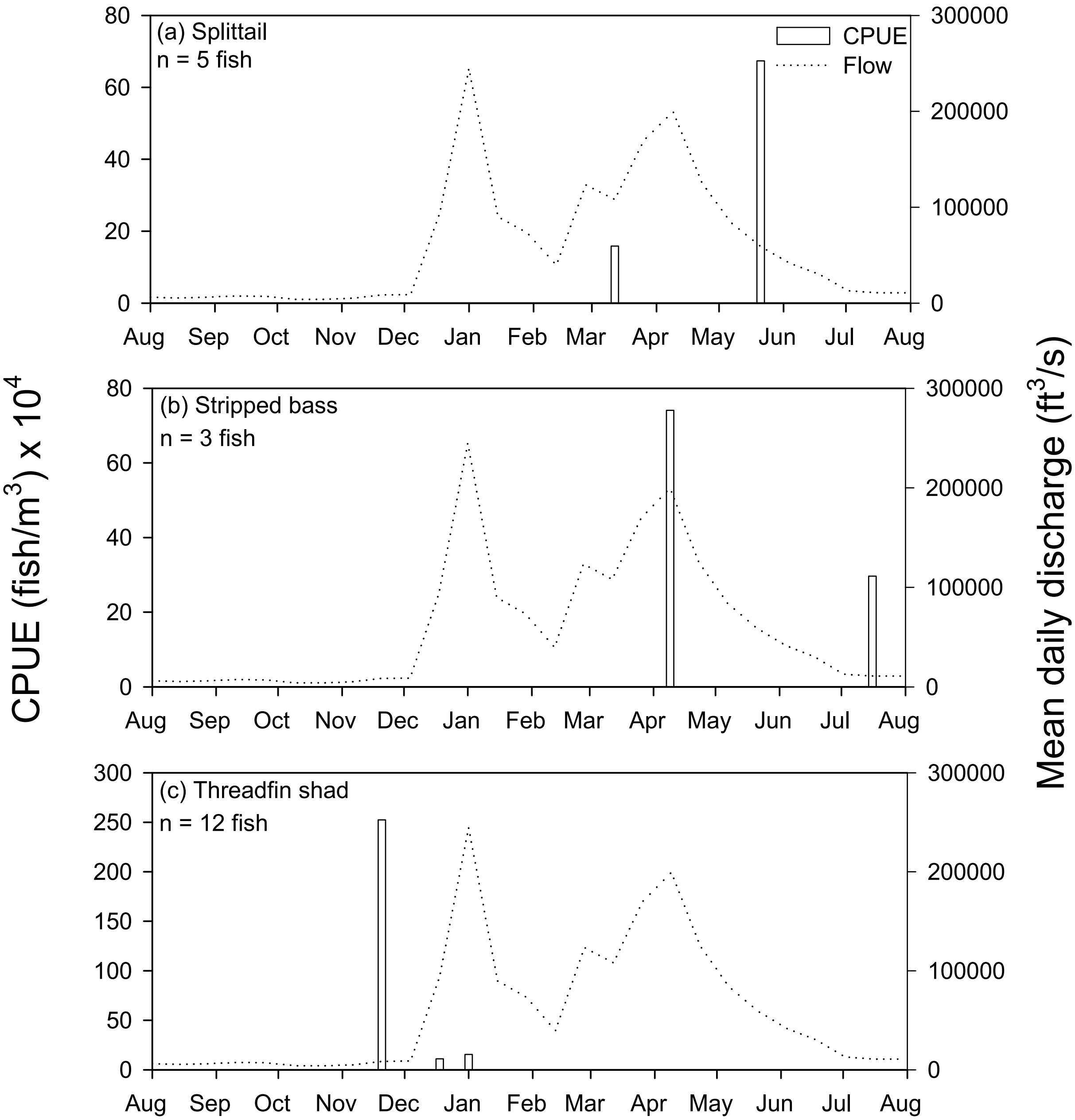

Figure 13. Catch-per-unit effort (x 10^4) of (a) spilttail, (b) stripped bass, and (c) threadfin shad in beach seines in San Francisco/San Pablo Bays (Region 6) and delta discharge during the 2006 field season. All data were averaged biweekly because each site was sampled every other week. Sample size (n) corresponds to total number of fish caught during 2006 field season.

Table 5. Summary table of CPUE (fish/m^3) x 10^4 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): 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)
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)
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)
Yearly avg 1997-2005 (SE)		0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	37.6 (27.0)	58.9 (42.0)	77.0 (45.8)	11.1 (7.80)	9.38 (5.43)	0 (0)	0 (0)	81.9 (43.8)
2006	W	0	0	0	0	0	279	19.1	20.6	24.5	34.2	41.2	0	34.6 (17.3)

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: Figure 4). Sampling was conducted up to three times per week during October-January during the 2006 field season. 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 259 winter-run sized fry captured in the Sacramento area beach seines in the 2006 field season (Figure 14a). Peak weekly CPUE occurred in early December coinciding with increasing discharge in Sacramento River at Freeport. Peak monthly CPUE also occurred in December and was the third highest since 1995 (Table 6a). The mean monthly CPUE for 2006 was larger than the overall monthly mean for 1995-2005. In addition, 92 winter-run sized yearlings were captured from mid November to December (Figure14b). Peak weekly and monthly CPUE were observed in December, coinciding with increasing discharge. The annual weekly and monthly means of winter-run sized yearlings were larger than the overall annual weekly and monthly means for 1995-2005 (Table 6b).

Spring-run fry were slightly more abundant than winter-run fry in Sacramento area beach seines in 2006. From mid November to late January, 354 salmon were captured (Figure 14c). Peak weekly CPUE was observed the week of January 8, immediately following peak discharge in the Sacramento River. Peak monthly CPUE was observed in January (Table 6c). There were no spring-run yearling captured in 2006 (Figure 14d).

Consistent with all previous years of Sacramento area beach seines, there were no late fall-run salmon fry captured between October and January (Figure 14e). There were only four late fall-run salmon yearlings captured from mid November through early December for the 2006 field season. Peak weekly and monthly CPUE occurred in December (Figure 14e, Table 6f).

There were no rainbow trout (hatchery or wild), delta smelt, longfin smelt, or stripped bass caught in the Sacramento area beach seines in 2006.

There were 8 splittail captured from December 19 to January 3 coinciding with a spike in discharge in the Sacramento River (Figure 15a). Weekly CPUE peaked the week of January 1 when eight splittail were captured. In addition, there were 59 threadfin shad captured in Sacramento area beach seines (Figure 15b). Peak weekly CPUE occurred the week of December 4, three weeks prior to peak discharge in the Sacramento River.

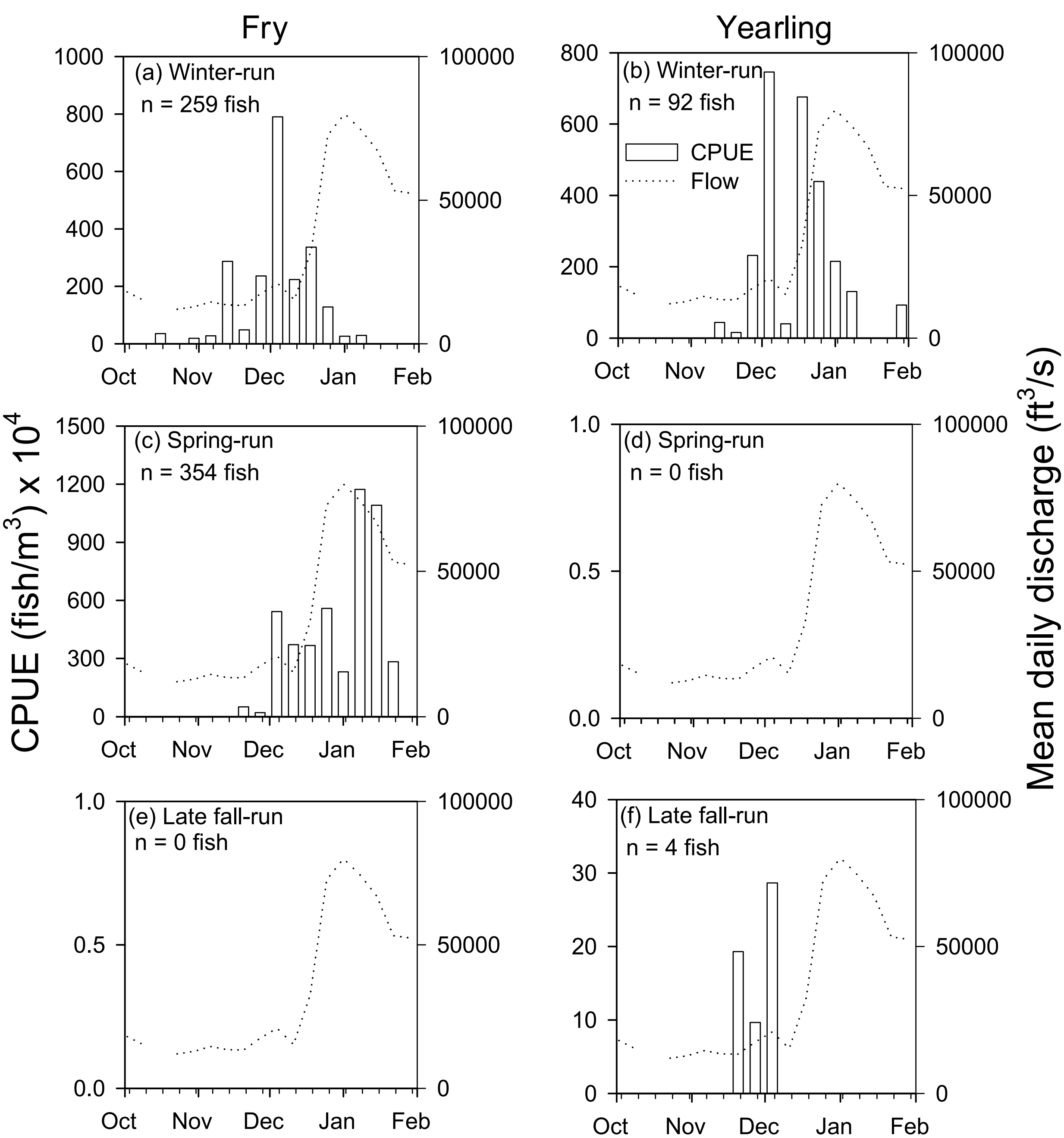

Figure 14. Catch-per-unit effort (x 10^4) of fry and yearlings from winter-, spring-, and late fall-run raced salmon in Sacramento area beach seines and concurrent mean daily discharge at Freeport during the 2006 field season. All data were averaged by week. Sample size (n) corresponds to total number of fish caught during the 2006 field season.

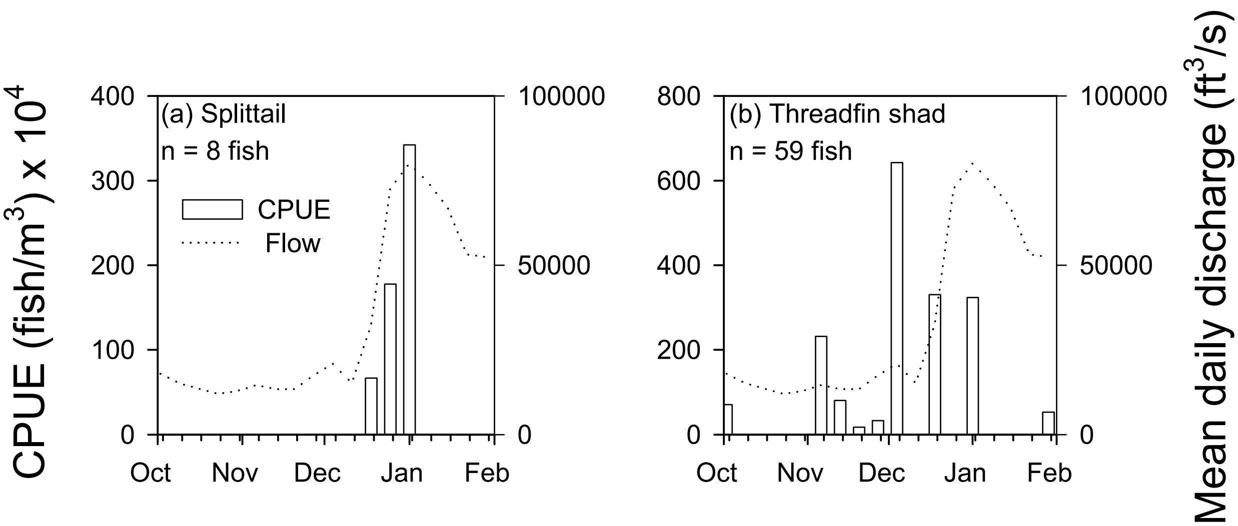

Figure 15. Catch-per-unit effort (x 10^4) of (a) spilttail, and (b) threadfin shad in Sacramento area beach seines and concurrent mean daily discharge at Freeport during the 2006 field season. All data were averaged by week. Sample size (n) corresponds to total number of fish caught during the 2006 field season.

Table 6. Summary table of CPUE (fish/m^3) x 10^4 of less common Chinook salmon races by age class during 1994-2006 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 = 11). 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; BN = below normal; D = dry; 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)
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)
Yearly mean 1995-2005 (SE)		1.51 (0.724)	63.5 (36.1)	159 (80.2)	15.6 (9.80)	0 (0)	77.5 (38.8)
2006	W	11.1	145	423	13.7	--	121 (47.2)

Table 6 cont.

(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)
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)
Yearly mean 1995-2005 (SE)		0 (0)	27.5 (15.7)	156 (45.3)	104 (21.2)	75.8 (31.8)	94.4 (18.9)
2006	W	0	24.4	200	122	--	146 (55.7)

(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)
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)
Yearly mean 1995-2005 (SE)		0 (0)	10.3 (7.30)	461 (114)	387 (86.2)	276 (100)	285 (53.0)
2006	W	0	18.5	415	700	--	261 (87.8)

(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)
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)
Yearly mean 1995-2005 (SE)		0 (0)	0 (0)	0 (0)	0 (0)	7.21 (4.01)	0.801 (0.434)
2006	W	0	0	0	0	--	0 (0)

Table 6 cont.

(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)
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)
Yearly mean 1995-2005 (SE)		0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
2006	W	0	0	0	0	--	0 (0)

(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)
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)
Yearly mean 1995-2005 (SE)		0.568 (0.390)	10.5 (7.09)	28.3 (6.0)	5.57 (3.03)	0.504 (0.504)	10.9 (2.59)
2006	W	0	7.67	9.49	0	--	3.20 (1.90)

Trawls

Methods

Midwater Trawls

Midwater trawls (MWTR) are conducted to estimate relative abundance of fishes using 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 16). 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 attach to the net with shackles to spread the bottom line of the mouth. Hydrofoils are made of 0.7 cm (¼”) aluminum plates with split floats (one on each side of the net float line) and attach to the net with shackles to spread the top of the net at the surface. 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 (USFWS 1993).

A larger MWTR net is used at Chipps Island (Figure 17). 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. 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 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 mechanical flow meter (General Oceanics, Model #2030, Miami, Florida). This measure of distance is not related to distance traveled relative to land, which can be affected by river flow rate and direction.

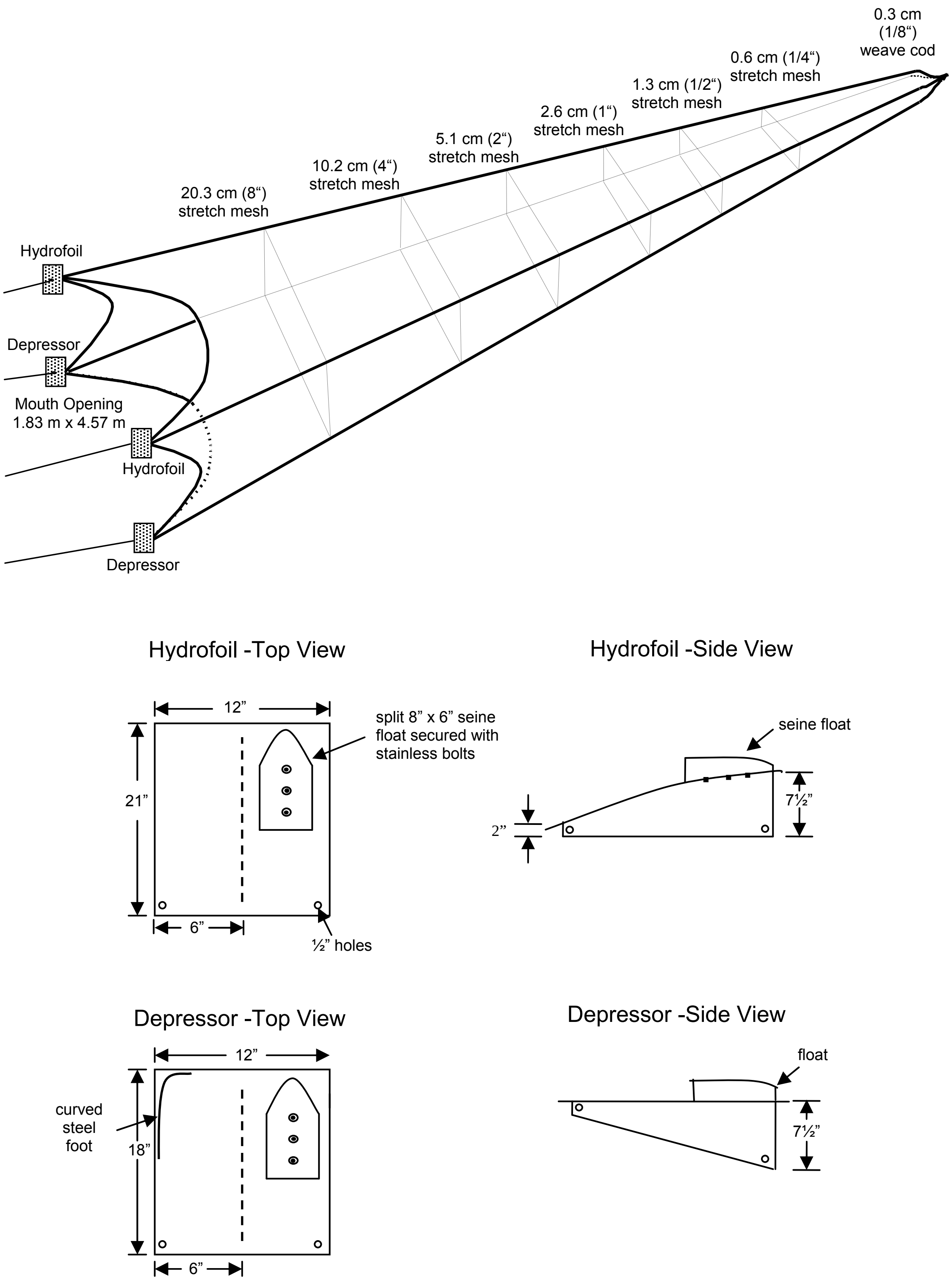

Figure 16. Schematic drawing of midwater trawl net (top), and hydrofoils and depressors (bottom) used at Sacramento during 2006 field season.

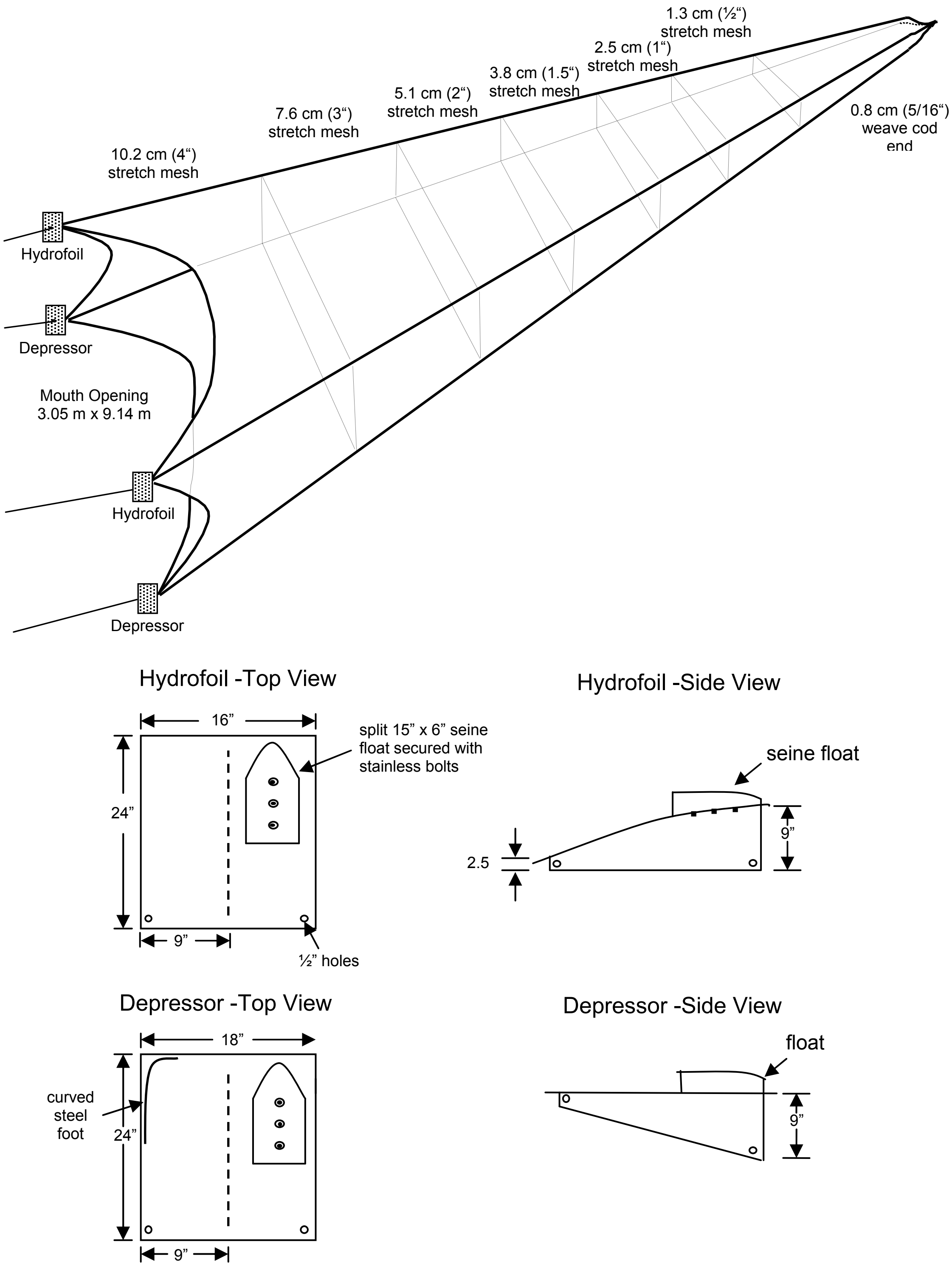

Figure 17. Schematic drawing of midwater trawl net (top) and hydrofoils and depressors (bottom) used at Chipps Island during 2006 field season.

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, 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 18). 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).

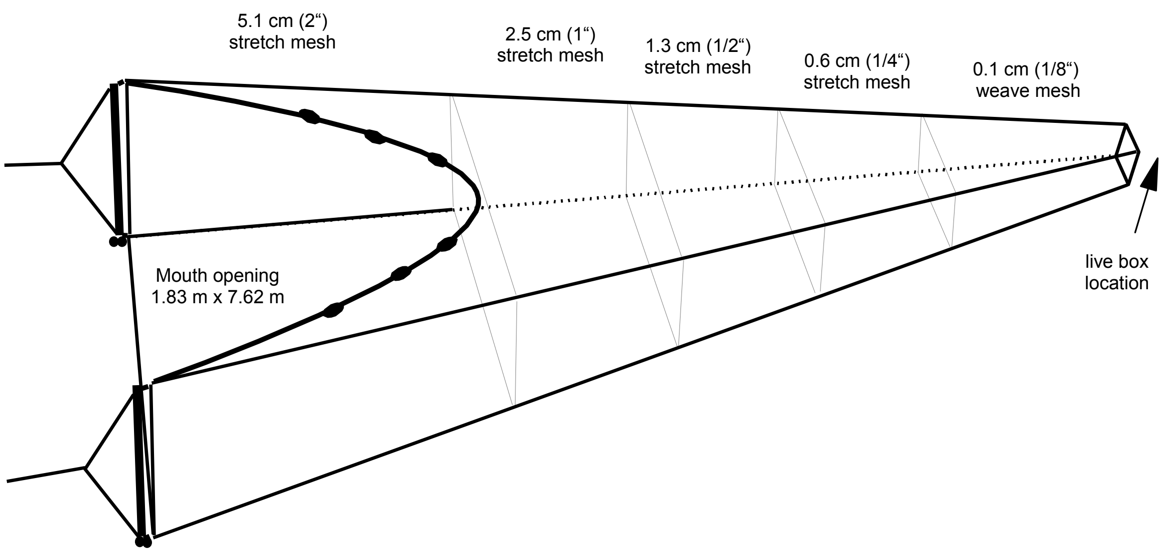

Figure 18. Schematic drawing of Kodiak trawl net used at Sacramento during 2006 field season.

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, 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 (not statistically) to historical monthly mean CPUE.

Sacramento Trawls

Methods

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

All trawling was conducted in the middle of the channel facing upstream against the current 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

We captured132 winter-run sized salmon in Sacramento trawls between November and May (Figure 19a). Peak daily CPUE occurred on December 5, coinciding with increasing flows in the Sacramento River. Peak monthly CPUE was observed in December consistent with the past three years (Table 7a).

During the 2006 field season, 4665 spring/fall run salmon were captured from early December to late July (Figure 19b). Peak daily CPUE occurred on May 3 during a period of high discharge in the Sacramento River. Monthly peak CPUE was observed in May at the second lowest peak monthly average since 1993.

Only four late fall-run sized salmon were captured in 2006, one in each month of August, December, April, and July (Figure 19c). There were two late fall yearling from the 2005 brood year and two late fall fry from 2006 brood year. Peak daily CPUE occurred on December 12 during a period of increasing discharge. Peak monthly CPUE was also observed in December (Table 7c).

There were 51 hatchery rainbow trout caught in Sacramento trawls (Figure 20a). Fifty were captured in Kodiak trawls and only one in midwater trawls. Peak daily CPUE occurred on February 17 when 10 trout were captured in Kodiak trawls. Only three wild trout were captured, one in mid-water trawls and two in Kodiak trawls (Figure 20b). Daily CPUE peaked on June 14 during a period of decreasing discharge in the Sacramento River.

The only delta smelt captured in Sacramento trawls was on May 31 during mid-water trawling (Figure 20c). This individual was captured as discharge was decreasing in the Sacramento River. There were no longfin smelt captured in any Sacramento trawls.

We captured 33 splittail while mid water trawling in 2006 (Figure 20d). No splittail were captured while Kodiak trawling. All were captured, during periods of decreasing discharge in the Sacramento River. Daily CPUE peaked on August 24.

Only three stripped bass were captured in Sacramento trawls (Figure 20e). All three bass were caught while mid-water trawling. Daily CPUE peaked on July 28 coinciding with decreasing discharge in the Sacramento River.

Sacramento trawls captured 112 threadfin shad (Figure 20f), twenty in mid-water trawls and 92 in Kodiak trawls. Daily CPUE peaked on July 31 when 6 threadfin shad were captured while mid-water trawling.

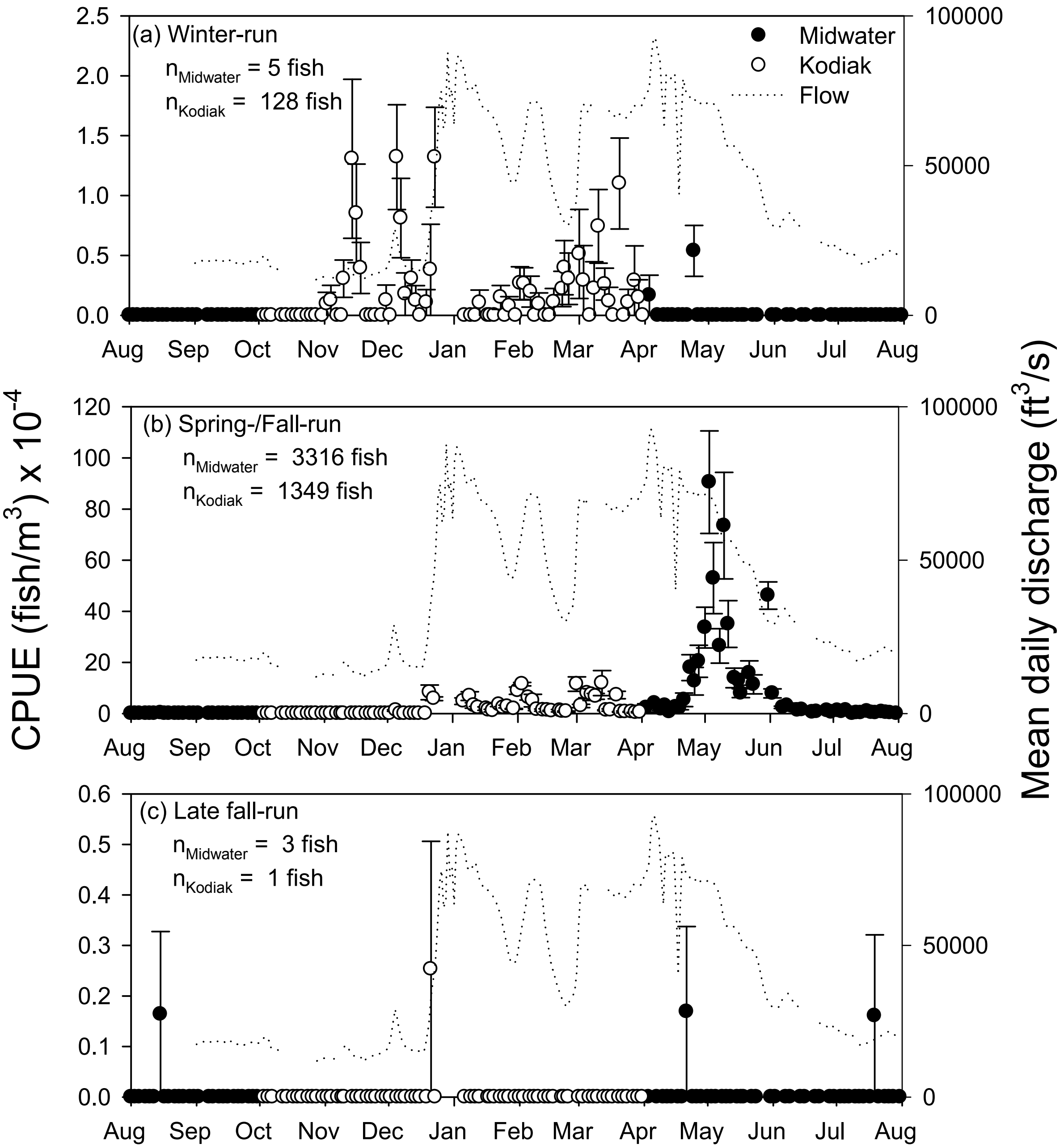

Figure 19. Mean-daily-catch per unit effort (x 10^{-4}) of (a) winter-, (b) spring/fall-, and (c) late fall-run Chinook salmon in trawls at Sherwood Harbor (Sacramento trawls) and concurrent mean daily discharge at Freeport, Sacramento River during the 2006 field season. Sample size (n) corresponds to total number of fish caught in each trawl during the 2006 field season. Error bars are ± 1 SE.

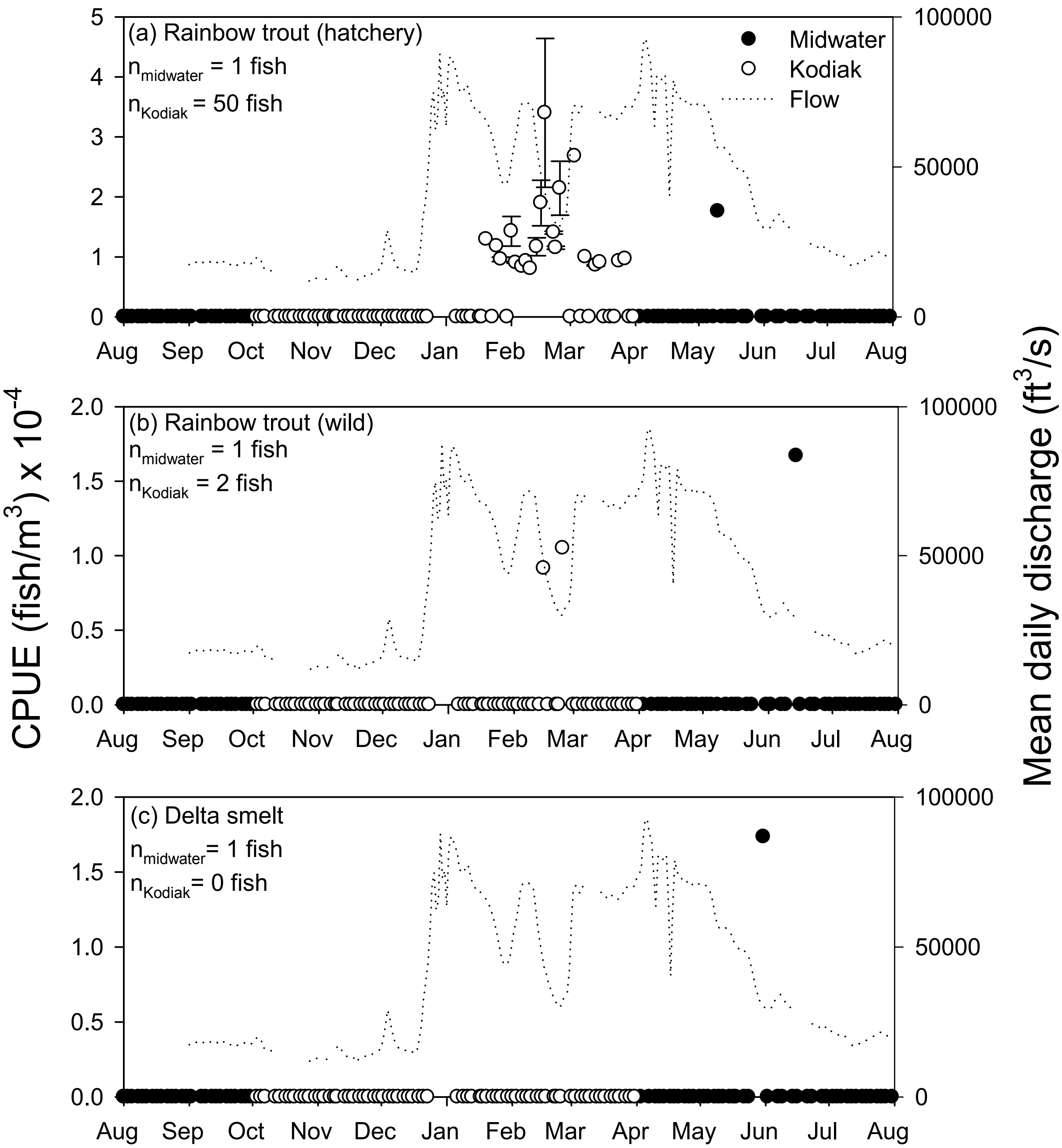

Figure 20. Mean daily catch per unit effort (x 10^{-4}) of (a) rainbow trout (hatchery), (b) rainbow trout (wild), (c) delta smelt, (d) longfin smelt, (e) spilttail, (f) stripped bass, and (g) threadfin shad in trawls at Sherwood Harbor (Sacramento trawls) and concurrent mean daily discharge at Freeport, Sacramento River during the 2006 field season. Sample size (n) corresponds to total number of fish caught in each trawl during the 2006 field season. Error bars are ± 1 SE.

Figure 20 cont.

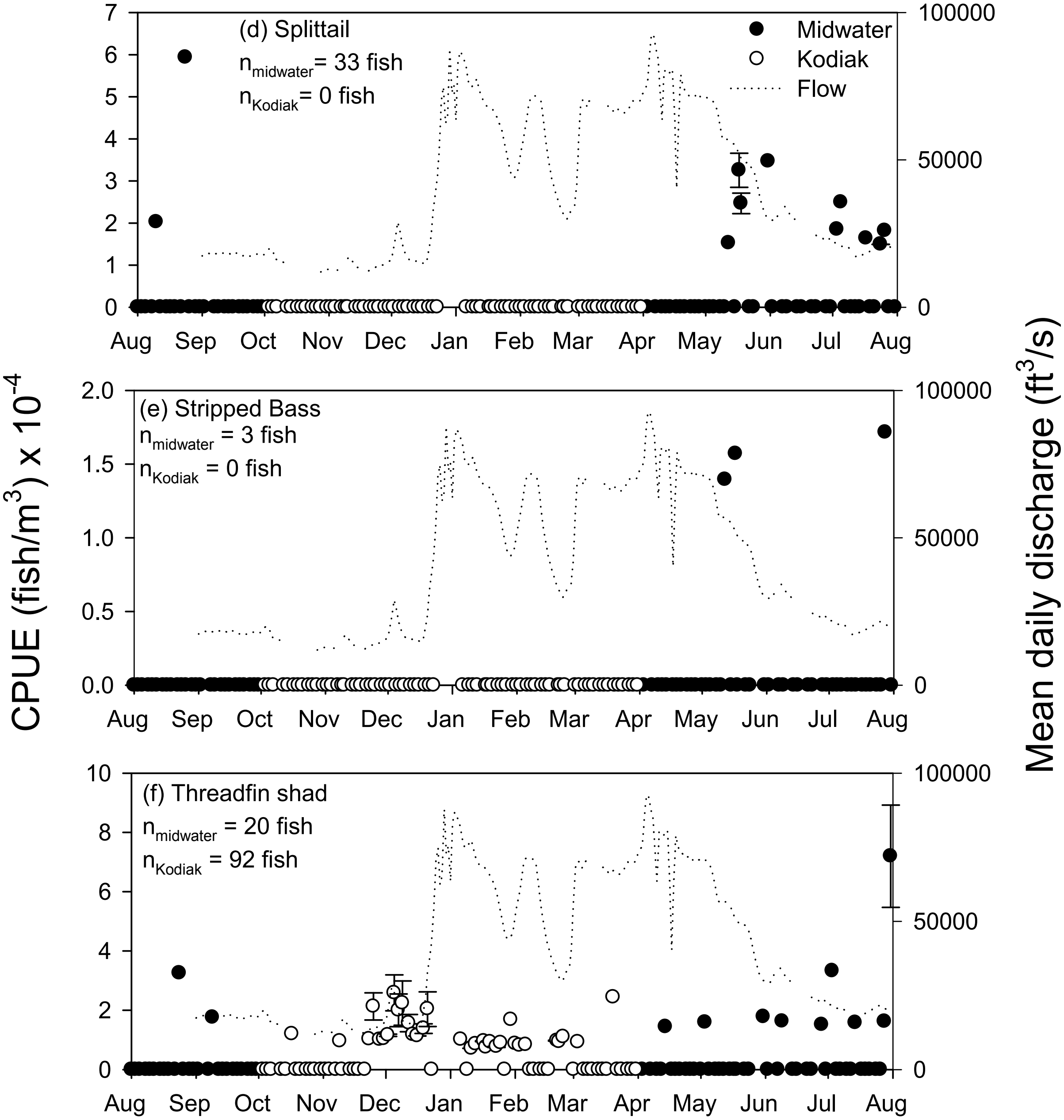

Table 7. Summary table of CPUE (fish/m^3) x 10^{-4} of (a) winter-, (b) fall/spring-run, and (c) late fall-run Chinook salmon in midwater and Kodiak trawls at Sherwood Harbor (Sacramento trawls) by month and year. Yearly mean and standard error (SE) values were calculated using years as replicates (n = 3-13 for MWTR, n = 10-11 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)
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)
Yearly mean 1993-2005 MWTR (SE)		0 (0)	0.00185 (0.00178)	0 (0)	0 (0)	0.144 (0.130)	0.0373 (0.0373)	0.186 (0.0825)	0.130 (0.0645)	0.0715 (0.0321)	0 (0)	0 (0)	0 (0)	0.0344 (0.0109)
Yearly mean 1995-2005 KDTR (SE)		--	0 (0)	0.00142 (0.00142)	0.109 (0.0637)	0.198 (0.0636)	0.0826 (0.0195)	0.192 (0.0390)	0.234 (0.0915)	0.202 (0.142)	--	--	--	0.148 (0.0198)
2006 MWTR	W	0	0	--	--	--	--	--	--	0.0641	0	0	0	0.00974 (0.00573)
2006 KDTR	W	--	--	0	0.247	0.455	0.0302	0.169	0.271	--	--	--	--	0.1889 (0.108)

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)
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)
Yearly mean 1993-2005 MWTR (SE)		0.0490 (0.0180)	0.0116 (0.00528)	0 (0)	0.0163 (0.0128)	0.109 (0.0553)	2.30 (0.253)	18.8 (13.3)	8.02 (2.85)	44.2 (6.57)	27.2 (4.65)	2.41 (0.803)	0.261 (0.0288)	18.4 (3.33)
Yearly mean 1995-2005 KDTR (SE)		--	0 (0)	0 (0)	0.00645 (0.00293)	1.75 (0.843)	18.0 (6.10)	37.5 (14.5)	7.86 (4.83)	30.3 (20.9)	--	--	--	11.3 (3.40)
2006 MWTR	W	0.0113	0	--	--	--	--	--	--	6.59	35.0	2.09	0.459	6.99 (1.82)
2006 KDTR	W	--	--	0	0	1.52	2.88	3.59	4.34	--	--	--	--	2.19 (0.548)

Table 7 cont.

(c) Late fall-run

		Previous season brood year								Current season brood year				
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)
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)
Yearly mean 1993-2005 MWTR (SE)		0.0185 (0.00886)	0.0317 (0.0141)	0.0341 (0.0260)	0.203 (0.194)	0.177 (0.0903)	0.0390 (0.0285)	0.00890 (0.00664)	0 (0)	0.00692 (0.00294)	0.0161 (0.0127)	0.00108 (0.00108)	0.00134 (0.00134)	0.0331 (0.00711)
Yearly mean 1995-2005 KDTR (SE)		--	0 (0)	0.00167 (0.00112)	0.0485 (0.0227)	0.0624 (0.0152)	0.0311 (0.0145)	0.00126 (0.00126)	0 (0)	0 (0)	--	--	--	0.0253 (0.00484)
2006 MWTR	W	0.0117	0	--	--	--	--	--	--	0.0153	0	0	0.0124	0.00609 (0.00609)
2006 KDTR	W	--	--	0	0	0.0253	0	0	0	--	--	--	--	0.00337 (0.00337)

Kodiak Trawl at Mossdale

Methods

Kodiak trawling at Mossdale has been conducted since the 1997 field season to document juvenile salmon moving into the Delta from the San Joaquin River and tributaries. 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 of low flows on the San Joaquin River. 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).

Results

We captured 2,787 fall run-salmon in Mossdale trawls in the 2006 field season. Salmon were first detected in late December and continued through mid July (Figure 21). Peak daily CPUE occurred on June 4 as discharge was decreasing in the San Joaquin River. Peak monthly CPUE occurred in June for the first time since 1997 and was much greater than the overall average for 1997-2005 (Table 8).

There were no hatchery-reared rainbow trout captured in Mossdale trawls during the 2006 field season. However, there were 11 wild rainbow trout captured from early April to early June (Figure 22a). All were captured during increased discharge in the San Joaquin River. Daily CPUE peaked on April 3. In addition, there were no delta smelt or longfin smelt captured in Sacramento trawls.

Spilttail was the most abundant fish captured in the 2006 Mossdale trawls (n = 127,724 fish, Figure 22b). Most fish were captured between May and July. Daily CPUE peaked on June 7 when 39,293 fish were captured during a period of decreasing discharge in the San Joaquin River. There were an additional 266 splittail captured on June 19; however, there were no flow meter measurements, so these fish were not included in the CPUE.

We captured 19 stripped bass in Mossdale Kodiak trawls in 2006 (Figure 22c). Daily CPUE effort peaked on August 8 during low flows in the San Joaquin River. The highest daily catch was on June 9 when five stripped bass were captured in four tows.

There were1,374 threadfin shad captured between August and July in Mossdale trawls (Figure 22d). Daily CPUE peaked on July 5 during decreasing flows in the San Joaquin River. The highest daily catch was on December 23 when 70 threadfin shad were captured.

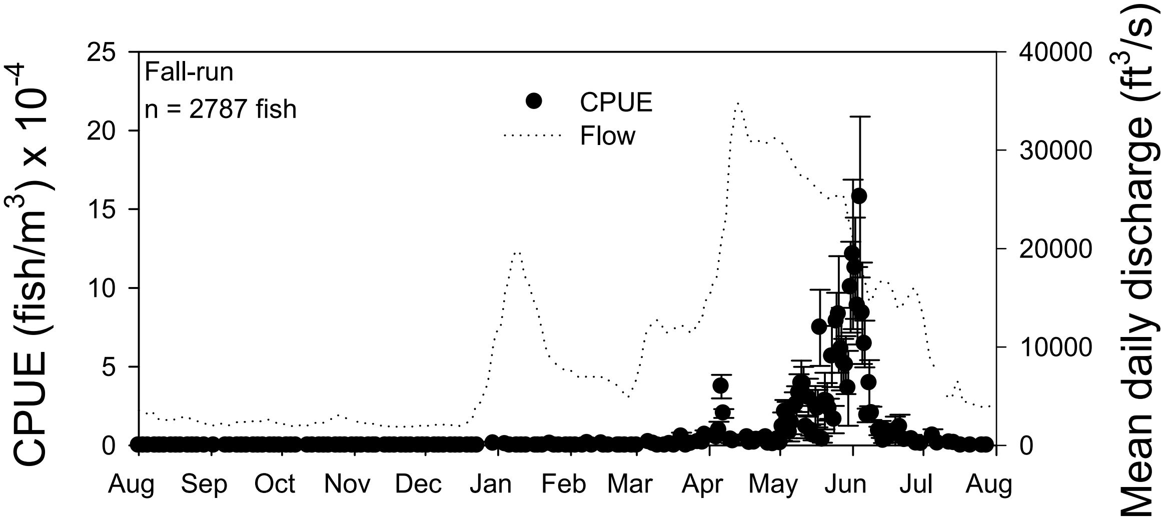

Figure 21. Mean daily catch-per-unit effort (x 10^{-4}) of fall-run Chinook salmon juveniles in Kodiak trawls at Mossdale, San Joaquin River and concurrent mean daily discharge at Vernalis during the 2006 field season. Sample size (n) corresponds to total number of fish caught during each field season. Error bars are ± 1 SE.

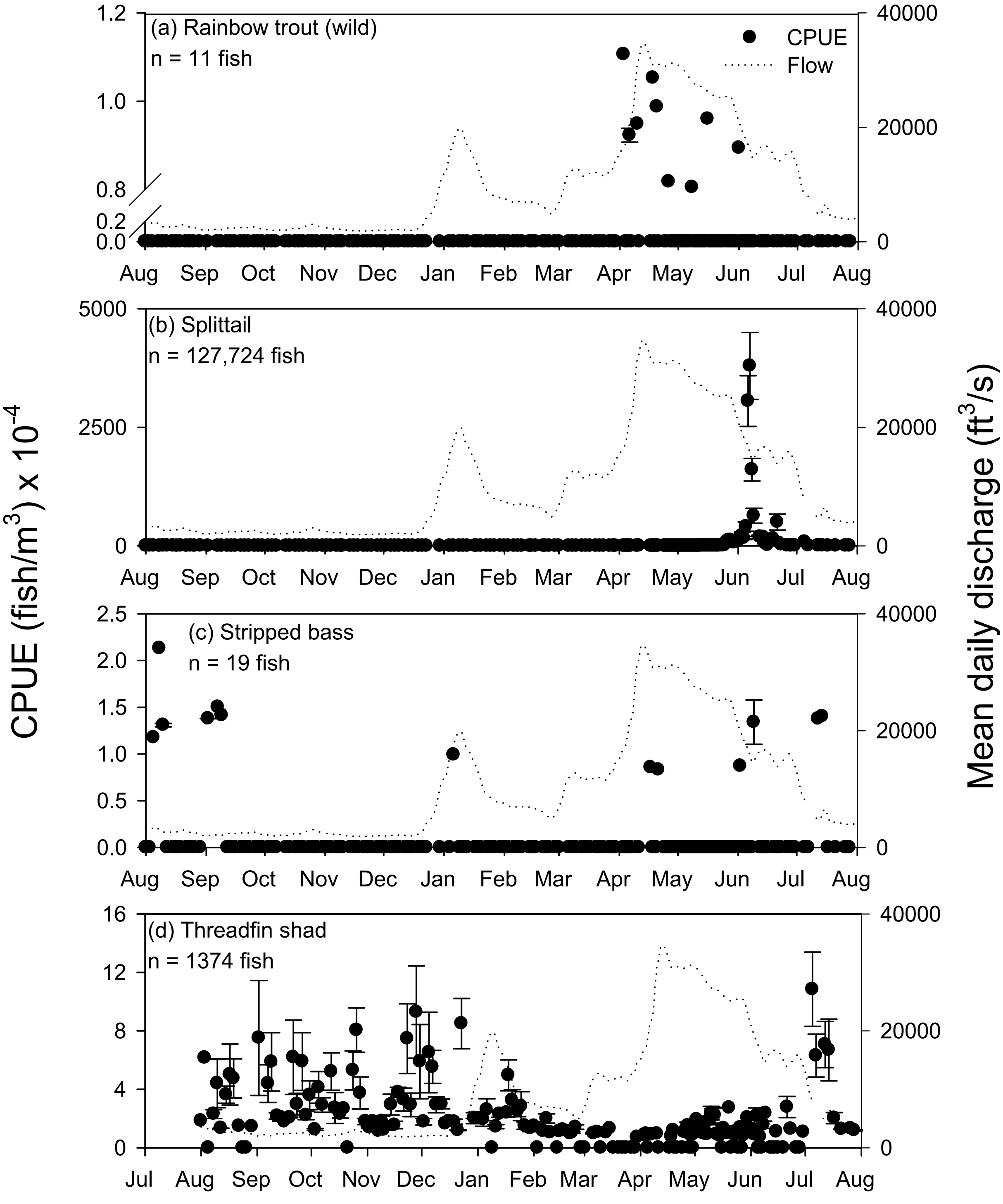

Figure 22. Mean daily catch-per-unit effort (x 10^{-4}) of (a) rainbow trout (wild), (b) spilttail, (c) stripped bass, (d) threadfin shad in Kodiak trawls at Mossdale, San Joaquin River and concurrent mean daily discharge at Vernalis during the 2006 field season. Sample size (n) corresponds to total number of fish caught during each field season. Error bars are ± 1 SE.

Table 8. Summary table of CPUE (fish/m^3) x 10^{-4} 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 = 3-9). 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)
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)
Yearly mean 1997-2005 (SE)		0	0	0 (0)	0 (0)	0 (0)	0.407 (0.205)	0.973 (0.570)	0.627 (0.239)	3.03 (1.01)	4.25 (1.42)	0.603 (0.201)	0.00712 (0.00440)	1.41 (0.315)
2006	W	0	0	0	0	0.0102	0.0160	0.0223	0.150	0.591	3.34	4.30	0.109	1.12 (0.187)

Chipps Island Trawl

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/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. Coded wire tag 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 in salmon emigration 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 2006 field season, 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/week, except during CWT recapture periods. Recapture periods during the 2006 field season were as follows: December 5 through January 15. During this recapture period, sampling increased to seven days/week. Efforts during VAMP releases were increased further to twenty 20-minute tows seven days/week. The VAMP period during the 2006 field season was: May 4 – June 17.

Results

We captured 323 winter-run salmon from mid December through mid May in the 2006 field season (Figure 23a). Daily CPUE peaked on April 17 at the onset of decreasing total delta discharge. Peak monthly CPUE was the highest on record and unlike the previous 12 years occurred in April (Table 9a).

There were 22,019 spring/fall-run salmon captured in Chipps Island trawls in 2006 (Figure 23b). Nearly all salmon were captured from mid April through July. Peak daily CPUE occurred on May 5, well after peak delta discharge. The highest peak monthly CPUE of spring/fall-run salmon since year round sampling began at Chipps Island occurred in May of the 2006 field season (Table 9b).

Only 28 late fall-run salmon were captured in 2006 trawls at Chipps Island (Figure 23c). All late fall-run salmon were captured from late October through mid February and were yearlings from the 2005 Brood Year. The highest daily CPUE occurred on December 12 when only two salmon were caught. Peak monthly CPUE occurred during December at the third highest since 1994 (Table 9c).

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.

There were 109 hatchery-reared rainbow trout caught in 2006 (Figure 24a). The first one was captured on January 27 and the last one on June 2. Daily CPUE peaked on February 13 during a period of decreased delta discharge. In addition, there were 22 wild rainbow trout captured in the Chipps Island trawls (Figure 24b). Their daily CPUE peaked on June 9, also during decreasing delta discharge.

We captured 875 delta smelt throughout the 2006 field season at Chipps Island (Figure 24c). Delta smelt were captured in greater numbers during the months of February, March, June, and July. Daily CPUE peaked on June 22 during decreasing delta discharge.

In the 2006 field season, 774 longfin smelt were captured at Chipps Island (Figure 24d). Chipps Island MWTR was the only sample location in 2006 that captured longfin smelt. Most of the smelt were captured between December and March. Daily CPUE peaked on February 22 when 9 longfin smelt were captured during decreased delta discharge.

There were 520 splittail captured in Chipps Island trawls from August to July (Figure 24e). Peak daily CPUE was observed on January 15 a week after peak delta discharge. The greatest number of splittail were captured on January 19 when 24 fish were caught.

The largest number of stripped bass captured in all sample gear types occurred at Chipps Island (n = 2428 fish, Figure 24f). Although stripped bass were captured regularly in 2006, their numbers generally declined in the months of February, March, and April. Daily CPUE peaked on July 26 coinciding with low delta discharge.

There were 3052 threadfin shad captured in MWTR at Chipps Island (Figure 24g). Daily CPUE peaked on December 18 when 101 threadfin shad were captured. The highest daily catch of 230 shad occurred on December 2.

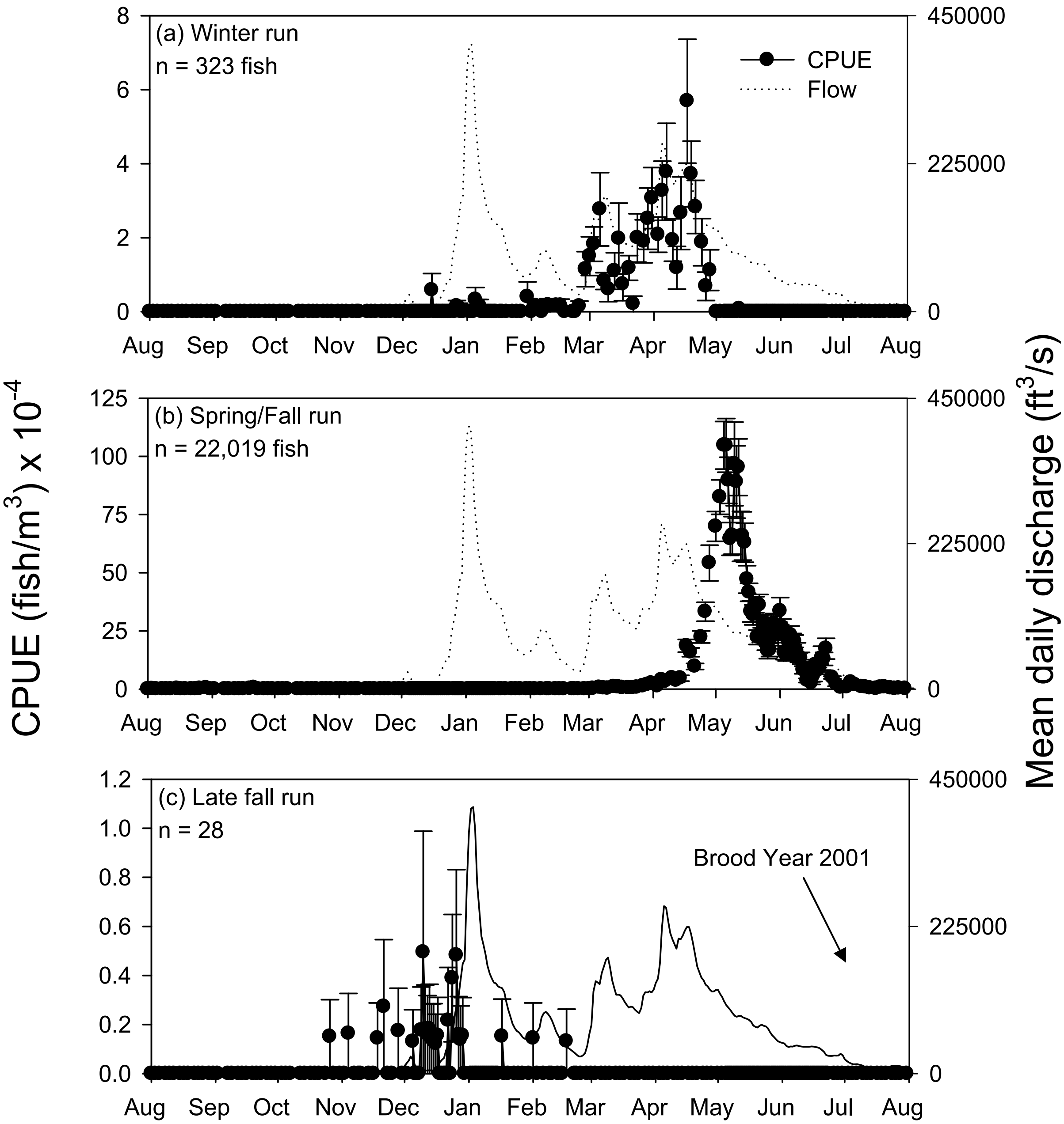

Figure 23. Mean daily catch-per-unit effort (x 10^{-4}) of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in midwater trawls at Chipps Island and concurrent daily Delta discharge during the 2006 field season. Sample size (n) corresponds to total number of fish caught during the 2001 field season. Error bars are ± 1 SE.

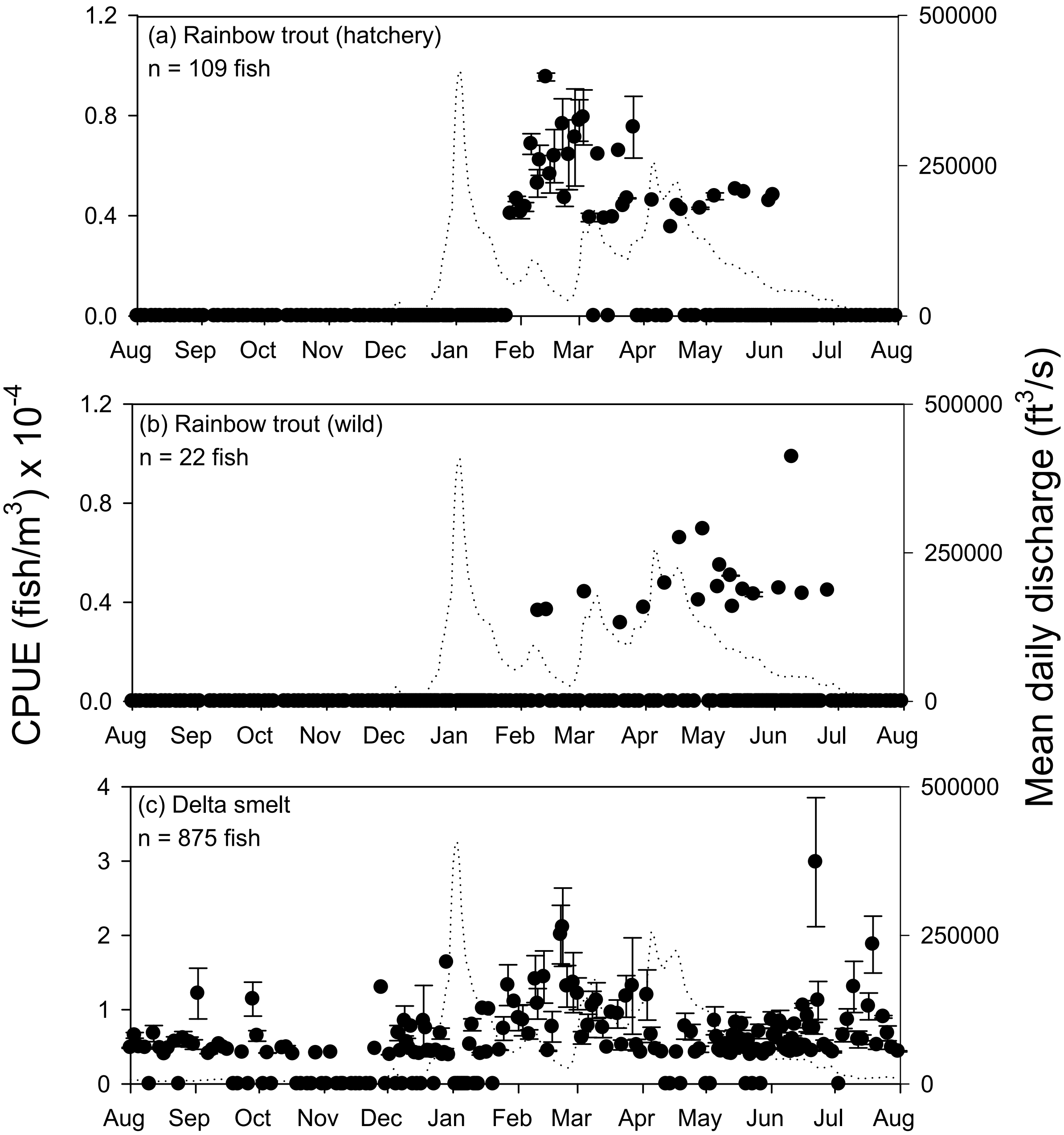

Figure 24. Mean daily catch-per-unit effort (x 10^{-4}) of (a) rainbow trout (hatchery), (b) rainbow trout (wild), (c) delta smelt, (d) longfin smelt, (e) spilttail, (f) stripped bass, and (g) threadfin shad in midwater trawls at Chipps Island and concurrent daily Delta discharge during the 2006 field season. Sample size (n) corresponds to total number of fish caught during the 2001 field season. Error bars are ± 1 SE.

Figure 24 cont.

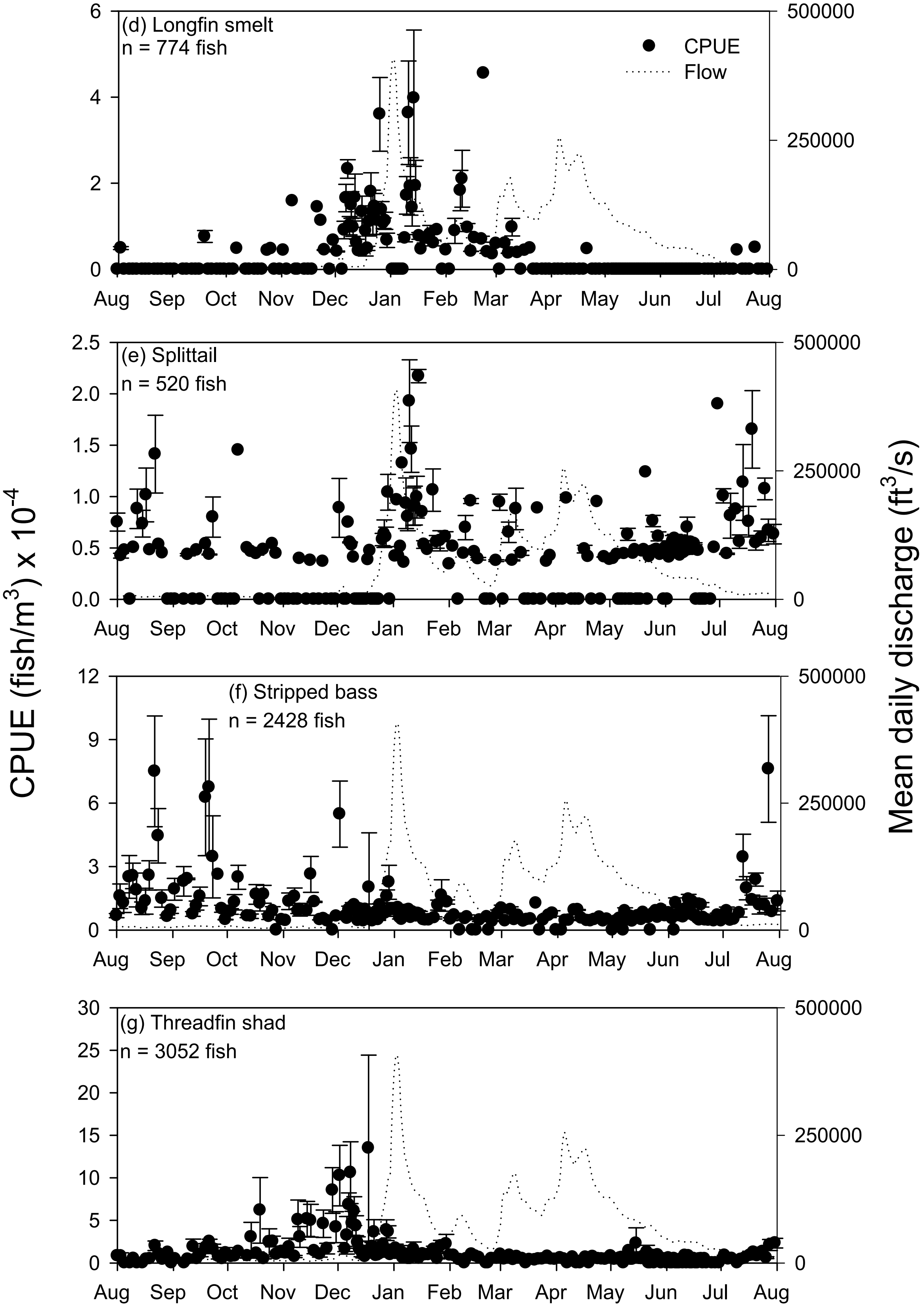

Table 9. Summary table of CPUE (fish/m^3) x 10^{-4} of (a) winter-, (b) spring-/fall-, and (c) late fall-run Chinook salmon in midwater trawls at Chipps Island by month and year. Among-year mean and standard error (SE) values were calculated using years as replicates (n = 9-13). Within-year mean and 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)
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)
Yearly mean 1993-2005(SE)		0 (0)	0 (0)	0 (0)	0 (0)	0.0154 (0.00603)	0.0287 (0.00826)	0.0778 (0.0135)	0.293 (0.0428)	0.0947 (0.0273)	0.00192 (0.000459)	0 (0)	0 (0)	0.0541 (0.0101)
2006	W	0	0	0	0	0.0339	0.0529	0.439	1.57	1.93	0.00274	0	0	0.354 (0.117)

Table 9 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	--	--	--	--	--	--	--	--	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)
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)
Yearly mean 1993-2005 (SE)		0.0344 (0.0141)	0.0279 (0.00823)	0.0546 (0.0266)	0.0107 (0.00416)	0.00392 (0.00271)	0.124 (0.0611)	0.549 (0.363)	0.701 (0.206)	7.89 (0.941)	8.66 (1.24)	2.0 (0.491)	0.154 (0.043)	2.07 (0.485)
2006	W	0.0678	0.0656	0	0	0	0	0.0147	0.906	33.59	43.7	11.1	0.790	7.01 (2.52)

Table 9 cont.

(c) Late fall-run

		Previous field season brood year								Current field season				
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)
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)
Yearly mean 1993-2005 (SE)		0.00244 (0.00207)	0.0185 (0.00703)	0.00458 (0.00198)	0.0372 (0.0183)	0.0865 (0.0136)	0.0224 (0.00505)	0.00307 (0.00156)	0.00031 (0.00031)	0 (0)	0.0002 (0.000135)	0.000152 (0.000152)	0.00253 (0.00174)	0.0208 (0.00698)
2006	W	0	0	0.0224	0.0492	0.137	0.0129	0.0109	0	0	0	0	0	0.0187 (0.00573)

All Fish Species Captured in all Sampling Gears

In 2006 field season, 548,811 fish from 65 different species were captured in the combined efforts of the DJFMP trawls and beach seines (Table 10). Of the 65 different species captured, 5 species comprised 85% of the total catch. Those five species were: splittail (n = 138,010 fish), carp (n = 109,990 fish), inland silverside (n = 100,602 fish), American shad (n = 70,203 fish) and Chinook salmon (n = 45,634 fish). Catch from Mossdale trawls comprised 45% of the total catch and the top five species captured at Mossdale were the same top five species in the overall catch.

Table 10. Total of all species captured from all trawl sites and seine regions.

	Trawl sites			Seine regions			
Fish	**Chipps Island**	**Mossdale**	**Sherwood Harbor**	**1**	**2-4**	**5**	**6**
American Shad	69622	13	301	12	235	0	20
Arrow Goby	0	0	0	0	0	0	5
Barred Surfperch	0	0	0	0	0	0	14
Bay Goby	0	0	0	0	0	0	4
Bay Pipefish	0	0	0	0	0	0	23
Bigscale Logperch	0	1	0	134	102	164	0
Black Bullhead	0	0	0	1	1	0	0
Black Crappie	13	159	3	28	23	17	0
Black Sea Jellyfish	20367	0	0	0	16	0	0
Bluegill	25	61	18	18	483	102	0
Brown Bullhead	0	1	0	0	0	0	0
Calico Surfperch	0	0	0	0	0	0	1
California Halibut	0	0	0	0	0	0	2
Channel Catfish	1	98	5	1	4	0	0
Chinook Salmon	23733	3701	5049	2580	10379	135	57
Common Carp	34	107882	18	102	1231	723	0
Delta Smelt	875	0	1	0	77	0	0
Dwarf Surfperch	0	0	0	0	0	0	22
English Sole	0	0	0	0	0	0	1
Fathead Minnow	1	2	3	1104	344	54	0
Golden Shiner	12	201	5	1798	1119	29	0
Goldfish	3	20	0	2	4	5	0

Table 10 cont.

	Trawl sites			Seine regions			
Fish	**Chipps Island**	**Mossdale**	**Sherwood Harbor**	**1**	**2-4**	**5**	**6**
Green Sturgeon	2	0	0	0	0	0	0
Green Sunfish	2	1	0	6	0	1	0
Hardhead	0	1	1	6	59	6	0
Hitch	0	0	0	30	81	9	0
Inland Silverside	5	587	79	6788	85626	7452	65
Lamprey Unknown	0	0	35	4	1	0	0
Largemouth Bass	10	170	2	200	495	129	0
Longfin Smelt	774	0	0	0	0	0	0
Northern Anchovy	16	0	0	0	0	0	11
Pacific Herring	228	0	0	0	0	0	1388
Pacific Lamprey	0	14	13	0	0	0	0
Pacific Staghorn Sculpin	1	0	0	0	0	0	78
Pleurobrachia bachei	25	0	0	0	0	0	4
Prickly Sculpin	1	1	0	12	83	14	0
Rainbow / Steelhead Trout	131	11	54	1	41	0	0
Rainwater Killifish	0	0	0	0	50	1	6
Red Shiner	0	32	0	336	7832	11907	0
Redear Sunfish	5	29	4	11	273	23	0
Redeye Bass	0	0	0	0	2	0	0
River Lamprey	8	309	26	0	0	0	0
Sacramento Blackfish	1	136	0	2	38	26	0
Sacramento Pikeminnow	17	22	37	663	1248	31	0

Table 10 cont.

	Trawl sites			Seine regions			
Fish	**Chipps Island**	**Mossdale**	**Sherwood Harbor**	**1**	**2-4**	**5**	**6**
Sacramento Sucker	0	117	1	836	2133	483	0
Shimofuri Goby	69	2	0	0	244	0	5
Shiner perch	0	0	0	0	0	0	30
Shokihaze Goby	24	0	0	0	0	0	0
Siberian Prawn	647	30	3	110	179	22	21
Smallmouth Bass	0	1	0	0	8	1	0
Splittail	520	127990	33	1430	6734	1298	5
Spotted Bass	0	3	0	0	26	10	0
Starry Flounder	10	0	0	0	0	0	3
Striped Bass	2428	19	3	3	49	2	3
Threadfin Shad	3052	1374	112	774	7550	720	12
Threespine Stickleback	11	0	0	0	13	0	119
Topsmelt	2	0	0	0	0	0	4749
Tule Perch	25	0	3	1	126	0	0
Wakasagi	2	0	104	345	192	0	0
Walleye Surfperch	0	0	0	0	0	0	19
Warmouth	5	0	2	1	0	0	0
Western Mosquitofish	0	0	4	769	656	455	1
White Catfish	13	169	6	143	2	4	0
White Crappie	0	112	1	149	12	2	0
Yellowfin Goby	21	0	0	1	195	0	15

Absolute Abundance Estimates

Methods

Absolute abundance estimates of juvenile salmon migrating downstream past Chipps Island have been calculated each year from 1980 to 2004, excluding 1987, using methods established by USFWS (1987). Abundance estimates are based on recovery rates calculated from Chipps Island MWTR and ocean-recovery estimates obtained from the Regional Mark Processing Center, (www.rmpc.org accessed on 6/15/2007), operated by the Pacific States Marine Fisheries Commission (PSMFC, 2006). Estimates of salmon abundance is limited to years prior to 2004 because ocean harvests are not 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 coded wire tag code such that recovered fish can be traced back to their original hatchery information and related release information.

Trawl recovery rate at Chipps Island were 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:

$$R_{control} = \frac{N_{control,\,recovered}}{N_{control,\,released}} \tag{3}$$

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:

$$R_{release} = \frac{N_{release,\,recovered}}{N_{release,\,released}} \tag{4}$$

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:

$$\hat{s}_{release} = \frac{R_{release}}{R_{control}} \tag{5}$$

This calculation assumes 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:

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

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

$$N_{\text{Chipps, available}} = N_{\text{Chipps, survived}} \times p_{time} \tag{7}$$

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

$$p_{time} = \frac{t_{sampled}}{t_{total}} \tag{8}$$

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:

$$TRR_{release} = \frac{N_{Chipps,\ recovered}}{N_{Chipps,\ available}} \tag{9}$$

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

$$\overline{TRR} = \sum_{i=1}^{n} TRR_{release} \tag{10}$$

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 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; therefore, values of $\overline{TRR}$ and absolute abundance have also changed.

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 are likely violated, they provide the best estimate currently available.

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 2004 field season was 0.0090 ± 0.0024 (Figure 25; Appendix 1,2). This average is above the average of the past 7 years (0.0055 ± 0.0014).

It is estimated that 202,655 winter-run, 9,522,581 spring/fall-run and 42,008 late fall-run juvenile salmon passed Chipps Island during the 2006 field season (Table 11). Abundance estimates of winter and spring/fall-run salmon were the second lowest in 10 years. Estimates of late fall-run salmon were the lowest on record since 1994. All fairly consistent with estimates from the previous years, winter-run salmon abundance estimate was highest in March, the spring/fall abundance estimate was highest in April and May, and the late fall abundance estimate was highest in November and December.

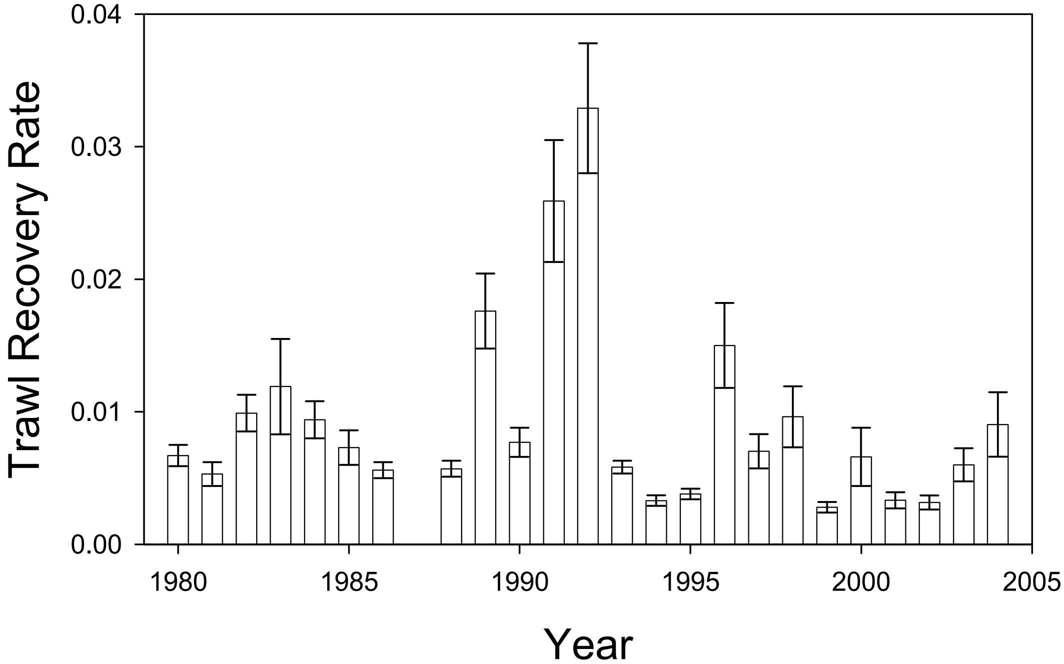

Figure 25. Trawl-recovery rates of mid-water trawls at Chipps Island between 1980 and 2004. No recovery rate was calculated for 1987 because no control release was conducted. Error bars are ± 1 SE.

Table 11. Abundance estimates of (a) Winter-, (b) Spring-/fall-, and (c) Late fall-run Chinook salmon passing Chipps Island by month and field season.

(a) Winter

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Aug	--	--	0	0	0	--	0	0	0	0	0
Sep	--	--	0	--	0	0	0	0	0	0	0
Oct	--	0	0	0	0	0	0	0	0	0	0
Nov	0	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	4,805
Jan	5,099	21,258	30,590	18,417	17,243	11,283	6,691	17,455	24,880	72,959	6,073
Feb	10,041	168,638	34,546	59,253	9,239	67,566	57,743	77,752	32,303	100,800	18,729
Mar	146,669	576,841	264,607	173,495	133,634	274,159	181,936	372,608	211,759	305,912	167,820
Apr	37,735	461,435	31,388	48,608	21,641	70,890	30,530	46,281	73,141	46,901	5,229
May	2,069	7,850	1,731	1,894	909	0	1,170	1,187	1,248	2,516	0
Jun	0	0	0	0	0	0	0	0	0	0	0
Jul	--	0	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	202,655

(b) Spring/fall

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Aug	--	--	17,714	25,336	94,177	--	0	31,459	35,316	0	11,717
Sep	--	--	19,193	14,303	--	60,919	14,856	80,975	6,285	7,310	4,138
Oct	--	68,116	69,925	2,120	0	101,831	153,931	71,384	8,213	0	0
Nov	58,898	46,742	8,571	0	6,510	0	8,438	26,358	0	1,899	0
Dec	2,627	0	14,917	1,045	9,235	0	0	0	0	0	0
Jan	0	971,492	47,496	256,178	51,902	35,460	1,338	0	0	0	0
Feb	5,021	554,730	1,651,909	321,045	3,591	698,186	83,150	3,702	0	0	2,341
Mar	25,288	1,386,535	761,714	1,422,956	65,061	531,184	671,476	81,002	50,154	522,358	333,774
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	4,932,810
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	3,826,409
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	373,846
Jul	--	491,946	0	--	69,960	61,450	83,106	126,772	199,770	42,779	37,546
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	9,522,581

(c) Late fall

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Aug	--	--	0	12,668	0	--	0	0	0	0	0
Sep	--	--	1,745	21,454	--	66,457	7,428	0	0	7,310	6,207
Oct	--	0	4,662	12,719	0	0	4,810	7,138	57,492	7,620	0
Nov	42,835	25,968	0	12,720	0	126,368	37,969	43,929	47,848	3,797	4,103
Dec	136,628	113,906	74,586	51,190	97,629	85,597	21,325	74,122	109,774	94,021	25,625
Jan	10,198	72,277	16,100	14,779	20,091	6,447	5,353	17,455	7,464	24,913	6,073
Feb	25,103	0	1,047	0	0	3,754	6,929	3,702	0	0	0
Mar	0	0	0	0	0	0	0	0	5,573	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0
May	0	1,963	577	0	0	0	0	0	0	0	0
Jun	7,941	0	0	0	0	0	0	0	0	0	0
Jul	--	0	0	--	0	30,725	0	7,457	7,135	0	0
Total	222,705	214,114	98,717	125,530	117,721	319,348	83,813	153,804	235,285	137,661	42,008

Although numerous sources of error exist in our abundance estimates, two sources are particularly influential. First, some fish releases yielded $\hat{s}_{release}$ ≥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 a 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 & 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.

In 2004, the abundance of juvenile salmon passing Chipps Island was at it lowest since 1978 (Figure 26). We provide a general index of the absolute production of Chinook salmon passing Chipps Island through time. Only April-June estimates were included because these are the only months in which we have sampled consistently since 1978.

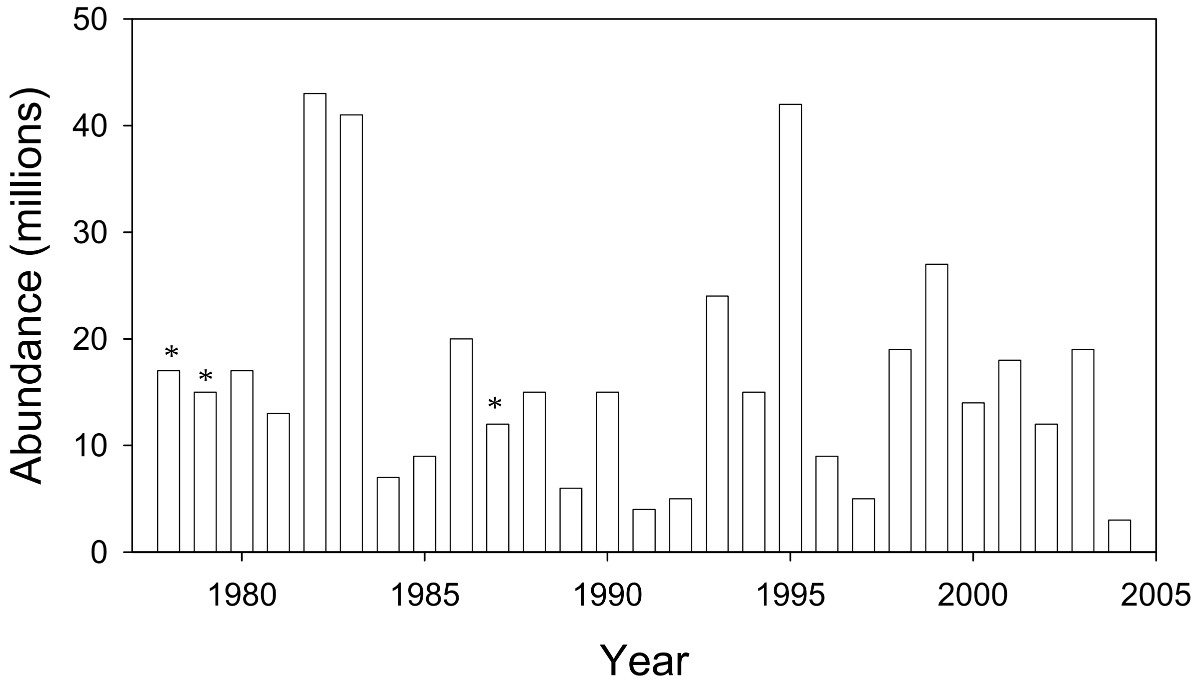

Figure 26. Absolute abundance estimates of all juvenile Chinook salmon between April 1 and June 30 from 1978-2004 using mean annual trawl-recovery rates from ocean recoveries. Asterisk indicates trawl-recovery rate was estimated using average mean annual trawl-recovery rate from 1980-2004 (excluding 1987).

Other Coded wire tag recoveries in sampling gears during the 2006 field season

Coded wire tagged Chinook salmon of all races are recovered in all sampling gears throughout the field season(Table 12).

Results

<u>Fall-run</u>
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 2006 field season, 852 CWT fall-run salmon were recovered. DJFMP trawls recovered 518 fish, 426 in Chipps Island trawls and 92 in Sherwood Harbor trawls. DJFMP beach seines recovered 196 CWT fall-run salmon (Table 12). The water facilities recovered 138 CWT salmon, 113 fish at CVP, and 25 fish at SWP. A map of these sites is available at (http://www.delta.dfg.ca.gov/data/ rtm2000/sample-sites.asp).

Late fall-run

In 2006, there were 388 CWT late fall-run salmon recovered. The majority late fall-run salmon recovered were captured at Chipps Island (263 fish), Sherwood Harbor trawls (27 fish), CVP (16 fish) and SWP (63 fish). As expected, the majority of CWT late fall-run salmon recoveries occurred in either trawls or salvage efforts and was largely from Battle Creek releases (Table 12).

Winter-run

Livingston Stone National Fish Hatchery (LSNFH) released 173,515 winter-run salmon in the upper Sacramento River at Caldwell Park on 2/2/06. Only 47 of these fish were recovered: 32 in DJFMP trawling efforts (Chipps Island: 24, Sherwood Harbor: 8), six in DJFMP beach seines (Colusa St. Park: 2, Isleton: 2, Verona: 1, and Wards Landing: 1), and three at the SWP and six at the CVP (Table 12).

Spring-run

In 2006, the Feather River hatchery released 1,892,334 CWT spring-run hatchery salmon and 6,318 wild spring-run salmon. We recovered 632 of t CWT spring-run salmon, 541 in Chipps Island trawls and 91 in Sherwood Harbor trawls (Table 12).

Table 12. Recoveries of coded wire tagged juvenile Chinook salmon during the 2006 field season. Blank cells indicate no fish were recovered.

Release Location	Recovery Location																													Total
	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	King's Island	Knights Landing	Koket	Medford Island	Miller Park	Mossdale	Rio Vista	Sherman Island	Sherwood Harbor	State Fish Facility	Steamboat Slough	Stump Beach	Terminous	Verona	Wards Landing	
(a) Fall																														
Clarksburg		8	4	18					1			1	5								6				2	11	2			58
Dos Reis			7				3																							10
Elkhorn		2	9	4		1				18		4									1	15			1	1				56
Hatfield Park			15					2			39													8						64
Isleton		6	3											3							17				3	7				39
Jersey Point			102																				1							103
Knights Ferry			3								32													6						41
Lighthouse		3	1															7									2			13
Merced River FF			7								13													2						22
Mokelumne River			4												4															
Mossdale			15								2									14				3						34
New Hope Landing			6																											6
Port Chicago			14																											14
Red Bluff Diversion Dam			8																			1	2							8
San Pablo Bay																														
Selby																														
Two rivers			4								10																			14
Vieira's		10	7																			2				6				25

Table 12 cont.

Release Location	Recovery Location																													Total
	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	King's Island	Knights Landing	Koket	Medford Island	Miller Park	Mossdale	Rio Vista	Sherman Island	Sherwood Harbor	State Fish Facility	Steamboat Slough	Stump Beach	Terminous	Verona	Wards Landing	
West Sacramento			199									12					1						74							286
Yolo Bypass			3																											3
Fall Total		25	386	13		1	3	2		18	96	108	2	3			1	7		14	19	5	77	19	3	20	3			25
(b) Late fall																														386
Battle Creek	3		202	1	5						12	3				1			1				27	36				1	1	293
Georgiana Slough	1		6								3													26						36
Port Chicago			2																											2
Ryde			23								1			1										1		1				27
Sherman Island			11																											11
Late fall Total	4		244	1	5						16	3		1		1			1				27	63		1		1	1	369
(c) Spring																														
Butte Creek			2																											2
Feather River			290																				46							336
San Pablo Bay			5																											5
San Pablo Bay & Feather River			246																				45							291
Spring Total			543																				91							
(d) Winter																														
Caldwell Park			24		2						6			2									8	3				1	1	47
Winter Total			24		2						6			2									8	3				1	1	

References

Brandes P.L. 2000. 1999 South Delta salmon smolt survival studies. USFWS. 32 pp.

Brandes P.L, K. Perry, E. Chappell, J. McLain, S. Greene, R. Sitts, D. McEwan, and M. Chotkowski, 2000. Interagency Ecological Program Delta Salmon Project Work Team Delta Juvenile Salmon Monitoring Program Review Stockton, CA. On web site: http://www.delta.dfg.ca.gov/jfmp/datareports.asp

Brandes P.L., and J.S. McLain. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. In: Brown RL, ed. Contributions to the Biology of Central Valley Salmonids. Fish Bulletin 179. (2): 39-136

Brandes, P., R. Burmester and J. Speegle. 2006. Estimating Relative Abundance and Survival of Juvenile Chinook Salmon in the Sacramento-San Joaquin Estuary. Interagency Ecological Program for the San Francisco Estuary, IEP Newsletter, Volume 19, Number 2, Spring 2006.

California Department of Water Resources. 2006. California Data Exchange Center (CDEC) web site. http://cdec.water.ca.gov

Greig, C., D.P. Jacobson, and M.A. Banks. 2003. New tetranucleotide microsatellites for fine-scale discrimination among endangered Chinook salmon (*Oncorhynchus tshawytscha*). Molecular Ecology Notes 3:376-379.

Hansen, L.J. 2004. Movement of Juvenile Chinook Salmon in the Vicinity of the Delta Cross Channel, Fall 2001: Coded Wire Tag Recovery Component. Final Technical Report to CalFed.

Hedgecock D., M.A. Banks, V.K. Rashbrook, C.A. Dean, and S.M. Blankenship. 2001. Applications of population genetics to conservation of Chinook salmon diversity in the Central Valley. In: Brown RL, editor. Fish Bulletin 179: Contributions to the biology of Central Valley salmonids. Sacramento (CA): California Department of Fish and Game.

Interagency Ecological Program. 2006. Dayflow web site. http://www.iep.ca.gov/dayflow

Moyle, PB. 2002. Inland fishes of California. Revised and expanded. University of California Press, Berkeley. 517 pp.

Newman, K. 2005. Remarks on Delta Action 8 Workshop of May 27, 2005. dated June 14, 2005. 17 pgs. Can be obtained from USFWS, 4001 N. Wilson Way, Stockton CA 95205

Newman, K. 2008. An evaluation of four Sacramento-San Joaquin River Delta juvenile salmon survival studies. March 31, 2008. The report can be found on the web at http://www.science.calwater.ca.gov/pdf/psp/PSP_2004_final/PSP_CalFed_FWS_salmon_studies_final_033108.pdf

National Oceanic and Atmospheric Administration (NOAA). 1998: Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-35, February, 1998. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service

Orsi, James J., editor. 1999. Report on the 1980-1995 fish, shrimp, and crab sampling in the San Francisco Estuary, California. Technical Report 63. Sacramento, California: The Interagency Ecological Program for the Sacramento-San Joaquin Estuary.

Pacific States Marine Fisheries Commission (PSMFC). 2006. Regional Mark Information System (RMIS) web site. http://www.rmis.org

Perry, R. 2005. Letter to Dr. Randall Brown from Russ Perry dated June 3, 2005. 6 pgs. Can be obtained from USFWS, 4001 N. Wilson Way, Stockton CA 95205

San Joaquin River Group Authority 2002. 2001 Annual Technical Report on the Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2002.

San Joaquin River Group Authority 2003. 2002 Annual Technical Report on the Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2003.

San Joaquin River Group Authority 2004. 2003 Annual Technical Report on the Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2004.

San Joaquin River Group Authority 2005. 2004 Annual Technical Report on the Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2005.

San Joaquin River Group Authority 2006. 2005 Annual Technical Report on the Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2006.

San Joaquin River Group Authority, 2007. 2007 Annual Technical Report on the Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2007.

Shaffter, R.G. 1980. Fish occurrence, size, and distribution in the Sacramento River near Hood, California during 1973-1974. Administrative Report No. 80-3. California Departments of Fish and Game.

United States Fish and Wildlife Service. 1987. Exhibit 31: The needs of Chinook salmon, *Oncorhynchus tshawytscha* in the Sacramento-San Joaquin Estuary.

United States Fish and Wildlife Service. 1993. 1992 Annual progress report. Abundance and survival of juvenile Chinook salmon in the Sacramento-San Joaquin Estuary.

United States Fish and Wildlife Service. 1995. 1994 Annual progress report. Abundance and survival of juvenile Chinook salmon in the Sacramento-San Joaquin Estuary.

U.S. Fish and Wildlife Service. 2006. 2001-2005 Annual progress report Abundance and survival of juvenile Chinook salmon in the Sacramento-San Joaquin Estuary.

Wickwire, R.H., and D.E. Stevens. 1966. Migration and distribution of young king salmon, *Oncorhynchus tshawytscha*, in the Sacramento River near Collinsville. Anadromous Fisheries Branch Administrative Report No. 71-4. California Department of Fish and Game.

Wilder, R.M., and J.F. Ingram.2006. Temporal patterns in catch rates of juvenile Chinook salmon and trawl net efficiencies in the lower Sacramento River. Interagency Ecological Program Newsletter. 19(1):18-28.

Wullschleger, J. 1994. Estimating winter run survival with late-fall run fish. Interagency Ecological Program Newsletter. 7(2):8-9.