**IEP Gear Efficiency Evaluations in Support of Modeling Efforts for Delta Smelt**

COOPERATIVE AGREEMENT
between the
U.S. FISH AND WILDLIFE SERVICE
and
State of California Department of Fish and Wildlife

FWS Agreement No.: F12AC00796

# Final Report

**Reporting period**: August 1, 2012 – July 31, 2015

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## Overview

This final report for the contract identified above and entitled IEP Gear Efficiency Evaluations in Support of Modeling Efforts for Delta Smelt (Gear Selectivity Evaluation Study) contains three sections: 1) Problems and Delays in meeting Agreement; 2) Disposition on Real and Personal Property; and 3) Accomplishments, Results and Products are detailed in a "Findings" section. Each section includes some information from the periods lacking quarterly reports: November 2014 through January 2015 and February 2015 through April 2015. Although we completely spent funding as of April 2015, we report results through the last field sampling date in July 2015 and include those data in final data sets.

The final contract award, $495,000, was sufficient to support a portion of the work originally proposed at roughly $1,626,000. Due to reductions in funding and Endangered Species Act take considerations (see Problems and Delays…) a decision was made to focus field efforts on two of the four life-stage periods (Table 1). Those periods included the transitions from larvae to juveniles and from juveniles to sub-adults. The main field effort consisted of multi-gear, replicate parallel tows to provide data to evaluate the relative efficiency of the gears employed

(Objectives 1 and 2). During most multi-gear field efforts, we affixed depth loggers to the trawls to track their behavior underwater (Objective 3). In addition, we collaborated on four field efforts using the Smelt Cam (Objective 2). In fall 2014, we conducted a series of field days targeting Delta Smelt with the Fall Midwater Trawl possessing a covered cod-end (Objective 1). In December 2014, we "shadowed" the Fall Midwater Trawl Survey with the Kodiak Trawl and conducted a full Kodiak Trawl Survey and included replicate tows at a couple stations to investigate false zeros (Objective 1).

During the study period, project staff periodically (approximately annually) transferred up-to-date and corrected sampling data-sets to Dr. Ken Newman and his staff (USFWS) so that they could make use of results prior to the conclusion of the sampling.

Table 1. Target delta smelt life stages and the gears, time period and sampling effort proposed to determine relative efficiencies of standard fish monitoring survey gears and lateral distribution.

| Life Stage(s) | Gears Deployed Simultaneously | Time Period for Field Work | Sampling Effort (days) |
|---|---|---|---|
| Juvenile to Sub-Adult | TNS, FMWT, , Bay Study OT, SKT[1], Chipps Island, Beach Seine[3] | August through October | Monthly field efforts involve 2 days (yr 1) with an option of up to 4 days total (yrs 2&3). |
| Pre-Spawning Adults | FMWT, SKT[2], Bay Study OT, Chipps Island, Beach Seine[3] | December through January | Same as above |
| Spawning Adults | FMWT, SKT[2], Bay Study OT, Chipps Island, Beach Seine[3] | March through April | Same as above |
| Larvae to Juveniles | SLS, 20mm, TNS, Chipps Island, Beach Seine[3] | April through June | Same as above |

[1] Spring Kodiak (DFG gear) operated by FWS staff, fish processed by DFG staff
[2] Spring Kodiak (DFG gear) operated and fish processed by DFG staff
[3] Beach seine used for objective 2, lateral distribution, only

An added benefit of this project resulted from our targeting and successfully collecting Delta Smelt that were then transferred to collaborators at UC Davis working on a Delta Smelt health project (collaboration with Dr. Swee Teh), and off shoot of the Fall Low Salinity Habitat investigation. The Gear Selectivity project facilitated Delta Smelt collection and preservation in liquid nitrogen that contributed to (and will contribute to) a broad suite of analyses on individual fish including: otolith growth and chemistry, genetics, diet, several measures of lipid content, liver histopathology, gill histopathology and parasites.

## Problems and Delays in meeting Agreement

Problems encountered fell into two broad categories, Endangered Species Act take limits and personnel and boat availability issues. Most personnel and boat availability issues posed temporary difficulties that tended to delay comparisons of specific gears rather than leading to missing a particular comparison.

**<u>Federal Salmonid and Sturgeon Take Authorization.</u>** The most important problem encountered was the lack of take for federally listed salmonids and green sturgeon that persisted throughout the project term. As mentioned in many quarterly reports, the NOAA process to obtain take for listed salmonids and green sturgeon began prior to the implementation of the

Gear Selectivity Evaluation Study, thus application paperwork was submitted without the Gear Selectivity Study description and take request. During the project period, NOAA was not accepting amendments to IEP take limits. Thus, we avoided targeting pre-spawning and spawning adults during December through April to avoid take of listed salmonids. In part, we did not implement comparisons including Bay Study Otter Trawl due to green sturgeon take concerns, but more so due to concerns about the effectiveness of this gear for Delta Smelt and applicability of these data for comparison when allocating limited boat and operator time.

In one instance, we made an informed decision to sample during winter and complete a data set. Specifically, we continued FMWT covered cod-end sampling one day each in December 2014 and January 2015 based on real-time juvenile salmonid migration data indicating few individuals of listed races were in the Delta. Previous sampling in August, September and October produced very good catches, but even in October Delta Smelt remained small and almost none were retained by the ½" stretch-mesh of the standard FMWT cod-end; we anticipated about 50% retention in October. Limited staffing precluded sampling in November; thus, either we needed to extend sampling into the winter or orphan the three previous FMWT CCE sampling days until complementary sampling of larger Delta Smelt could occur at some future date. We chose to extend sampling, and suffered no salmonid take.

**Federal Delta Smelt Take Authorization.** After completing state and federal processes to obtain Delta Smelt take, the IEP allocated an annual take limit of 1300 fish to the Gear Selectivity Study in 2013 (down from 1600 originally allocated in 2012). This limit, though generous, would not allow us to complete the full schedule of sampling proposed for each year, even if we had sufficient resources otherwise. A second challenging aspect surfaced when implementing gear comparisons focused on larvae and small juveniles and a third when implementing the SmeltCam. In both cases – larva sampling and SmeltCam -- personnel time to "process samples" and determine Delta Smelt take was not available in a timely manner. This lead to delays in take reporting of several months in each case and in the case of larvae processing, lead to a slight delay in sampling September 2013.

In 2013, we had early-season take concerns because we were not able to promptly process spring samples containing primarily larval smelt: our dedicated fish ID person was out on maternity leave late spring and early summer. Larval fish processing was not completed until early August. At that time we determined that spring field sampling only collected 165 Delta Smelt. Later in summer, sporadic extremely high Delta Smelt catches in SKT rapidly increased take. During and subsequent to days with individual tow catches of 100+ Delta Smelt, we cut SKT tow durations in half to 5-min and also cancelled 30 to 50% of the SKT tows planned for the day to limit take.

The other main issue regarding Delta Smelt take occurred in 2014 and concerned the amount of take to allocate to SmeltCam. Two factors related to SmeltCam affected field work planning: 1) high initial take requests (600 Delta Smelt); and 2) protracted delays between field sampling and image post-processing for identification to determine take. In April 2014 (late in the planning process), project PIs initiated discussions within IEP to obtain additional Delta Smelt take for SmeltCam subsequent to the development of a new 2014-2015 study plan for this component. For reasons discussed below, the SmeltCam request for take of 600 Delta Smelt in 2014 was initially believed to require cancellation of other planned fall fieldwork involving multi-gear parallel tows and FMWT covered cod-end. In August, PIs and the IEP MT agreed to the following process moving forward: 1. Manage take for SmeltCam as long as possible within the limit for the overall Gear Efficiency project; 2. Report back to the MT once 50% of the take has been used and at regular times thereafter; 3. Begin internal IEP discussion regarding means to complete work with minimal additional take and by reallocating take from other IEP projects.

Spring and summer (April through June) multi-gear sampling that focused on larval and juvenile Delta Smelt resulted in total cumulative take of 410 Delta Smelt and 19 Longfin Smelt. Both take numbers were well within assigned take limits. No other ESA species were collected.

As a result of only modest Delta Smelt take during spring sampling, plans for late-Summer through Fall sampling (August through October) started broadly focused, but because of limited personnel to lead multi-gear sampling crews (see Personnel Issues for summer and fall 2014), ended focused on covered cod-end work, which required only Baxter to lead. August 2014 field work, consisted of one day of multi-gear sampling using 20-mm, STN and SKT gear (insufficient vessels and crew to conduct FMWT) and one separate day of FMWT covered cod-end (CCE) work. SKT conducted 5-min tows only during August sampling and stopped after the 5$^{th}$ of 8 planned tows due to high Delta Smelt catches. Delta Smelt take was high in August (504 for both multi-gear and FMWT CCE), but diminished almost exponentially in subsequent months, such that it was not a strong consideration when planning October through December fieldwork.

**Vessel Issues**:

June 2013 Vessel break-downs restricted June sampling to a single day and use of only 20-mm and STN gears; SLS sampling had been planned for comparison prior to the breakdown.

August 19, 2014, R.V. Munson in the shop. Multi-gear sampling proceeded with the remaining two Region 3 tow-vessels and R.V. Triakis (borrowed from Marine Region) towing Summer Townet. Since we have regularly borrowed this vessel in the past several years for summer and fall sampling, its use was deemed appropriate.

**Personnel Issues:**

April – June 2013, our Larval Fish Identification lead-person, Michelle Avila was out on maternity leave. She returned in July 2013 and completed fish identification by August.

May-August 2014, our Fall Midwater Trawl lead-person, Dave Contreras, transferred and his positon remained vacant until September when Julio Adib-Samii transferred into it.

May-August 2014, FMWT and STN lead-person back up, Steve Slater worked part-time and was otherwise on paternity leave and not available for the field until his return to full-time work in September.

July 2014, Project Lead Randy Baxter two-week vacation and high priority assignment and other staffing issues precluded fieldwork for the month.

August 2014, USFWS personnel were not available for beach seine or Chipps Island Trawl sampling due to a combination of planned and un-planned time off.

September - December 2014, Spring Kodiak Trawl lead person, Julio Adib-Samii transferred to the FMWT lead position and the SKT position remained vacant through the calendar year.

September 2014 – March 2015, Summer Townet lead person, Katie Osborn separated from State service to return to school. This position remained vacant until March 2015.

October 2014 through June 2015, FMWT lead person Julio Adib-Samii was no longer available for fieldwork. FMWT lead position was subsequently vacated and remained vacant until June 2015.

## Disposition on Real and Personal Property

Property acquired using contract funding.

1. May 2013 Dentonis -- $2,335.26 fabrication of sled skis used for 20-mm Survey and Summer Townet Survey net frames.
2. July 2013, $153.00 for calibration standards for Hach turbidity meters.
3. August 2013, $1,500, ½" stretched-mesh for Townet and Fall Midwater Trawls
4. September 2013, $113, Rite in Rain paper for data sheets. Used.
5. February 2014?, $2,180 subscription Canadian Journal of Fisheries and Aquatic Sciences
5. Vessel maintenance and repairs amounting to low thousands of dollars were not itemized when this section was written.

## Findings

### *Objective 1: Gear Selectivity Evaluation (GSE)*

Introduction

The development of a state-space life history model for Delta Smelt (Newman et al., in progress), which works to integrate data from all fish-monitoring surveys targeting Delta Smelt, required estimates of the relative catch efficiency of the various gear-types. This study, the Gear Selectivity Evaluation Study, investigated relative catch efficiency by conducting repeated, simultaneous, parallel tows involving two to four different gear-types per field day from fall 2012 through winter and spring 2015 study period. We investigated relative gear selectivity across three Delta Smelt life-stages and two transitions, larvae to juvenile in spring and summer, and juvenile to sub-adult in summer and fall. Gear types currently employed by IEP fish monitoring programs were included in these multi-gear sampling comparisons when appropriate to: 1) document their relative efficiency as Delta Smelt grew through a life-stage  or transition; 2) to document their selectivity during their primary period of use; and 3) to document their relative selectivity in comparison to other gears used for sampling adjacent temporal periods.  All selectivity comparisons were relative and based on the gears employed during each field sampling event.  Repeating the process through time and across years captured changes and strengthened relationships.  This report emphasizes documenting the preparation for and process of field sampling to support proper use of the data collected.  Additional documents are cited and attached that present results in more detail than will be presented in this document.

In summer and fall of 2014, we initiated additional gear evaluations, in part, because we had insufficient field-lead staff to conduct simultaneous multi-gear trawling.  The alternative evaluations each developed important information for modeling and understanding the limitations of current monitoring gears.  Three separate evaluations were conducted: 1) Fall Midwater Trawl Covered Codend (FMWT CCE) investigated "contact selectivity", the size of complete retention of Delta Smelt by the FMWT, and secondarily contrasted based on catch density the standard oblique tows with two-boat surface tows using the same net; 2) Shadow-trawling, in which a Kodiak trawl crew "shadowed" the Fall Midwater Trawl Survey in regions inhabited by Delta Smelt and conducted parallel tows; and 3) a full December Spring Kodiak Trawl survey in which multiple tows were conducted at a couple selected locations to begin to address the "false-zero" question (i.e., whether for SKT, zero catches are indicative of no fish or very low densities).  Of these investigations, only FMWT CCE has resulted in much follow-up analyses. Results are limited for the Shadow Trawling and multiple SKT tow evaluations. Datasets for these field efforts are provided (see Products at end of this Object section).

## Methods

### *Multi-Gear Sampling*

Fieldwork employed fish-monitoring gear used to collect the life stage(s) present in a given season. In spring and early summer, we investigated selectivity during the larval and early juvenile stages using all or a subset of Smelt Larva Survey (SLS), 20-mm Survey and Summer Townet Survey (STN) gear (GSE Table 1).  Only once, on May 22, 2014, were we able to coordinate Beach Seining with our trawl sampling.  In summer and fall, we dropped SLS and 20-mm gear types and focused on STN, Fall Midwater Trawl (FMWT), Chipps Island Midwater Trawl (CMWT) and the Spring Kodiak Trawl (SKT) (GSE Table 1).  Occasionally we overlapped other gear types. For example in August 2014 and July 2015, we used 20-mm, STN and SKT gears.  For each field-sampling event, field lead persons and crews were selected from experienced staff who actually conducting each monitoring project. For SLS, 20-mm, STN and FMWT all tows were standard oblique or stepped-oblique and 10 min in duration.  CMWT was towed near surface, per its protocol, and SKT was towed between two boats on the surface.  We planned for 10 min tows for both CMWT and SKT; however, SKT frequently caught high numbers of Delta Smelt, so its tow duration was often reduced to 5 min, and on several occasions high Delta Smelt catches caused us to terminate SKT sampling prior to completing the number of tows planned for the day.

Prior to field work, we used recent trawl survey Delta Smelt catches and knowledge of its behavior and habitat to select general regions for sampling. After selecting a region to sample, field dates were selected by reviewing predicted tide stages so that trawling commenced during a morning flood tide, if possible, and continued through some portion of the ebb later in the day. We used Google Earth to identify, gain GPS coordinates and plot trawl lanes. We located and plotted either 3 or 4 lanes for smaller channels in the San Joaquin River at Jersey Point or in the Sacramento Deepwater Ship Channel and 4 lanes for the large Sacramento River channel adjacent to Sherman Island. Typically, outside lanes were located relatively near shore over or near shoal areas, whereas one or two lanes were located over deep water on either side (if four lanes selected) or approximately on the center of the channel (three lanes). Starting locations remained fixed for each sampling date, but varied across dates, moving upstream or downstream with changing location of salinity and turbidity habitat. At the start of the sampling, lanes were randomly assigned for each crew/gear-type. Crews then conducted one or more tows in each lane (multiple tows in a lane, identified as replicates, were used to increase sample volume) then moved to the next lane in sequence until the entire circuit of three or four lanes was completed. At this point crews were randomly re-assigned to lanes and the process repeated itself. Generally, crews conducted one tow per lane prior to moving to the next lane; however, in some cases when small dimension gears (20-mm, STN) were being towed alongside large dimension gears (FWMT, CMWT or SKT), two or three tows per lane were conducted by small dimension gear crews to increase volume sampled and increase the likelihood of Delta Smelt capture.

Prior to deploying sampling gear, numerous data were recorded and environmental measurements taken (GSE Table 2). Water temperature (°C) and specific conductance (micro Siemens per cm) were measured with a YSI 30; turbidity (NTUs) with a Hach 2100P turbidity meter. All three measures were taken from a single-bucket, surface "grab" sample before each tow; water temperature and specific conductance only were also measured from bottom-water samples collected with a Van Dorn water sampler. For surface oriented gears, SKT and CMWT, only surface measurements of specific conductance and water temperature were taken. For other gear types both surface and bottom specific conductance and water temperature were taken. Once environmental measurements were completed and recorded, gear was deployed on roughly a 5:1 scope or 5 feet of cable beyond the blocks for every foot of bottom depth; for the FMWT cable out did not count the 100 foot bridles connecting to top and bottom doors on port and starboard sides, respectively. Once full cable out (and depth) was achieved by the gear, start time was recorded a timer set, the flow meter deployed, GPS set (and later recorded) and for obliquely towed gear, retrieval started. For surface towed SKT, start time commenced when the two boats separated and the net opened. Crews retrieved obliquely towed gear throughout the 10 min tow duration. At the end of 10 min, obliquely towed gear was at the stern and hoisted into the boat; CMWT retrieved gear rapidly and brought it onboard immediately; SKT net and chase boats maneuvered together, ending the tow. Once together, the chase-boat net-line was handed to the net boat crew and the gear brought on board. At the end of each tow, end time and GPS coordinates were recorded and the flow meter retrieved, read and recorded.

GSE Table 1. Maximum mouth, estimated “fishing” mouth area and mesh descriptions of net types used in multi-gear, side-by-side selectivity comparisons of larval and small juvenile fishes (Smelt Larva Survey [SLS], 20-mm Survey [20-mm] and Summer Townet [STN]) and of sub-adult fishes (STN, Fall Midwater Trawl [FMWT], Chipps Midwater Trawl [CMWT], and Spring Kodiak Trawl [SKT]) from fall 2012 through summer 2015. Mouth Areas used in analyses are bolded and underlined.

| Gear | Maximum Mouth Area | Fishing Mouth Area | Mesh Size and Composition |
|---|---|---|---|
| SLS | 0.37 $m^2$ * | <u>**0.37**</u> $m^2$ * | 500 micron Nitex mesh throughout |
| 20-mm | 1.51 $m^2$ * | <u>**1.51**</u> $m^2$ * | 1,600 micron Nitex mesh throughout |
| STN | 1.51 $m^2$ * | <u>**1.51**</u> $m^2$ * | 2,500 micron woven mesh rear portion(2.5 mm); 1.3 cm knotted stretched-mesh front portion |
| FMWT | 13.4 $m^2$ ** | <u>**10.7**</u> $m^2$ +++<br>10.1 $m^2$ *** | Knotted mesh graduates in eight panels from 20.3 cm stretch mesh at mouth down to 1.3 cm stretched-mesh at the cod-end |
| CMWT | 28.71 $m^2$ ** | <u>**18.58**</u> $m^2$ ++++ | Knotted mesh graduates in seven panels from 10.2 cm stretched-mesh at the mouth down to 0.7 cm woven mesh at the cod-end |
| SKT | <u>**13.95**</u> $m^2$ ** | 12.5 $m^2$ **** | Knotted mesh graduates in five panels from 5.1 cm stretched-mesh at the mouth down to 0.7 cm woven mesh at the cod-end |

* Mouth area fixed in size by metal frame. Values listed for 20-mm and STN are based on outer edge measurements of the net frames; inner edge measurements are often listed as 1.49 $m^2$.

** Mouth area variable in size and maintained by planing doors while deployed; size listed is based on the maximum dimensions when held open on land.

+++ Mouth area assumed by Bay Study based on undefined literature.

*** Mouth area measured with acoustical technology, FMWT August 2009.

++++ Mouth area used by USFWS for CMWT

**** Mouth area estimated from on-the-water measurements of mouth width, USFWS 1998.

GSE Table 2. Information collected prior to each tow by the Gear Selectivity Evaluation Study, 2012 through 2015.

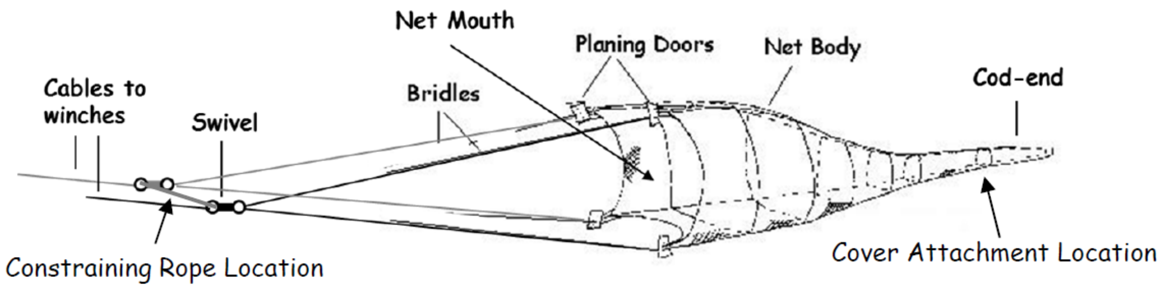
| Database Field Names | Content descriptions |
|---|---|
| SampleDate | Calendar date of sample collection in mm/dd/yy format |
| GearType | Abbreviation for sampling gear: SLS= Smelt Larva Survey gear; 20-mm = 20-mm Survey gear; STN = Sum Townet; FMWT = Fall Midwater Trawl; CMWT = Chipps Island Midwater Trawl; SKT = Spring Kodiak Traw |
| Meter No. | Serial number of the General Oceanics flow meter being used |
| Vessel(s) | Name(s) of the vessel(s) being used to deploy gear |
| Crew | Full names on first sheet, than initials of individuals making up the crew. |
| Station | Represents the trawl lane occupied during a tow (letters represent channel orientation; lane number increa from 1 north to south or west to east depending on channel orientation. |
| Tow | Ascends from 1 on each sampling date; numbers increment each time a new sampling lane is occupied |
| Replicate | Ascends from 1 in each sampling lane and represents the number of times net was deployed in the lane |
| Cable Out | Amount of cable outside the blocks and necessary to get the gear to the target depth |
| Start Time | For each tow, time (24:00 clock) at which gear was deployed to the desired depth (cable out) or fully opene towing began |
| End Time | For each tow, time (24:00 clock) at which gear closed (SKT -when boats came together) or was retrieved t stern of the boat, and towing ended. |
| Depth | Water depth (ft) at the sampling location taken using the boat's depth finder. |
| Top EC | Specific conductance (electrical conductivity at 25°C) taken of a surface water sample |
| Bot EC | Specific conductance (electrical conductivity at 25°C) taken of a bottom water sample collected with a Van water sampler |
| Top Temp | Temperature in degrees centigrated taken from a surface water sample |
| Bot Temp | Temperature in degrees centigrated taken from a bottom water sample collected with a Van Dorn water sampl |
| TideCode | Numerical code: 1= high slack (no current apparent on fixed object0; 2 = ebb; 3 = low slack; 4 = flood |
| Tow Direction | Numerical code: 1= with the prevailing current; 2 = against current; 3 = neither, typically denotes slack tide |
| Turbidity | Measured in NTUs from a surface water sample; bottom water samples always stirred sediments biasing mea |
| Secchi | Depth at Secchi disk disappearance to nearest cm, taken on shady side of boat. |
| Meter Start | Numbers showing on the General Oceanics flow meter prior to deploying at the tow start time (see start time a |
| Meter End | Numbers showing on the General Oceanics flow meter upon retrieval at the tow end time (see end time above |
| Microcystis | Rank values based on observations and a chart: 1 = absent, 2= low, 3 = medium, 4 = high, 5 = very high |
| Weather | Represents percentage of cloud cover: 1= 0 - 33%. 2 = 33-66%, 3 = 66-99%, 4 = rain |
| Waves | Ranking: 1= calm; 2 = waves withou white caps; 3 = white caps |
| Wind Direction | From: N, NE, E, SE, S, SW, W, NW, or NA for none |
| Start Latitude | Latitude at start of tow (datum for all is WGS 1984) |
| Start Longitude | Longitude at start of tow |
| End Latitude | Latitude at end of tov |
| End Longitude | Longitude at end of tow |
| Species | Numerical designation of organism based on system used by FMWT and SKT in conjunction with various contractions of the common name; "no catch" inserted for organism code for deployments with no catch, z entered for catch and zero entered for one length record to ensure records of effort are complete when sel for all lengths in creating files for analyses. |
| Catch | Total count individuals of a single species caught in a single net deployment |
| ForkLength | Fish length (mm) measured from tip of snout to fork of tail or the farthest edge along the center line of tail f with rounded tails; invertebrates not measured; in deployment records with "no catch" or no fish measuren zero was inserted for length in 1 record to ensure that a record was retained when the length table was use create the flat file for analysis |

Once on board, SLS and 20-mm nets were washed from the outside directing any organisms into a collection jar at the cod-end. Identifiable juvenile fish (typically >25 mm) were removed from the collection jar, measured and released. All other material in the collection jar along with rinse water was transferred to a sample jar, which when filled created a 10 percent solution of formalin; rose bengl dye was added to help distinguish otherwise transparent larvae. Sample jars were then labeled with date, gear type, tow, replicate and then staged to be returned to the lab for identification. For all gear types, all juvenile and older fish that were possible to identify in the field were enumerated, measured to the nearest mm fork-length and released. In several instances of extremely high catches of Threadfin Shad, after recording hundreds of measurements, we plus counted remaining individuals to save time. All species except Delta Smelt were released after processing. For Delta Smelt, after measurement almost all were assigned a unique serial number and individually wrapped in aluminum foil and then preserved in liquid nitrogen. These fish were returned to UC Davis for processing as part of of a FLaSH fish health, growth and diet study. In a few cases, where >100 Delta Smelt were captured in one tow, some fish were measured and released, and some preserved in ethanol for otolith and genetic analyses. In the lab, all smelts were identified and re-measured to nearest mm fork length (or to the mid-point of the distal edge of the caudal fin) to assess shrinkage and measurement error on the boats.

*Covered-Codend and Contrast between One-Boat Oblique and Two-Boat Surface Towed Fall Midwater Trawl*

Cod-end cover design and construction. This effort used a standard FMWT net to which a cover of much smaller-pored woven mesh was affixed over the standard cod-end mesh to retain fish that passed through the standard 1.3 cm (½ in) stretch mesh (SM) cod-end material (GSE Figure 1). The FMWT cod-end is composed of 1.3 cm SM, 200 meshes in circumference and 220 meshes longitudinally. A cover should not physically impede fish movement through the 1.3 mm SM, nor should it create backpressure, which might allow fish to swim above the cod-end mesh and pass through a larger mesh. Using equations from Fridman (1986), the open area of the 1.3 cm mesh on a standard FMWT was conservatively estimated at 2,126,085 $mm^2$. Doubling this open area for the cod-end cover will allow unimpeded flow passage. The cod-end cover was composed of the cod-end mesh material from Summer Townet (GSE Table 1). This material possesses about 4.9 $mm^2$ of pore area per mesh and 62.5 pores per $in^2$. To double the pore area of the 1.3 mm stretch mesh required **13,885 $in^2$** of STN cod-end material. To allow unimpeded passage into the covered cod-end, additional circumference was required beyond that of the 1.3 mm SM. The maximum circumference of the 1.3 mm SM cod-end is 100 inches. Adding a couple inches to the radius of a circle of circumference 100 inches produces a circumference of 113 inches. Using the 113 inch dimension (material width) and dividing it into the total area of material required produces a needed length of 123 inches. The cover material was affixed to the FMWT net at the mesh seam between the 2.54 and 1.3 cm SM panels and oriented to cover the 1.3 cm SM cod-end. As the cover material was sewn on, small pleats were incorporated to create the extra circumference, so the cover material would not press-up against the cod-end material when fishing. The cover material lateral edges were sewn together forming a longitudinal seam and a cord was sewn outside and about 20 cm from the distal edge to tie-closed the cover. The cod-end cover added a considerable amount of material to the end of the

FMWT and functioned like lengthening the tail of a kite: it likely impeded net movements somewhat, causing the net to drop more slowly during deployment and perhaps creating a little more drag, limiting movement during towing. No means was devised to attempt to quantify any difference in FMWT fishing behavior with the cod-end cover affixed.




GSE Figure 1. Schematic of the Fall Midwater Trawl and associated gear used in its deploy.

<u>Preparation for Two-Boat Surface Towing.</u> The FMWT was designed to be deployed from a single vessel, so unlike the SKT, the FMWT was not constructed to limit lateral spread and maintain vertical height and mouth-shape when tow boats spread out and towed at an angle slightly away for the direction of net travel. For this reason, if we deployed the FMWT between two boats without additional modification of gear, the lateral pull of the boats would periodically collapse the net vertically. During standard oblique tows, the shape of the FMWT is maintained in part by the cables it is deployed on having a fixed separation distance (i.e., block-width, which is the distance between the blocks/pulleys that guide the cable off the stern of the boat) that is about the same as the width of the net when towing (ca. 3 m ±). For two-boat sampling, we used the block width distance on the Scrutiny (3.2 m) to establish the length of a constraining rope that crew affixed between the FMWT bridles just as they exited the blocks during deployment (GSE Figure 1). This constraining rope maintained a “normal” bridle width and thus the proper net shape during two boat towing.

Surface tows with the FMWT were achieved by deploying the gear so that the 100 ft bridles begin just past the blocks. The bridles are composed of two 100 ft Kevlar ropes, each with one end connected to a planing door (connected to each corner of the net), and top and bottom cables on each side of the net connected together at a swivel and the swivels connected to starboard and port main cables that run of hydraulic winches (GSE Figure 1). We needed to maintain the full 100 ft length of the bridles and constrain their separation so the FMWT would maintain normal shape and mouth area in the water. To accomplish this and allow the boats to separate during towing, we added 75 ft lines with quick-release carabiners on either and attached them between the main lines and the bridles. Thus, during deployment, the crew tossed the net off the stern. Cable was released from winches until the bridles passed the blocks. Here the winches were stopped and the constraining rope connected between the swivels of the starboard and port bridles, and then the cable let out again until the carabiners connecting the 75 ft lines to the main line were 3-5 ft outside the blocks. Once the carabiners were outside the blocks, the chase boat moved alongside starboard and the net-boat reduced forward momentum, reducing tension on the lines and allowing both 75ft lines to be disconnected from the main lines. The starboard line was handed-off to the chase boat and the port line connected to a towing point mid-deck on the net boat for towing. Once lines to both boats were connected to tow points, they throttled-up slightly and began separating; this initiated the tow (i.e., time recorded, timer started, GPS, flow meter deploy). The chase and net boats maintained a course at slight angle away from one another during towing. After 10 min, the boats moved alongside one-another, the starboard line was transferred back to the net boat, it and the port line were re-attached to their respective main cables and the main cables and lines winched back. Once the net reached the stern, crew pulled onto the boat.

Fish processing commenced by untying and emptying the contents of the cover into one tub partially filled with water and then untying the cod-end and emptying it into a separate tub. Starting with fish from the cover, we identified, enumerated and measured all to the nearest mm fork length, identified and enumerated macro-invertebrates and recorded these data under the heading “outside ½” mesh” on data sheets. For the cod-end, we identified and enumerated all species and typically measured several hundred of each fish species but in some cases catches were prohibitively high to measure all. Data from the cod-end were recorded under the heading “inside ½” mesh” on data sheets.

During sampling in November 2014, we measured boat separation distance during two-boat towing using a Bushnell Scout 1000 laser range finder (5-1000 m range; ± 1 m accuracy). To measure, the range finder was held about three feet directly above the hull midway between stem and stern of the net boat and targeted the hull of the chase boat at the same relative location. Measurements were made at about 1 min intervals through several minutes during each of the tows.

Field Sampling Design. Sampling design varied through successive field days as Delta Smelt densities diminished, but the primary goal was to catch sufficient numbers and sizes to develop a contact selectivity curve for the FMWT (see Millar and Fryer 1999). Secondarily, we had keen interest in investigating Delta Smelt depth distribution by contrasting differences in surface and oblique tow densities based on paired oblique and surface tows. Initially on August 21, paired oblique and surface tows used the same lane locations and sampling design as the multi-gear field effort two days prior: four lanes in the lower Sacramento River near FMWT survey station 706 and four in the SDWSC near station 797. We intended the August 21 FMWT standard-mesh catches to be roughly comparable to the other multi-gear sampling on August 19, when the FMWT was not able to participate. On August 21, one partial circuit (i.e., 3 of 4 lanes occupied) of randomly-ordered, paired tows was completed in the lower Sacramento River and another was started in the Sacramento Deepwater Ship Channel (SDWSC), but high catches through the day, and again in the SDWSC resulted in only a single oblique and surface tow pair being completed in the SDWSC. On September 25, one partial circuit ( 3 of 4 lanes occupied) of randomly-ordered, paired tows was completed in the lower Sacramento River and another in the Sacramento Deepwater Ship Channel (SDWSC). On October 21, we began paired oblique and surface tow sampling in the lower Sacramento River in a pre-established lane on the north side of the channel, but after completing two sets of paired oblique and surface tows, we moved the next sets of paired tows downstream attempting to locate higher turbidities and Delta Smelt. We completed one set of paired tows downstream and completed the oblique tow of the second, but after two failed tows, we skipped the final surface tow and moved to the SDWSC to station 797 and conducted three sets of paired tows moving successively south attempting to catch Delta Smelt. On December 2, 2014 and January 27, 2015, we only conducted surface tows because of very low Delta Smelt densities and the need to collect sufficient numbers of Delta Smelt > 55 mm to complete the upper limb of the retention curve. In December, we made six tows in the lower Sacramento River below and above light 17 and after only low Delta Smelt catches we traveled up into the SDWSC to conduct two more tows. High catches of shads limited the number of tows we were able to complete in the SDWSC. In January, as a result of low catches, we made 20 tows in the lower Sacramento River between Sherman Lake and Decker Island. Most tows occurred on the northwest side of the channel. Roughly mid-day, regular, small catches of Delta Smelt of sufficient size to be retained in the 1.3 cm mesh encouraged us to remain in the lower Sacramento River rather than expend the time needed to reach the SDWSC. No additional sampling was planned because we collected Delta Smelt surpassing the size of full retention and risk increased of "taking" a winter-run or spring-run Chinook.

*Spring Kodiak Trawl Shadowing Fall Midwater Trawl, and Replicate Spring Kodiak Trawling*

Two additional investigations were conducted in December 2014 and were not repeated for this project. The first investigation involved the SKT "shadowing" the FMWT during that portion of the December FMWT survey likely to catch Delta Smelt. Sampling dates occurred December 8$^{th}$ through the 10$^{th}$. SKT gear was deployed at 41 FMWT stations either in parallel with FMWT deployment, if channel width allowed, or some distance in arrears when trawl space was narrow. Both crews used their respective protocols: 12 min oblique tow for FMWT and 10 min two-boat surface tow for SKT. Both gear types occupied FMWT station locations, so FMWT station designations were used for SKT data which is identified as "Survey 22" in the summary spread sheet, part of this package (SKT_FMWTShadow_Replicate_2014.xlsx) and in the SKT database (not provided, but available on the DFW FTP site). The intent of this sampling was to compare the performance of both gear typed for catching Delta Smelt across a broad range of environmental conditions.

The second investigation involved replicate SKT tows at two select locations chosen for their low Delta Smelt density. These replicate tows were added to a full SKT survey conducted in December 2014. We implemented this work to investigate "false zeros". Prior to sampling, biologists conferred to identify a couple locations where multiple tows might produce some detections. We also considered how many additional tows could be completed in a sampling day without extending it overlong (>8 hrs on the water) or into a second day. We limited additional tows to two a day, which added 40-60 min depending on fish numbers caught. We selected stations 711 and 809 for multiple tows for their low smelt densities and, since each is sampled on a different field day, the additional two tows could be accomplished without extending either day too long.

*Data Management*

Data sheets for all evaluations were reviewed by field leads after each tow to ensure all data were recorded; any missing data were identified so the oversight was not repeated. Once back in the office, we reviewed data sheets for clarity and checked questionable entries with the person who recorded the data. Subsequently, correct clear entries were made on the data sheet margin, adjacent to the questioned entry. Once laboratory identification of larval, small juvenile and fish un-identifiable in the field was completed and data recorded on the data sheets, we scanned datasheets to PDF and filed them for database entry.

All data were key entered into a Microsoft Access relational database. Separate databases were used for multi-gear and covered cod-end data sets because of a need for different table structure for the latter. Data derived from SKT shadow trawling and replicate tows were entered into the CDFW SKT Access database. Shadow trawling was entered as Survey 22 for 2014 and the station numbers entered reference FMWT station locations (not SKT stations). The replicate tows were conducted as part of a December SKT full survey and labeled at Survey 12 for 2014. We produced Excel datasets containing sampling date, survey, station, start time, volume filtered, conductivity, temperature, turbidity, Secchi, bottom depth and catches of all species (SKT_FMWTShadow_Replicate_2014.xlsx, attached).

*Data Analysis*

<u>Calculating contact selectivity</u>. Current estimates based on multi-gear sampling do not include 2014 sampling data, and thus will be improved in the future. Gear specific contact selectivity functions were estimated using data from several side-by-side gear evaluation studies carried out during 2012 and 2013 by California Department of Fish and Wildlife and the US Fish and Wildlife Service. The estimated procedures are described elsewhere (Mitchell, et al. in prep), but the essential ideas follow. The side-by-side evaluations took place on seven dates, which included sampling of larvae, post-larvae, and juvenile fish (during the months of April, May, and June) as well as samples of older juveniles and “sub-adults", during September, October, and November. Gear types used for the younger fish included the SLS, 20mm and STN surveys' gear, and for the older fish included the STN, FMWT, CMWT, and SKT gear. Multiple tows with each gear type were made with the gear being simultaneously deployed in parallel and adjacent lanes along a section of the lower Sacramento River (or in the lower San Joaquin River or Sacramento Deepwater Ship Channel).

For analysis purposes, a logistic contact selectivity curve (Millar and Fryer, 1999) was assumed for each gear type, *g*,:

$$r_g(l) \quad = \quad \frac{\exp(\zeta_{0,g} + \zeta_{1,g} l)}{1 + \exp(\zeta_{0,g} + \zeta_{1,g} l)},$$

and the number of fish caught on date *d* by gear *g*, during tow *w*, and belonging to length class $l_i$, was assumed to follow a Poisson distribution:

$$y_{d,g,w,l_i} \sim \text{Poisson}\Big(\delta_{d,g}\, v_{d,g,w}\, P_d\,(l_i)\;\, r_g\,(l)\Big).$$

Here, $\delta_{d,g}$ represents the density of fish encountered by gear *g* on date *d* (explained below), and $v_{d,g,w}$ is the volume of tow *w* by gear g on date *d*. $P_d$ ($l_i$) is the probability, given that a fish was present, that it would have a length falling into length class $l_i$ on date *d*, and was found by integrating $f_{t=d}(l)$ between the lower and upper bounds of length class *i*, where the widths of all classes were set at 5mm.

Fish density, $\delta_d(z)$, was assumed to vary linearly with depth, *z*. Surface density, $\alpha_d$, was assumed constant for a given date, *d*, and the density below four meters was always assumed zero;

$$\delta_d(z) = \begin{cases} \alpha_d\left(1 - \frac{z}{4}\right) & : z \leq 4 \\ 0 & : z > 4 \end{cases}$$

In equation above, $\delta_{d,g}$ was taken to be the average value of the function $\delta_d(z)$ between the surface (z = 0) and the maximum deployment depth for gear *g* ($z = z_g$). In the analysis presented here, the maximum deployment depth $z_g$ was taken to be 2 meters for SKT and 10 meters for the remaining gears (supported assumption, see Objective 3 Results).

The contact selectivity model was fit using data from six sampling dates: September 27, 2012, October 15, 2012, April 18, 2013, June 13, 2013, September 26, 2013, and November 21, 2013. Maximum likelihood estimates of the contact selectivity coefficients, $\zeta_{0,g}$ and $\zeta_{1,g}$, were obtained for CMWT, SKT, STN, and 20mm. In the case of FMWT these values were fixed based on a previous covered cod-end analysis (Newman 2008). GSE Table 3 gives a summary of the resulting coefficient estimates by gear-type. Estimates of _d for the six sampling dates were also obtained during model-fitting. We note that because the goal of this analysis was to obtain estimates of the contact selectivity coefficients, the _d's were considered nuisance parameters. We also note that the estimates of the contact selectivity parameters were quite sensitive to choice of maximum depth for Delta Smelt, here assumed to be 4m.

GSE Table 3. Estimated contact selectivity coefficients for different gear types. The FMWT results are from analysis of a covered cod-end study (Newman 2008). The Bay MWT coefficients were set equal to the FMWT values.

| Gear | $\hat{\zeta}_0$ | $\hat{\zeta}_1$ |
|---|---|---|
| Chipps MWT | -14.450 | 0.2012 |
| FMWT | -3.89 | 0.0585 |
| SKT | -9.713 | 0.2496 |
| STN | -7.175 | 0.1126 |
| Twentymm | -10.677 | 0.6925 |

Using the FMWT CCE data, we fit three competing contact selectivity models and compared them using AIC techniques. See Mitchell et alDraftFMWTCCE_article_v64-kbn_rdb.pdf (included in package) for detailed methods and results.

## Results and Discussion

### *Multi-Gear Sampling*

We compared six trawl types completing almost 500 successful tows (GSE Table 4). This included two annual series of sampling efforts using gear targeting larvae and young juvenile Delta Smelt (SLS, 20-mm, STN) and two annual efforts using gear targeting juveniles and sub adults (STN, FMWT, CMWT, SKT) (GSE Table 4). Multi-gear sampling in fall of 2014 was limited by staff availability (but see FMWT CCE below). On a couple dates, we reduced the number SKT tows because of high Delta Smelt catches (9/27/2012, 9/26/2013). On 11/21/2013, SKT crews limited tow times to 5 min and did not catch excessive numbers of Delta Smelt, but high winds created unsafe conditions for parallel tows so of the eight tows planned for SKT only five were completed. Similarly, all other gear types planned for 16 tow and were not able to complete them (GES Table 4). We also scheduled two dates to compare gear targeting larvae and small juveniles (20-mm, STN) with SKT, but were not able to schedule for the spring.

Across all gear types, we caught 27,646 fishes over all sampling dates (GSE Table 5). We caught decent numbers of Delta Smelt when targeting larvae and small juveniles with SLS, 20-mm and STN gear (small juveniles accounted for most of STN Delta Smelt catch), but when targeting juveniles and sub adults later in the year, catches were low for STN, FMWT and CMWT(GSE Table 5); catches of Delta Smelt in SKT were very good and sampling effort was frequently reduced to avoid excessive take. In addition, catches of American Shad, Threadfin Shad and perhaps Striped Bass appear sufficient across most or all gear types to allow comparisons of relative efficiency.

Due to time constraints and occasional extremely high catches, not all fishes were measured (GSE Table 6). A limited number of extremely high catches of Gobies and Threadfin Shad resulted in a subsample of measurements. Otherwise, typically all fishes were measured; on rare occasions fish were damaged while being brought onboard so that accurate measurements were not possible and not taken for a small number of fish.

GSE Table 4. Multi-gear sampling effort by date for the Gear Selectivity Study, September 2012 through July 2015. Gear types include: Smelt Larval Survey (SLS); 20-mm; Summer Townet (STN); Spring Kodiak Trawl (SKT); Chipps Island Midwater Trawl (CMWT); and Fall Midwater Trawl (FMWT). US Fish and Wildlife Service Beach Seine sampling (not shown below) occurred only on May 22, 2014, and comprised six seine hauls.

| | Gear Types | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | SLS | 20-mm | STN | SKT | CMWT | FMWT | Total |
| 9/27/2012 | | | 25 | 7 | 9 | 18 | 59 |
| 10/25/2012 | | | 16 | 8 | 14 | 17 | 55 |
| 4/18/2013 | 18 | 18 | 18 | | | | 36 |
| 5/17/2013 | 16 | 16 | 16 | | | | 32 |
| 6/13/2013 | | 18 | 18 | | | | 36 |
| 9/26/2013 | | | 16 | 2 | 16 | 16 | 50 |
| 11/21/2013 | | | 11 | 5 | 12 | 11 | 39 |
| 4/24/2014 | 18 | 18 | 18 | | | | 36 |
| 5/22/2014 | 18 | 18 | 18 | | | | 36 |
| 6/19/2014 | | 18 | 18 | | | | 36 |
| 8/19/2014 | | 16 | 16 | 9 | | | 41 |
| 7/2/2015 | | 16 | 16 | 9 | | | 41 |
| Total | 70 | 138 | 206 | 40 | 51 | 62 | 497 |

GSE Table 5. Multi-gear sampling species catch (common name) by gear type, for the Gear Selectivity Study, September 2012 through July 2015. See GSE Table 4 for gear type abbreviations.

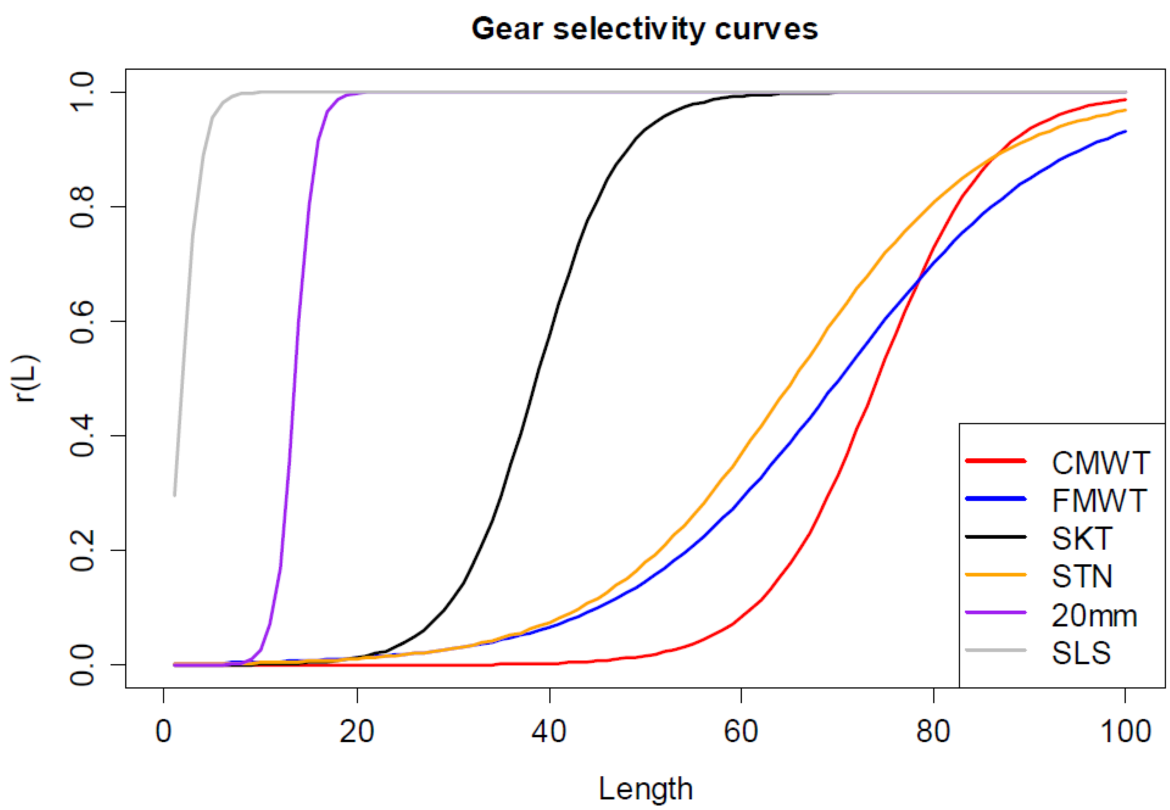
| | Gear Types | | | | | | |
|---|---|---|---|---|---|---|---|
| Common Name | SLS | 20-mm | STN | SKT | CMWT | FMWT | Grand Total |
| American Shad | 48 | 273 | 213 | 123 | 1741 | 130 | 2528 |
| Bigscale Logperch | 31 | | | | | | 31 |
| California Halibut | | | 1 | | | | 1 |
| Centrarchids (Unid) | 18 | | | | | | 18 |
| Chinook Salmon | | | | | | 1 | 1 |
| Clupidae (Unid) | | 2 | | 167 | | | 169 |
| Common Carp | 3 | | | | | | 3 |
| Cyprinid (Unid) | 29 | | | | | | 29 |
| **Delta Smelt** | **79** | **356** | **190** | **1696** | **23** | **34** | **2378** |
| Gobies (Unid) | 6016 | 5712 | 1230 | 2 | | 8 | 12968 |
| Mississippi Silverside | 11 | 3 | 9 | 71 | | 2 | 96 |
| Largemouth Bass | | | | 1 | | | 1 |
| Longfin Smelt | 31 | 152 | 16 | | | 5 | 204 |
| Northern Anchovy | | | | 16 | | | 16 |
| Osmeridae (Unid) | | 1 | | | | | 1 |
| Pacific Herring | | 4 | | | | | 4 |
| Prickly Sculpin | 1184 | 14 | | | | | 1198 |
| Shimofuri Goby | | 2 | 4 | | 1 | 3 | 10 |
| Shokihaze Goby | | 6 | 114 | | | 9 | 129 |
| Splittail | | | | | | 1 | 1 |
| Starry Flounder | | 1 | | | | | 1 |
| Striped Bass adult | | | | | 2 | | 2 |
| Striped Bass age 0 | 1379 | 497 | 57 | | 60 | 19 | 2012 |
| Threadfin Shad | 526 | 1253 | 118 | 2810 | 857 | 144 | 5708 |
| Tule Perch | | | | | 1 | | 1 |
| Unid | 2 | 13 | 4 | 3 | | | 22 |
| Wakasagi | | | 4 | | 1 | | 5 |
| White Catfish | | 50 | 50 | | | | 100 |
| Yellowfin Goby | 1 | 3 | 3 | 1 | | 1 | 9 |
| Total Fishes | 9358 | 8342 | 2013 | 4890 | 2686 | 357 | 27,646 |
| | | | | | | | |
| Crangon Shrimp | | 8 | 1010 | | | 204 | |
| Maeotias | | 77 | 425 | 172 | 86 | 245 | |
| Palaemon Shrimp | | | 62 | | 1 | 2 | |
| Shrimp (Unid) | | | 1 | | | | |
| Siberian Prawn | | 89 | 617 | | 16 | 293 | |
| | | | | | | | |
| Grand Total | 9358 | 8516 | 4128 | 5062 | 2789 | 1101 | 30954 |

GSE Table 6. Counts of individuals measured by gear type for the Gear Selectivity Study, September 2012 through July 2015. See GSE Table 4 for gear names

| Common Name | SLS | 20-mm | STN | SKT | CMWT | FMWT | Grand Total |
|---|---|---|---|---|---|---|---|
| American shad | 48 | 273 | 213 | 122 | 1739 | 130 | 2525 |
| Bigscale Logperch | 31 | | | | | | 31 |
| California Halibut | | | 1 | | | | 1 |
| Centrarchids (Unid) | 18 | | | | | | 18 |
| Chinook Salmon | | | | | | 1 | 1 |
| Clupidae (Unid) | | 2 | | 68 | | | 70 |
| Common Carp | 3 | | | | | | 3 |
| Cyprinid (Unid) | 29 | | | | | | 29 |
| Delta Smelt | 79 | 356 | 190 | 1696 | 23 | 34 | 2378 |
| Gobies (Unid) | 6016 | 5118 | 1051 | 2 | | 8 | 12195 |
| Mississippi Silverside | 11 | 3 | 9 | 71 | | 2 | 96 |
| Largemouth Bass | | | | 1 | | | 1 |
| Longfin Smelt | 31 | 152 | 16 | | | 5 | 204 |
| Northern Anchovy | | | | 16 | | | 16 |
| Osmeridae (Unid) | | 1 | | | | | 1 |
| Pacific Herring | | 4 | | | | | 4 |
| Prickly Sculpin | 1182 | 14 | | | | | 1196 |
| Shimofuri Goby | | 2 | 4 | | 1 | 3 | 10 |
| Shokihaze Goby | | 6 | 114 | | | 9 | 129 |
| Splittail | | | | | | 1 | 1 |
| Starry Flounder | | 1 | | | | | 1 |
| Striped Bass adult | | | | | 2 | | 2 |
| Striped Bass age 0 | 1367 | 497 | 57 | | 60 | 19 | 2000 |
| Threadfin Shad | 526 | 1253 | 118 | 813 | 857 | 144 | 3711 |
| Tule Perch | | | | | 1 | | 1 |
| Unid | 2 | 13 | 4 | 3 | | | 22 |
| Wakasagi | | | 4 | | 1 | | 5 |
| White Catfish | | 50 | 50 | | | | 100 |
| Yellowfin Goby | 1 | 3 | 3 | 1 | | 1 | 9 |
| Grand Total | 9344 | 7748 | 1834 | 2793 | 2684 | 357 | 24760 |

Gear selectivity curves developed from data collected through November 2013 only depicted initial retention and do not depict the potential for growth to influence catch as fish increase in size and better avoid nets (GSE Figure 2). Contact selectivity (or retention selectivity) is a function of the smallest (cod-end) mesh size and the size and more specifically the girth of the fish, which influences its ability to slip through the mesh. Thus, all other aspects assumed equal, the selectivity curves should assort in the same order as the size of their cod-end meshes: SLS, 20-mm, STN, SKT and CMWT about the same, and FMWT. Curves for larvae assorted correctly at expected locations with respect to Delta Smelt length (e.g., SLS and 20-mm, GSE

Figure 2). This was not the case for STN (GSE Figure 2): it appeared that spring and early summer data were not used for fitting the STN curve. For SKT, its curve assorted correctly, but it appeared that sampling in 2012 and 2013 was typically too late to observe fish sizes within the range of initial retention. Future use of August 2014 and July 2015 sampling data should add considerably to the accuracy of the STN curve, which is shifted far to the right of true selectivity (which is likely just left of the current SKT curve, and extending up sharply in the low 20mm range and reaching 1 by the mid- to high 20 mm range). The FMWT and CMWT curves though closer to accurate, suffered from low catches in general (GSE Table 5), which provide little data for accurate curve fitting. Similar to STN, the true retention curves for FMWT and CMWT are likely to be slightly closer to the SKT curve. For FMWT, retention selectivity was more accurately depicted by covered cod-end data analyses (see below). Based on cod-end mesh size (GSE Table 1), the CMWT curve should be to the left of that for FMWT and likely needs substantial additional field effort during a period when Delta Smelt are in the 45 to 60 mm range to improve its selectivity curve.




GSE Figure 2. Contact selectivity curves for Delta Smelt from six long-term fish monitoring gears based on 2012 and 2013 Gear Selectivity multi-gear sampling. Gear types include: Smelt Larval Survey (SLS), 20-mm Survey, Summer Townet Survey (STN), Spring Kodiak Trawl Survey (SKT), Fall Midwater Trawl Survey (FMWT) and Chipps Island Midwater Trawl Survey (CMWT).

*Covered Cod-end Sampling*

Covered Cod-end sampling incorporated both surface and oblique tows to contrast the methods as a means to examine depth distribution with the same gear type. More importantly, we believed surface trawling would enhance catches and provide sufficient numbers of Delta Smelt to effectively calculate a contact selectivity curve (GSE Table 7). As Delta Smelt densities declined in fall 2014, we discontinued oblique tows in favor of more effective surface towing (GSE Table 8). In addition, at about the same time we reduced sampling effort in the Sacramento Deepwater Ship Channel because of low success (Table GSE Table 9) and the long travel time cut into sampling effort. The standard cod-end mesh did not begin to retain Delta Smelt well until they achieved > 55mm FL in December and sampling continued into January to try to depict size at full retention.

For Delta Smelt captured in January 2015, interpretation of size of retention might have been confounded slightly by gonad development leading to slightly more girth at length than for similar sized fish caught in previous months. Specifically, by late January, Delta Smelt (at least females) begin a more rapid gonad-development phase leading to slight improvement in condition factor (weight at length and thus girth)(Kurobe et al. accepted) and perhaps increasing retention. It is not clear that the increased condition factor observed by Kurobe et al. (accepted) was sufficient to influence size at full retention.

GSE Table 7. Fall Midwater Trawl Covered Cod-end field effort summary August 21, 2014 through January 27, 2015. Regions sampled are the lower Sacramento River (Lower Sac) from adjacent to Decker Island downstream to Sherman Lake marsh, and the Sacramento Deepwater Ship Channel (SDWSC).

**a) Sets of paired oblique and surface tows.**

| Date | Location | No. of Sets |
|---|---|---|
| Aug 21, 2014 | Lower Sac | 3 |
| Aug 21, 2014 | SDWSC | 1 |
| Sept 25, 2014 | Lower Sac | 3 |
| Sept 25, 2014 | SDWSC | 3 |
| Oct 21, 2014 | Lower Sac | 2 |
| Oct 21, 2014 | SDWSC | 3 |

**b) Surface tows only.**

| Date | Location | No. of Tows |
|---|---|---|
| Oct 21, 2014 | Lower Sac | 2 |
| Dec 2, 2014 | Lower Sac | 6 |
| Dec 2, 2014 | SDWSC | 2 |
| Jan 27, 2015 | Lower Sac | 20 |

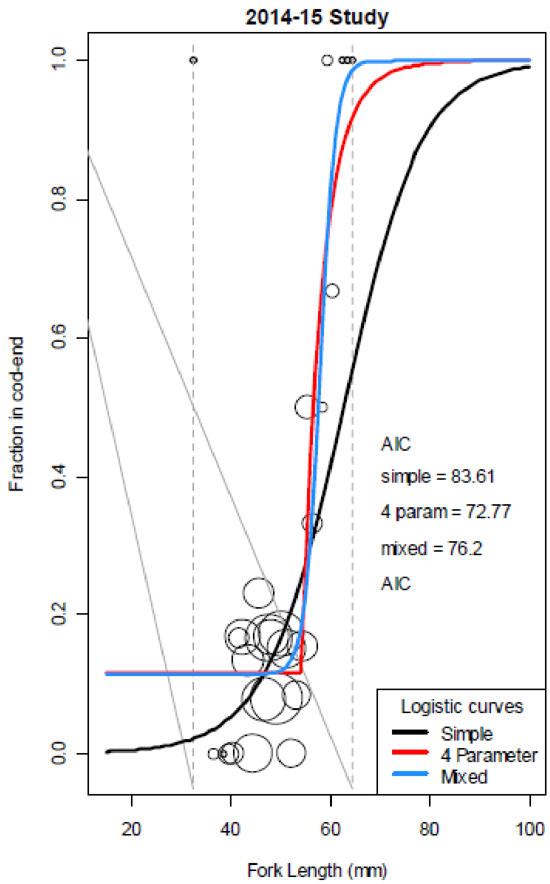
GSE Table 8. Mean Delta Smelt catch densities (# per 10,000 $m^3$ filtered) by date, location and tow method for Fall Midwater Trawl Covered Cod-end, August 21, 2014 through January 27, 2015. The number of tows is shown in parentheses. Density calculations are based on total catch in both the cod-end and the cover. Locations are described in GSE Table 7.

| | Aug 21, 2014 | | Sep 25, 2014 | | Oct 21, 2014 | | Dec 2, 2014 | | Jan 27, 2015 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Oblique | Surface | Oblique | Surface | Oblique | Surface | Oblique | Surface | Oblique | Surface |
| Lower Sac | 12.8 (n=3) | 26.2 (n=3) | 9.2 (n=3) | 57.0 (n=3) | 1.2 (n=2) | 3.5 (n=4) | NA | 3.4 (n=6) | NA | 0.7 (n=20) |
| SDWSC | 2.0 (n=1) | 157.6 (n=1) | 0 (n=3) | 1.0 (n=3) | 0 (n=3) | 0 (n=3) | NA | 1.7 (n=2) | NA | NA |

GSE Table 9. Delta Smelt catch in cod-end and cover by date, location, and tow method for Fall Midwater Trawl Covered Cod-end, August 21, 2014 through January 27, 2015. Fork-length range by date and tow method. Locations are described in GSE Table 7.

| Date | Location | Tow Method | Number of Tows | Total Volume ($m^3$) | Delta Smelt Catch | | | Fork Length Range (mm) |
|---|---|---|---|---|---|---|---|---|
| | | | | | Cod-end | Cover | Total | |
| Aug 21, 2014 | Lower Sac | Oblique | 3 | 16620 | 3 | 18 | 21 | 41 - 55 |
| Aug 21, 2014 | Lower Sac | Surface | 3 | 28738 | 20 | 55 | 75 | 33 - 57 |
| Aug 21, 2014 | SDWSC | Oblique | 1 | 4959 | 0 | 1 | 1 | 50 |
| Aug 21, 2014 | SDWSC | Surface | 1 | 7614 | 4 | 116 | 120 | 39 - 56 |
| Sept 25, 2014 | Lower Sac | Oblique | 3 | 14576 | 0 | 13 | 13 | 48 - 55 |
| Sept 25, 2014 | Lower Sac | Surface | 3 | 9850 | 8 | 44 | 52 | 44 - 61 |
| Sept 25, 2014 | SDWSC | Oblique | 3 | 13620 | 0 | 0 | 0 | NA |
| Sept 25, 2014 | SDWSC | Surface | 3 | 11232 | 0 | 1 | 1 | 55 |
| Oct 21, 2014 | Lower Sac | Oblique | 2 | 8326 | 0 | 1 | 1 | 56 |
| Oct 21, 2014 | Lower Sac | Surface | 4 | 14862 | 0 | 5 | 5 | 51 - 55 |
| Oct 21, 2014 | SDWSC | Oblique | 3 | 12440 | 0 | 0 | 0 | NA |
| Oct 21, 2014 | SDWSC | Surface | 3 | 6473 | 0 | 0 | 0 | NA |
| Dec 2, 2014 | Lower Sac | Surface | 6 | 35083 | 4 | 8 | 12 | 48 - 59 |
| Dec 2, 2014 | SDWSC | Surface | 2 | 11694 | 2 | 0 | 2 | 56 - 59 |
| Jan 27, 2015 | Lower Sac | Surface | 20 | 116947 | 7 | 1 | 8 | 55 - 65 |

Similar to the multi-gear contact selectivity curve for Delta Smelt (see GSE Figure 2), the simple logistic curve using CCE data fit poorly (GSE Figure 3). It was not able to accommodate the sharp increase and apparent full retention of Delta Smelt somewhere in the range of 60-65 mm FL and predicted a much larger size of full retention. Our four parameter and mixed logistic models appeared to fit progressively better at the top end, but did not include zero at the bottom end (GSE Figure 3). The highly variable retention of Delta Smelt in the 35 to 55 mm range is problematic, but likely at least partially a response to the total number of fishes caught at the same time. Specifically, as other fishes block meshes and create impediments to slipping through the mesh, fish that would otherwise slip through get caught in the mass of fish already retained. Regression analyses will be used to see if fish number is a predictor of proportional retention of the small fish.




GSE Figure 3. Contact selectivity curves for Delta Smelt based on August 2014 through January 2015 Fall Midwater Trawl Covered Cod-end sampling. See Mitchell et alDraftFMWTCCE_article_v64-kbn_rdb.pdf (included in package) for descriptions of the logistic model formulations used.

Another means of support for size of full retention can be interpreted from the size distribution of fish previously documented as "wedged" in the cod-end mesh. In October 2012, some Delta Smelt reached sufficient size to wedge in the standard FMWT 1.3 cm cod-end mesh; that is they possessed too large a girth to slip through the mesh (GSE Table 10). Delta Smelt as small as 55 mm FL were observed wedged in the 1.3 cm mesh. Beginning at 60 mm, there were no further gaps in the sequence of lengths of Delta Smelt observed wedged in the cod-end mesh. This weakly suggests that in the range of 60 mm and slightly larger, Delta Smelt become fully retained; however, slim fish in this size range might pass through the mesh. This size range of retention is supported by the covered cod-end data (GSE Table 9 Jan 27, 2015; GSE Figure 3).

Once Delta Smelt abundance recovers, we plan to conduct additional CCE sampling. We suspect that future data will to continue to support and more heavily weight measures of full retention in the 60 to 65 mm range. The difficulty modeling how retention changes with size remains a mathematical challenge that is being pursued.

GSE Table 10. Fork-length and frequency of Delta Smelt documented as wedged in the 1.3 cm mesh of the Fall Midwater Trawl (labeled “Y”) or retained by contacting the mesh laterally (labeled “N”) during multi-gear sampling, October 25, 2012.

| Fork Length | N | Y | Total |
|---|---|---|---|
| 55 | | 1 | 1 |
| 57 | | 1 | 1 |
| 58 | 1 | | 1 |
| 60 | 1 | 2 | 3 |
| 61 | | 1 | 1 |
| 62 | | 3 | 3 |
| 63 | | 2 | 2 |
| 64 | | 3 | 3 |
| 65 | 1 | 2 | 3 |
| 66 | | 3 | 3 |
| 67 | 1 | 1 | 2 |
| 68 | | 1 | 1 |
| 71 | | 1 | 1 |
| 72 | | 1 | 1 |

## Products

Multi-gear metadata (first tab) and complete flat file (attached: GearSelect_AllSpeciesLnEffortMar2015_v2.xls). Designed as a “one file does all” output for Ken Newman to import into a statistical software program, with at least one record of each gear deployment and multiple records (one for each species and individual measured).

Beach seine results summary and data from May 2014 (attached: GearSelectivitySeiningSummaryMay2014.docx, GearSelectivitySeineDataMay2014.xls )

Multi-gear Access 2002 Database (attached: GearEfficiency.mdb)

Dekar, M., K. Newman, and R. Baxter (2013) “Catch me if you can: quantifying relative species and size selectivity of IEP trawls”. Presentation. IEP Workshop, 2013. (attached: Catch_Dekar_et_al_IEP.pptx)

Newman, K, L. Mitchell and L. Polansky (2014) “Incorporating gear evaluation studies data in a Delta Smelt life cycle model (DSLCM)”. Presentation. Delta Science Conference 2014. (attached: newman-gear-eval.pdf)

Newman, K.B., L. Polansky, L. Mitchell, W. Kimmerer, P. Smith, R. Baxter, W. Bennett, M. Maunder, M. Nobriga, W. Meiring, E. Laca, F. Feyrer (2014) A Delta Smelt life cycle model. Draft Manuscript, December 17, 2014. 68 pages (attached: DSLCM.pdf)

Newman, K., L. Mitchell and L. Polansky 2015. “A cohort-specific approach to assessing entrainment of Delta Smelt”. Presentation. IEP Workshop March 19, 2015. (attached: Newman-

Cohort-Specific-Entrainment.pdf)

Baxter, R. (2015) “Insights into Delta Smelt habitat provided by gear selectivity studies”. Presentation. IEP Workshop March 2015 (attached: Baxter_DSHabitatGearSelect_PopAssess_IEP2015_vr1.ppt)

Mitchell, L., K. Newman and R. Baxter (draft manuscript) No Title. Fall Midwater Trawl covered cod-end and surface trawling vs oblique trawling. (attached: Mitchell_et al.DraftFMWTCCE_article_v64_kbn_rdb.dox)

### *Objective 2: Vertical and lateral distribution*

#### Introduction

The development of a state-space life history model for Delta Smelt (Newman et al., in progress), which intended to integrate data from all fish-monitoring surveys targeting Delta Smelt, benefited from the knowledge of vertical and lateral distributions, and the factors that influence them. This study, the Gear Selectivity Evaluation study, investigated the vertical and lateral distributions of Delta Smelt primarily through collaboration with several researchers to further develop and use the SmeltCam. The SmeltCam is an underwater video camera affixed to the cod-end of a midwater trawl that automatically collects and tracks images of fishes passing through the net without handling. Through review of the images, fishes can be identified and enumerated. Identification is accomplished in two stages: first, image recognition software is “taught” using an image library to distinguish species; and second, images captured and preliminarily identified by software as fish species are reviewed by fish biologists and confirmed. Once identified and enumerated, catches can be binned by tow number. Associating fish counts with net location (linked to tow number) and environmental measures at the time of detection allows for inferences to be made regarding fish habitat and behavior without having to handle the fish.

SmeltCam developed out of a collaboration among SureWorks LLC (engineer/software designer), US Bureau of Reclamation (initial funding and biological collaboration) and Department of Water Resources (subsequent funding and biological collaboration). In 2010, the gear was ready for field testing and more formal collaboration began with Department of Fish and Wildlife. Preparation for fieldwork included adapting a Fall Midwater Trawl net to hold the SmeltCam and the means to deploy and retrieve the net and camera (48.5 kg dry, 70+ lbs. when ballasted with water). Fieldwork took place October 20-21 and November 22-23, 2010 and gathered pelagic fish images across a variety of habitats and through a large range of turbidities. After contracting problems were resolved, SureWorks was again ready for more fieldwork in September and October of 2011. This work concluded the initial testing and actual sampling designs were implemented in fall 2012 and subsequent years as discussed below.

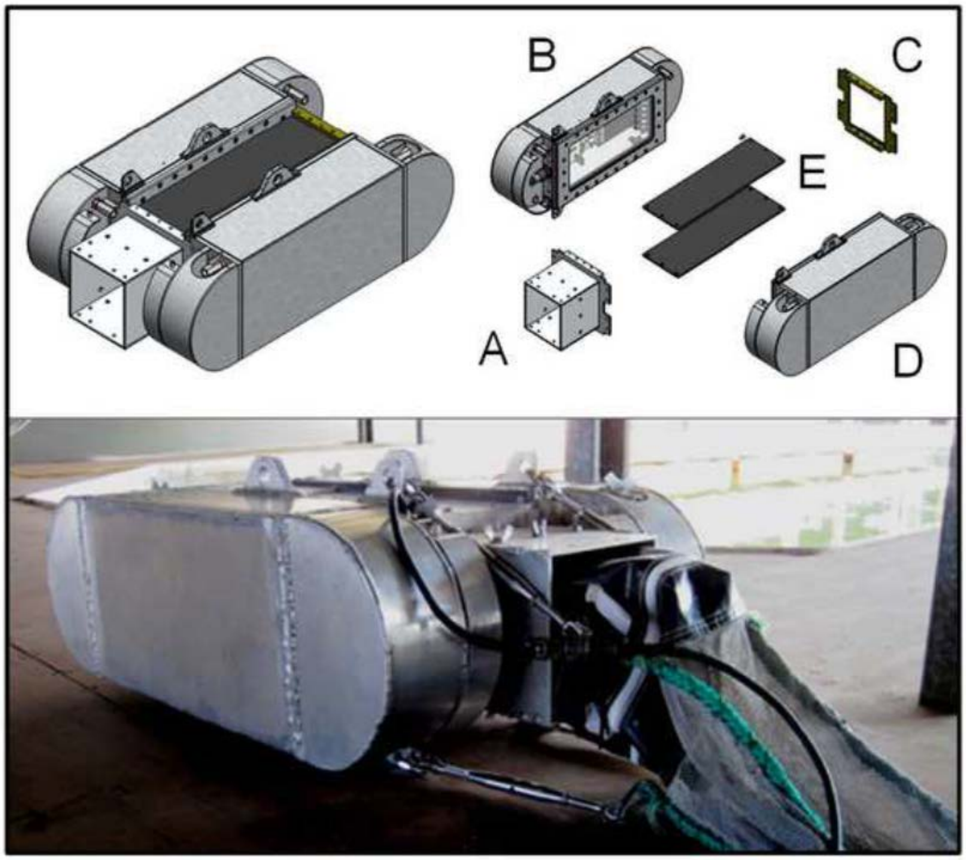
We used the SmeltCam to understand the fine-scale distribution of Delta Smelt in fall 2012; specifically, does its vertical and horizontal distribution vary by tidal stage? In subsequent fieldwork during 2014, the focus narrowed to vertical distribution, but the lack of Delta Smelt catch directed analyses to more abundant fish and invertebrate species. Our latest effort in summer of 2015 involved field-testing the second generation SmeltCam, which now uses infrared light and has been redesigned to be smaller, lighter and collect more direct water measurements at the point of fish image collection. We spent several days in summer 2015 on the water collecting new fish images and working out a few issues with lighting and water measurement.

The previously described multi-gear sampling designs also provided data suitable for addressing lateral distributions questions: fish presence and density from trawl lands along the sides of channels (lanes 1 & 4) compared to those toward the middle (lanes 2& 3). These analyses have not yet been completed.

## Methods

We deployed the first generation SmeltCam (GSE Figure 4) in the field for quantitative measures during November 26-30, 2012. Sampling took place in the lower Sacramento River adjacent to Sherman Island. This region was selected based on then current catches of Delta Smelt by other surveys and multi-gear sampling. We set up a factorial sampling design to investigate Delta Smelt distribution in the water column, with three factors and two levels for each factor. The three factors and corresponding levels were: 1) horizontal position in the water column (H: center of channel versus side of channel); 2) vertical position in the water column (V: upper half versus lower half); 3) tidal phase (T: flood tide versus ebb tide). The response variable, fish counts, was defined as the number of Delta Smelt detected in a 10-min trawl. We used GIS to generate 21 equidistant sampling lasts distributed across the channel, each lane running parallel to the current. The first and last seven lanes represented the sides of the channel and the middle seven lanes the center of the channel. Lane locations were entered into the GPS of the sampling vessel so that each could be occupied if selected for sampling. On the water, sampling depth (upper versus lower half of the water column) was achieved by maintaining the net either above or below the mid-depth, targeting either ¼ or ¾ depth, where water depth was determined by boat-mounted sonar. Net depth was first established by deploying sufficient cable to achieve the selected depth and then adjusted to the specific depth as determined by the SmeltCam's depth sensor monitored in real-time during trawls. We then towed the SmeltCam at depth for 10 min prior to rapid retrieval and moving to the next pre-determined trawl lane and depth. A general Oceanics flow meter deployed off the side of the boat when the net achieved proper depth and retrieved when the net was retrieved provided a measure of distance traveled to estimate volume filtered.

Fish images were identified by software, and then by biologists. Once confirmed, images were tallied by tow and associated with trawl lane, depth and water parameter measurements take prior to analyses. See Feyrer et al. (2013) for analytical details.




GSE Figure 4. Upper panel is a diagram of the SmeltCam showing (A) net cowling and front frame, (B) sealed electronics compartment, (C) stern frame, (D) ballast hull and € top and bottom vision tube covers. Bottom panel is a photograph of the SmeltCam coupled to the net and the black power/communication cable. Source Feyrer et al. 2013.

Our second effort to deploy the first generation SmeltCam occurred August 25-29 and October 20-24, 2014. Sampling occurred at locations along the long axis of the Sacramento River channel from the vicinity of Sherman Island upstream into the Sacramento Deepwater Ship Channel (Figure ). The SmeltCam was configured as described above. Sampling took place at center channel at the stations indicated. At each station the net was deployed to the bottom and retrieved obliquely to the surface over 12 min. A general Oceanics flow meter deployed off the side of the boat when the net achieved proper depth and retrieved when the net was retrieved provided a measure of distance traveled to estimate volume filtered. Environmental and depth measurements were collected by sensors on the SmeltCam (see Feyrer et al. submitted).

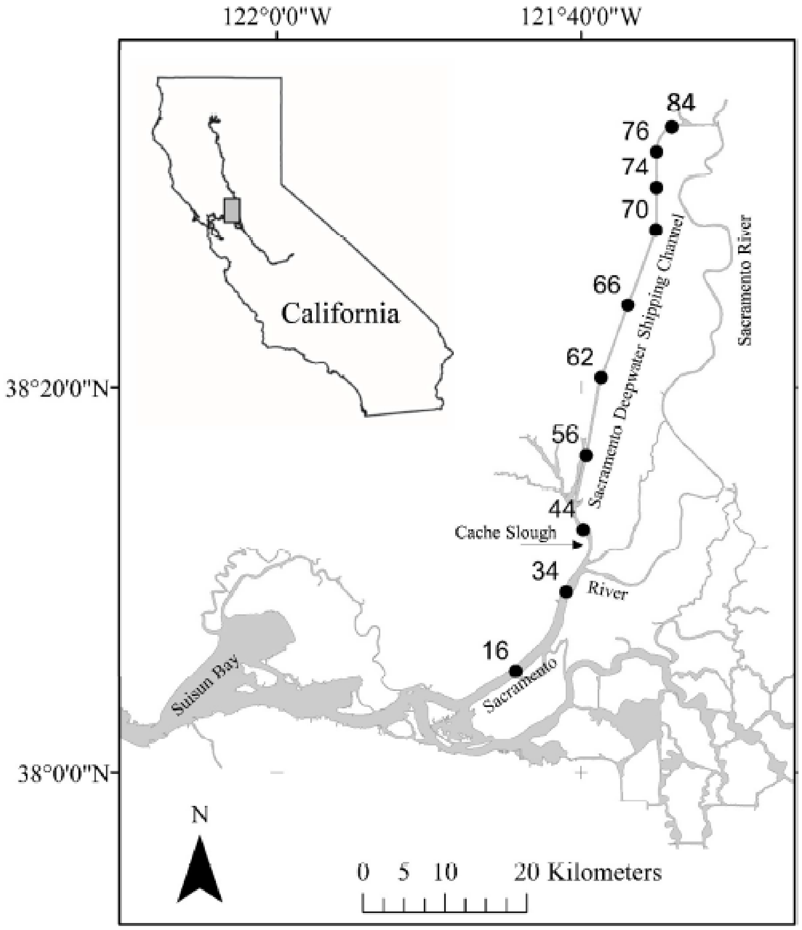



Figure . Location of sampling sites along the Sacramento River and Sacramento Deepwater Ship Channel during SmeltCam sampling August and October 2014. Numbers represent U.S. Coast Guard navigational marker numbers. Source Feyrer et al. (submitted).

Finally, we deployed the next generation SmeltCam, July 20 through 23, 2015. This field effort focused on working out deployment protocols, field testing new SmeltCam technology and redeveloping a fish image library. The next generation SmeltCam switched to infrared illumination to avoid the fish attraction of white light; this switch necessitated some recalibration of the image library, because the new light produced slightly different fish image characteristics. Field work involved sampling the lower Sacramento River in the vicinity of Sherman Lake and

## Results and Discussion

See Feyrer 2013_SmeltCam.pdf and Feyrer_North_Delta_Pelagic_Necton_8-15-2015.pdf (attached) for results and discussion of these field efforts.

## Products

No database is submitted in association with this element. Contact Fred Feyrer (ffeyrer@usgs.gov)

Feyrer, F., D. Portz, D. Odum, K. B. Newman, T. Sommer, D. Contreras, R. Baxter, S. B. Slater, D. Sereno, and E. Van Nieuwenhuyse. 2013. SmeltCam: underwater video codend for trawled nets with an application to the distribution of the imperiled Delta Smelt. Plos ONE 8(7):e67829. doi:10.1371/journal.pone.0067829 (attached: Feyrer2013_SmeltCam.pdf)

Feyrer, F. and many others (2013) "SmeltCam to the future". Presentation. IEP Workshop 2013. (attached: FeyrerIEP2013.pdf)

Feyrer, F., S. Slater, D. Portz, D. Odom, T. Morgan-King, L. Brown (submitted) Drivers of pelagic nekton abundance and distribution in the northern Sacramento-San Joaquin Delta, California, USA. Draft manuscript submitted to River Research and Applications. 29 pages. (attached: Feyrer_North Delta_Pelagic_Nekton_8-15-2015.pdf)

### *Objective 3: Volume sampled by depth*

#### Introduction

The development of a state-space life history model for Delta Smelt (Newman et al., in progress), which intended to integrate data from all fish-monitoring surveys targeting Delta Smelt, will benefit from quantified estimates of the tow time spent or tow volume sampled in each of three depth strata (surface, middle and bottom thirds of the water column). This component of the Gear Selectivity Evaluation study investigated relative proportions of tow time spent and tow volumes sampled by different gear-types in the aforementioned three depth strata. The resulting data identify what portions of the water column were sampled by each gear type and what portions were not.

#### Methods

To gather net-depth data, depth loggers were affixed to a lower part of each net deployed during much of the multi-gear sampling that took place from fall 2012 through fall 2014. For SLS, 20-mm, and STN net, depth loggers were attached to a ski, near the bottom edge of the net frame. For FMWT and CMWT, depth loggers were attached to the lower net corner behind the portside bottom door. The SKT had two depth loggers attached: one at the mid-point of the lead line and the other on the lower portside bridle, near the cannonball weight at the lower edge of the net mouth. Net depth data were collected for STN (September and October) and FMWT (October) in 2012 using Vemco mini-loggers. In 2013 and 2014, net depth data for all net types were collected using Reefnet Sensus Ultra third generation depth loggers. All the depth loggers were pressure activated and recorded depth data at 4-second intervals from the time they entered the water until they were removed from the water. Specifics of sampling design and gear deployment are provided in the Methods section of Objective 1, Multi-Gear Sampling. Briefly, all net types were deployed according to their individual study protocols, and all tows were standardized to 10 minutes. The only exception was SKT, in which the tow duration was adjusted between 5 and 10 minutes, in an attempt to limit excessive Delta Smelt catch. Each time a net was deployed and retrieved the following steps were taken: environmental and site data were recorded including depth to the bottom using the boat's sonar; gear was dropped overboard and lines/cables were let out to a predetermined length based on bottom depth; a timer was started once desired cable length was reached, and the net was retrieved using a winch according to tow schedule and a set retrieval speed. The tow "ended" and net was brought on board once the net was no longer fishing effectively, typically when the cable pulled the net up and partially out of the water. SKT and CMWT followed a slightly different process: once the nets were set, they were left in place on the surface (SKT) or near the surface (CMWT) for the duration of the tow.

The behavior of nets used for oblique tows (SLS, 20-mm, STN, FMWT) was assessed based on water column position in relation to overall site depth. The water column was split into three equal-sized depth strata (i.e. top, middle, bottom) based on channel depth and sampling sites were grouped by channel depth into shallow (11 – 24 feet deep), medium (25 – 34 feet deep), and deep (35 feet deep or greater) sites. Net depth data from tows conducted at sites shallower than 11 feet were excluded from this summary, because the nets always got to the bottom, and this depth strata was not sampled by all net types. Net depth data for the entire tow, from deployment to retrieval, were included. Once net-depth samples had been grouped by channel depth and depth strata "breaks" (depths delimiting surface and middle, and middle and bottom strata) established, we stepped through all records from each sample assigning depth strata to each record. We determined the proportion time or volume of each tow spent in each depth stratum by dividing the number of net depth records in each stratum by the total number of net depth records for the tow. To get mean proportions by channel-depth group, we then averaged across tows conducted at sites falling into each depth group (i.e., shallow, medium and deep groups). These calculations were performed for each net type in each channel depth group.

For net types typically deployed on oblique tows (SLS, 20-mm, STN, FMWT), we were interested in whether they actually reached the bottom at deep sites during initial deployment. To examine this, we identified the greatest net depth achieved during each tow and compared this maximum depth to the channel depth for the sites.

For net types typically deployed at or near the surface (SKT and CMWT), net depth data were analyzed using only the "active tow" portion. The net was defined as actively towing from the time of net set (i.e. full cable out and net depth achieved, and for SKT when boats separated) until the boats moved toward one-another (SKT) or the top doors collapsed together, and were no longer fishing effectively. For SKT depth analysis, we summarized data collected from both depth loggers, presuming that the port-side logger would travel deepest in the water column and that the depth logger on the lead-line mid-point might travel higher due to water tension on the net. For each, we determined the mean net depth, and the proportion of active tow time spent in each depth strata.

*Distance and Volume Calculations*

General Oceanics flowmeter counts (revolutions) were used to calculate distance traveled through the water. Flowmeter counts for each tow were obtained by subtracting the number recorded at the beginning of the tow from the number recorded at the end of the tow. To calculate mean tow distance (m), a mean flowmeter count per tow was calculated for each net type and then multiplied by the conversion factor provided by the manufacturer (0.02668764 m/count). The mean volume of water sampled during a tow was calculated as the product of mean tow distance and net mouth area for each net type. Net mouth areas as stated in project metadata were used in tow volume calculations (Table 1).

Table 1. Net mouth-area values for net types used in the Gear Selectivity Evaluation study, 2012 through 2015. Net mouth areas values were derived from project descriptions from each survey. SLS – Smelt Larva Survey; 20-mm – 20-mm Survey; STN = Summer Townet Survey; FMWT = Fall Midwater Trawl Survey; and CMWT = Chipps Island Midwater Trawl Survey. For FMWT, the first mouth area value represents 100% open, the second represents 80% open, which is assumed mouth area when towing and used for these analyses. See GSE Table 1 for additional details.

| Net Type | Mouth Area ($m^2$) |
|---|---|
| SLS | 0.37 |
| 20-mm | 1.51 |
| STN | 1.49 |
| FMWT | 13.4 / 10.7 |
| SKT | 13.95 |
| CMWT | 18.58 |

## Results and Discussion

Except for SKT, we monitored net depth on at least half the tows conducted by each net type (Table 2). Although only a limited number of SKT and CMWT tows were monitored for depth, because these nets were not towed obliquely, they presumably exhibited less variability in depth. For other net types, 40 or greater tows were monitored and provided ample data to resolve net depth behavior.

Table 2. Total study effort (tows) by net type, number of tows with depth data and proportion with depth data, by net type for the Gear Selectivity Evaluation study, 2012-2015. The two values reported for SKT represent the depth loggers attached to the lead-line mid-point and the port-side bottom bridle, respectively. See Table 1 for net type full names.

| Net Type | Total Tows | Tows with Depth Data | Proportion with Depth Data |
|---|---|---|---|
| SLS | 70 | 70 | 1.00 |
| 20-mm | 122 | 68 | 0.56 |
| STN | 190 | 181 | 0.95 |
| FMWT | 62 | 43 | 0.69 |
| SKT | 31 | 6/7 | 0.16/0.23 |
| CMWT | 51 | 28 | 0.55 |

*Oblique Tows*

Net-depth profiles (mean depth at time through the 10 min tow) showed consistent patterns across net-types of progressively poorer success achieving near bottom deployment with increasing channel depth (Figures 1-4). Calculating mean depths across many tows to generate profiles dampened variability in the profile traces: the nets are highly responsive to changes in currents, towing speed and retrieval speed, so there is much up and down movement that is averaged out.

The SLS net generally failed to deploy deeper than mid-depth at medium and deep sites (Figure 1). The SLS net frame lacked of added weight and its fine mesh slowed its decent. The larger 20-mm Survey net frame possesses lead weights to counteract its relatively fine mesh and facilitate its drop within the water column during deployment. This combination resulted in the 20-mm Survey net achieving full depth at shallow sites and about 75 and 80 percent of maximum channel depth at deep and medium sites, respectively (Figure 2).

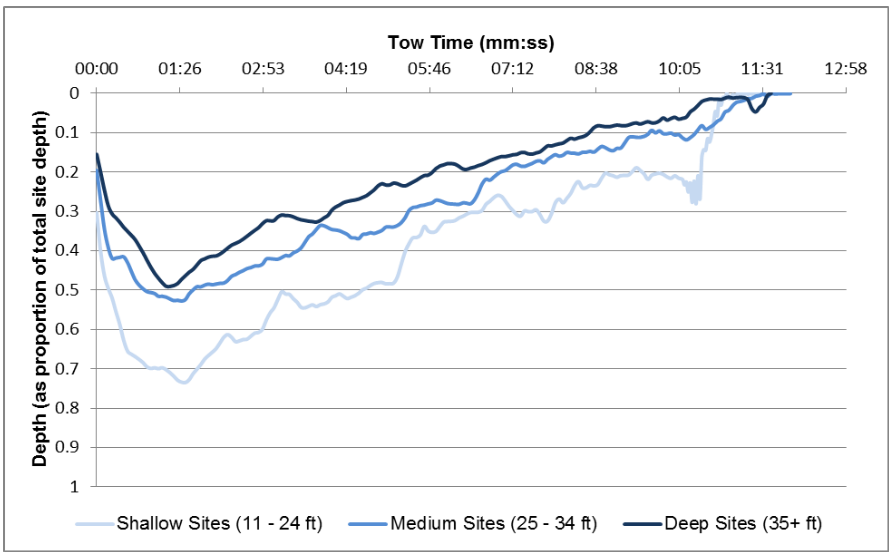


Figure 1. Net-depth profiles (fraction of maximum depth at time) for Smelt Larva Survey net tows conducted in shallow (11-24 ft), medium (25-34 ft) and deep (≥ 35 ft) channel depths during the Gear Selectivity Evaluation Study, 2012-2015.

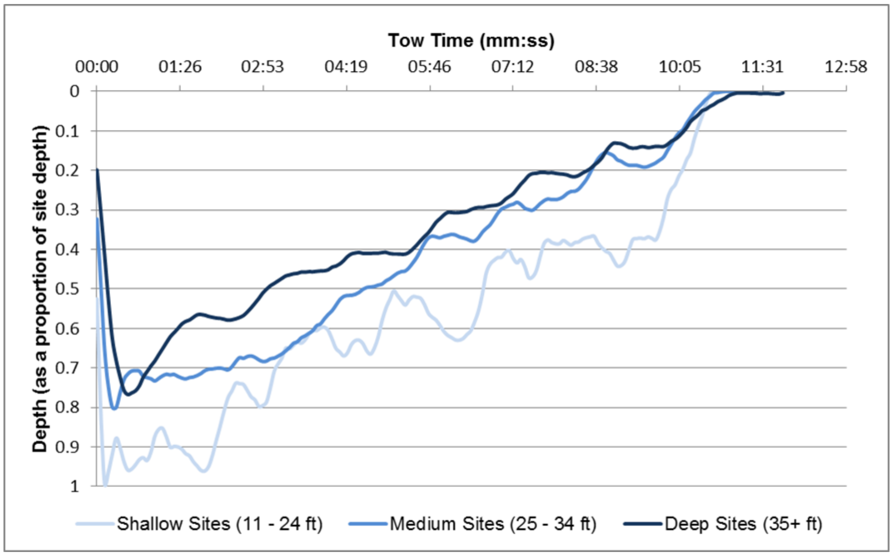



Figure 2. Net-depth profiles (fraction of maximum depth at time) for 20-mm Survey net tows conducted in shallow (11-24 ft), medium (25-34 ft) and deep (≥ 35 ft) channel depths during the Gear Selectivity Evaluation Study, 2012-2015.

The Summer Townet uses a sled identical to that of the 20-mm Survey, but without the added weight. Nonetheless, the larger mesh of the Summer Townet creates less drag in the water and it was able to achieve drops of 90 percent and almost 90 percent at sites with shallow and medium channel depths (Figure 3). At deep sites, STN was only able to drop to a little beyond 75 percent of the channel depth on a regular basis.

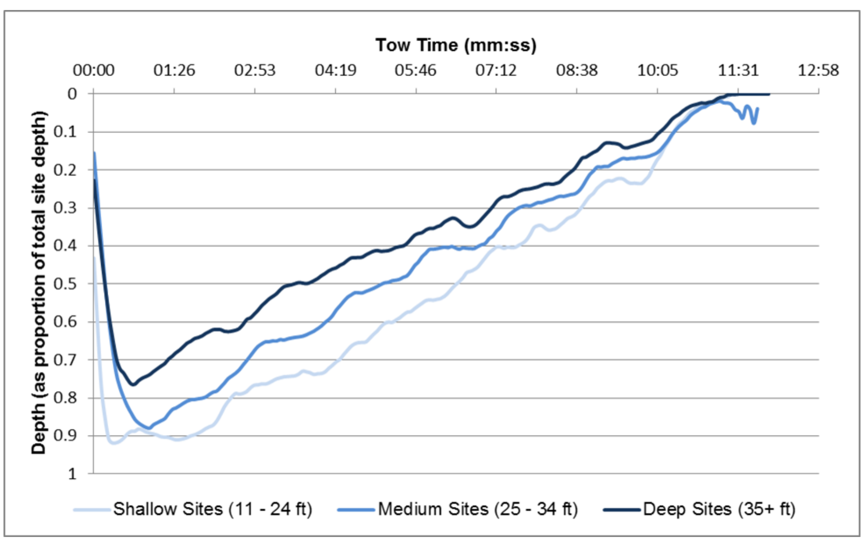



Figure 3. Net-depth profiles (fraction of maximum depth at time) for the Summer Townet Survey net tows conducted in shallow (11-24 ft), medium (25-34 ft) and deep (≥ 35 ft) channel depths during the Gear Selectivity Evaluation Study, 2012-2015.

The Fall Midwater Trawl relies on weighted bottom planing doors to assist its deployment to the bottom. In general its deployment only achieved about 75 percent of the channel depth at both medium and deep sites (Figure 4).

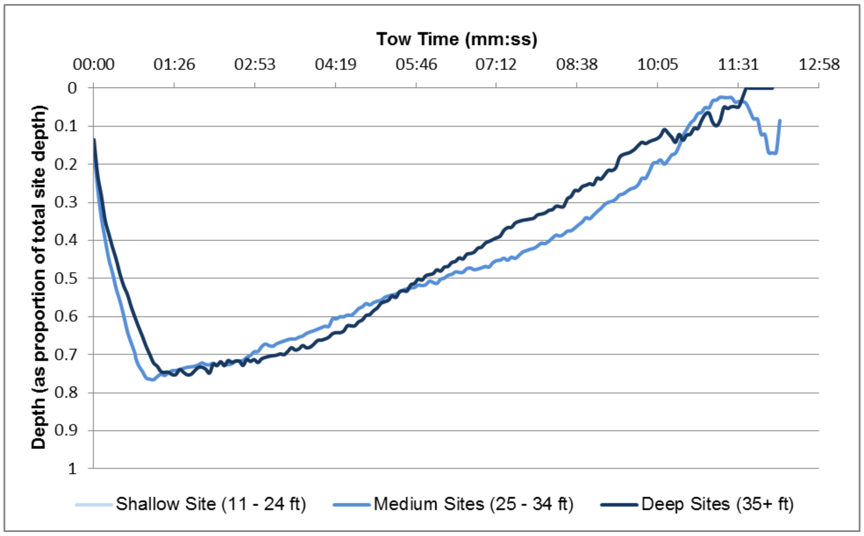


Figure 4. Net-depth profiles (fraction of maximum depth at time) for the Fall Midwater Trawl Survey net tows conducted in medium (25-34 ft) and deep (≥ 35 ft) channel depths during the Gear Selectivity Evaluation Study, 2012-2015.

The frequency of maximum net depth achieved over deep sites proved similar to the mean maximum depths (Figure 5). With only a couple exceptions, SLS failed to deploy deeper than 30 ft, and most deployments were much shallower (maximum and median maximum depth 35 and 21 ft, respectively). The 20-mm Survey net showed the deepest deployments and a broad variability around a median depth of 36 ft . The STN tended to deploy in high frequency between 32 and 37 ft depths (median 34), but only rarely achieved more than 40 ft. The FMWT showed a relatively narrow range of depths achieved (maximum 34 ft, median depth 29 ft) that would undoubtedly broaden with a larger sample size (Figure 5).

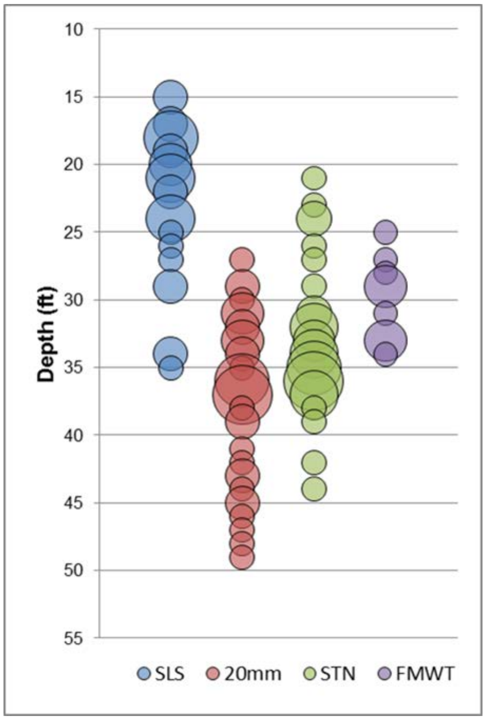



Figure 5. Frequency of maximum net depth achieved per tow over deep sited by net type for oblique tows during the Gear Selectivity Evaluation Survey, 2012-2015. Tows over deep sites: SLS (n=32), 20-mm (n=40), STN (n=39), FMWT (n=11).

During an oblique tow, ideally, the net would spend one-third of its tow time in each third of the depth strata. This proved rarely true for our analyses, but see STN over shallow depths (Table 3). As might be expected from its depth profile, the SLS did not approach proportional sampling in any depth stratum, but instead was typically biased toward the surface stratum (Table 3). The remaining net types performed better, particularly at shallow depths, but proportions of time spent in the bottom stratum declined with increasing site depth (Table 3). Somewhat unexpectedly given its maximum depth distribution in deep sites (Figure 5), the FMWT appeared to perform best at proportionally sampling depth strata at the same deep sites, (Table 3). The small number of FMWT deep site samples came at locations with a maximum depth near 35 ft.

Volume sampled by depth stratum (Table 4) followed an identical pattern to that of time spent within each depth stratum (Table 3), and is presented for completeness.

Table 3. Mean proportion of tow time (± SE) spent in each depth strata by net type and site depth during the Gear Selectivity Evaluation Study, 2012-2015. Includes data only for nets conducting oblique tows.

| Net Type | Depth Stratum | Site Depth | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Shallow (10 - 24ft) | | | Medium (25 - 34ft) | | | Deep (35ft+) | | |
| | | n | Mean Proportion | S.E. | n | Mean Proportion | S.E. | n | Mean Proportion | S.E. |
| SLS | Top | 22 | 0.42 | 0.04 | 16 | 0.65 | 0.04 | 32 | 0.76 | 0.03 |
| | Middle | | 0.39 | 0.03 | | 0.30 | 0.03 | | 0.22 | 0.03 |
| | Bottom | | 0.19 | 0.03 | | 0.06 | 0.03 | | 0.02 | 0.01 |
| 20mm | Top | 10 | 0.22 | 0.02 | 18 | 0.41 | 0.02 | 40 | 0.53 | 0.01 |
| | Middle | | 0.44 | 0.03 | | 0.39 | 0.02 | | 0.44 | 0.01 |
| | Bottom | | 0.33 | 0.03 | | 0.20 | 0.02 | | 0.04 | 0.01 |
| STN | Top | 36 | 0.30 | 0.02 | 106 | 0.31 | 0.01 | 39 | 0.49 | 0.02 |
| | Middle | | 0.34 | 0.02 | | 0.45 | 0.01 | | 0.41 | 0.02 |
| | Bottom | | 0.37 | 0.03 | | 0.24 | 0.02 | | 0.10 | 0.01 |
| FMWT | Top | 0 | n/a | n/a | 32 | 0.22 | 0.02 | 11 | 0.31 | 0.03 |
| | Middle | | n/a | n/a | | 0.50 | 0.02 | | 0.42 | 0.03 |
| | Bottom | | n/a | n/a | | 0.29 | 0.03 | | 0.28 | 0.04 |

Table 4. Mean volume sampled in each depth strata by net type and site depth during the Gear Selectivity Evaluation Study, 2012-2015. Includes data only for nets conducting oblique tows.

| Net Type | Depth Stratum | Site Depth | | |
|---|---|---|---|---|
| | | 11 - 24 ft | 25 - 34 ft | 35+ ft |
| | | Average Tow Volume ($m^3$) | | |
| SLS | Top | 89.20 | 138.04 | 161.40 |
| | Middle | 82.82 | 63.71 | 46.72 |
| | Bottom | 40.35 | 12.74 | 4.25 |
| 20mm | Top | 201.43 | 366.67 | 471.34 |
| | Middle | 396.35 | 348.79 | 392.32 |
| | Bottom | 298.71 | 181.03 | 32.83 |
| STN | Top | 281.11 | 287.72 | 459.15 |
| | Middle | 318.59 | 419.92 | 384.19 |
| | Bottom | 346.70 | 229.40 | 93.70 |
| FMWT | Top | n/a | 894.64 | 1260.63 |
| | Middle | n/a | 2033.28 | 1707.96 |
| | Bottom | n/a | 1179.30 | 1138.64 |

*Surface Tows*

Surface and near-surface towed gears tended to tow in a consistent and narrow range of depths (Table 5). Minimum values for SKT do not seem possible and likely represent data glitches. Maximum depths for SKT gear reflect the depth achievable when the gear is not under tension and the port-side weight and bridle drop low coming off a small wave; under the same conditions the center of the net sags from its own weight leading to maximum depths measured in the middle (Table 5). Under tension during most of the tow, logger depths diminish and become consistent at about 4.5 ft (Table 5), substantially shallower than when not under tow.

The CMWT appears to drop substantially during deployment (see max Table 5) and remain deeper while towing than SKT. Once under tow, CMWT tends to remain at depth without much variation (see Table 5, SE).

Table 5. Net depth mean (ft), standard error, minimum and maximum for surface towed Spring Kodiak Trawl, measured at the mid-point of the lead-line and on the port-side lower bridle, and the near-surface towed Chipps Island Midwater Trawl for "active" towing during the Gear Selectivity Evaluation Study, 2012-2015.

| | SKT (middle) | SKT (port) | CMWT |
|---|---|---|---|
| **n (data points)** | 498 | 571 | 3987 |
| **Min** | 1.71 | 1.19 | 8.44 |
| **Max** | 6.43 | 7.15 | 20.73 |
| **Mean** | 4.48 | 4.66 | 11.39 |
| **SE** | 0.04 | 0.05 | 0.02 |

The Spring Kodiak Trawl lead line spent most of its trawl time at depths between 3.6 and 5.5 ft (Table 6). The depth ranges outside of the aforementioned range likely represent a combination of equipment error and unusual circumstances occurring at the beginning and end of tows when the net relaxes and drops, and occurring during tows with net tension increases causing the lead-line to lift in the water column. Based on the relatively high proportion of time spent in the 3.6 to 4.0 ft range, the lead line achieves such shallow depths under relatively normal net tension. Based on proportion of time spent in different depth interval (Table 6), the SKT lead line depth appears more variable than the overall Standard Error suggests (cf. Table 5).

Table 6. Proportion of tow time the Spring Kodiak Trawl spent at each depth interval (all in the upper depth stratum) based upon depth logger data from the mid-point of the lead-line collected during the Gear Selectivity Evaluation Study, 2012-2015.

| Depth (ft) | Proportion of Active Tow Time |
|---|---|
| 1.5 - 2 | 0.02 |
| 2.1 - 2.5 | 0.02 |
| 2.6 - 3 | 0.02 |
| 3.1 - 3.5 | 0.05 |
| ***3.6 - 4*** | ***0.21*** |
| ***4.1 - 4.5*** | ***0.15*** |
| ***4.6 - 5*** | ***0.25*** |
| ***5.1 - 5.5*** | ***0.24*** |
| 5.6 - 6 | 0.02 |
| 6.1 - 6.5 | 0.02 |

The Chipps Island Midwater Trawl also exhibits some variation in depth during towing. The deepest values likely result from the net dropping rapidly during deployment in some instances then moving back through the water column to typical fishing depths (possibly represented by values bolded, Table 7) when under full tension during the tow. The bottom of the Chipps Island Trawl spends most of the tow in the 10-13 ft depth range, and only rarely more shallow (Table 7).

Table 7. Proportion of tow time the Chipps Island Midwater Trawl spent at each depth interval (generally in the upper depth stratum) based upon depth logger data from the lower port-side bridle collected during the Gear Selectivity Evaluation Study, 2012-2015.

| Depth (ft) | Proportion of Active Tow Time |
|---|---|
| 8.1 - 9 | 0.0010 |
| 9.1 - 10 | 0.0436 |
| ***10.1 - 11*** | ***0.3529*** |
| ***11.1 - 12*** | ***0.3574*** |
| ***12.1 - 13*** | ***0.1941*** |
| 13.1 - 14 | 0.0354 |
| 14.1 - 15 | 0.0115 |
| 15.1 - 16 | 0.0028 |
| 16.1 - 17 | 0.0005 |
| 17.1 - 18 | 0.0000 |
| 18.1 - 19 | 0.0005 |
| 19.1 - 20 | 0.0000 |
| 20.1 - 21 | 0.0003 |

## Products

Depth logger data and summary files (Excel Files)

These data will be reported in an IEP Newsletter article in the near future. The current draft text focuses too much on inconsequential detail, so will not be included in this package.

References All Final Report Objectives

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