MONITORING AND EVALUATION OF CURRENT AND HISTORICAL PHYSICAL HABITAT CONDITIONS, WATER QUALITY, AND JUVENILE SALMONID USE OF THE KLAMATH RIVER ESTUARY

FINAL REPORT

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INTRODUCTION

Estuarine environments play a vital role in the physiological adaptation of anadromous salmonids and provide an important feeding ground for juvenile salmonids prior to entrance into the ocean. Numerous estuaries on the west coast of North America have been documented to be essential in the rearing, maturation, and physiological functioning of anadromous salmonids and countless other fishes. Estuaries serve as an interface between fresh and salt water, and as such are the transitional environments where physiological and behavioral changes associated with migrating salmonids occur (i.e.: smoltification).

Historically, both the landscape in the Klamath River estuary and the abundance of fish were drastically different than current conditions. Thomas Gihon described the mouth of the Klamath River prior to European settlement as:

> "…..sheet of silver flowing swiftly on and mingling its waters with the Pacific just a few yards away. Looking upstream, we saw that the thick woods grew from the highlands down to the water's edge. In the distance we could see an Indian gliding along in his canoe……The river seemed alive with salmon and seal, yet here in this sequestered place was going on that interminable war, the struggle for existence. A seal would dive and presently appear with a salmon in his mouth, which he would thrash upon the water, breaking it to pieces. Then a cloud of gulls would swoop down upon him and seize the pieces, so that, surrounded with plenty, he had to fight for the little he got, like common humanity. We must have been the first white men that ever stood on that bank, and we saw the primeval forest undisturbed." (Holland 1996).

The Yurok People have inhabited the region surrounding the Klamath River estuary and relied on its resources for their subsistence, cultural, and economic livelihood since time immemorial. The Klamath River estuary serves as a nursery and physiological staging area for spring and fall-run chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), steelhead trout (*Oncorhynchus mykiss*), and coastal cutthroat trout (*Oncorhynchus clarki clarki*). It is likely that tens of millions of juvenile salmonids migrate through the Klamath estuary every year on their way to the ocean (Wallace 1995); therefore, the Klamath River Basin Fisheries Task Force identified the Klamath River estuary as a key habitat for Klamath and Trinity River anadromous salmonids (KRBFTF 1991). Other species such as green sturgeon (*Acipenser medirostris*), eulachon (*Thaleichthys pacificus*), and lamprey (*Lampetra tridentata*) are also important to the Yurok Tribe for cultural and subsistence purposes, although little research has been done to understand the status of these species in the Klamath River Basin and the effects that estuarine conditions may have on them.

During summer months, chronically elevated water temperatures in the mainstem of the Klamath and Trinity Rivers point to an even greater significance of Klamath estuary habitats as refugia from poor riverine conditions. Water quality within the Klamath River estuary is likely an important factor in the suitability of available habitat for outmigrating salmonids; however, available data are sparse regarding water quality parameters in the estuary and their effects on fish populations. Water quality in the Klamath River estuary was last addressed in detail during 1994 by the California Department of Fish and Game (CDFG), who concluded that high water temperatures from the mainstem Klamath were a concern (Wallace 1998). In addition, CDFG recommended the continuation of a "…monitoring program to assess the response of water quality parameters to…river flow and river mouth location along the spit…(Wallace 1998)."

Extensive assessment and monitoring activities have been implemented in the remainder of the Klamath-Trinity Basin, but with the exception of CDFG sponsored juvenile chinook studies (Mike Wallace), few comprehensive long-term studies have been completed in the estuary. Short-term CDFG studies such as the aforementioned Klamath River estuary water quality monitoring (1991-1994), juvenile chinook food preference research (1991-1992) and estuarine habitat typing efforts (1993-1994) underscore the need for better knowledge of whether conditions in the estuary are limiting factors for juvenile anadromous salmonids (Wallace personal comm. 2001).

Results obtained by Wallace (2000) indicate that rearing of juvenile chinook within the estuary tends to be brief, with mean residency time ranging between 8.7 - 16.2 days during studies conducted in 1997 - 1999. Poor water quality conditions and lack of preferred food items may be two primary factors that limit juvenile salmonid rearing in the estuary. Preliminary water quality and food availability studies conducted by CDFG reported high surface water temperatures reaching 24°C during summer months and a lack of preferred prey items for emigrating juvenile chinook during periods of outmigration, perhaps playing a role in the limiting residency of juvenile chinook within the estuary

The objectives of this project were to: 1) determine the physical changes in the Klamath River estuary size, shape, and habitat characteristics over time using GIS aerial photo analysis; 2) conduct sampling of fish populations present in the slough areas and within the deeper mid-channel waters of the estuary; 3) monitor and assess water quality parameters year-round within the estuary and surrounding sloughs; and 4) conduct a search for Klamath River estuary-related literature, historical data, and anecdotal observations and construct a narrative account of changes over time to the estuary.

LOCATION

The Klamath River estuary is located adjacent the town of Klamath, California. Township: 13N; Range: 1E; Section 5 (Figure 1). The estuarine environment extends approximately four to five miles upstream from the mouth of the Klamath River and is approximately one-half mile wide, on average.

METHODS

Juvenile Salmonid Sampling

We used a custom built purse seine to sample deeper mid-channel locations within the estuary to complement shoreline beach seining currently being conducted by CDFG. The purse seine, which was deployed from the bow of our research boat, was 200 ft long x 12 ft deep with ¼ inch mesh. Sampling began in Jun-02, but was sporadic during the 2002 field season due to logistical problems. A weekly schedule was established during the 2003 field season and five sampling stations were set up corresponding with CDFG beach seining activities. During sampling, all salmonids were placed in holding containers, anesthetized, measured to the nearest mm, weighed to the nearest 0.1g (during 2002), then placed in an aerated recovery container and released after recovery (Stickney 1983). Non-salmonids captured were enumerated by species and released.

Slough habitats were sampled using a variety of gear including minnow traps, a beach seine, and direct observations (snorkeling)(Hayes 1983, Hubert 1983). Minnow trapping was conducted during 2002 (February – October), but was not continued in 2003 due to poor performance. Beach seining was conducted during 2002 in April, October, and December. No sampling occurred during the late spring and summer months because of inaccessibility due to low flow conditions in the slough. Seining resumed in the south slough in Feb-03 and sampling occurred on an intermittent basis throughout the year. All salmonids captured were placed in holding containers, anesthetized, measured to the nearest mm, then placed in a recovery container and released after recovery (Stickney 1983). Non-salmonids captured during sampling were enumerated by species and released.

Juvenile chinook catch data from purse seine sampling was summarized by week-ending and mean fork length (mm) + / - standard deviation, mean weight (g) + / - standard deviation, and CPUE (chinook captured / set) were calculated. Weights were not taken in 2002, and some weight data from 2003 was not collected due to equipment malfunction. Week-ending summaries for other salmonids captured during purse seine sampling are included with the number captured and range of fork lengths (mm) and weights (g).

Data from south slough sampling (minnow trapping, snorkeling, hook and line, and beach seining) were not summarized due to the sporadic nature of sampling and differing sampling efficiencies. All data are presented by sample date, representing each salmonid captured.

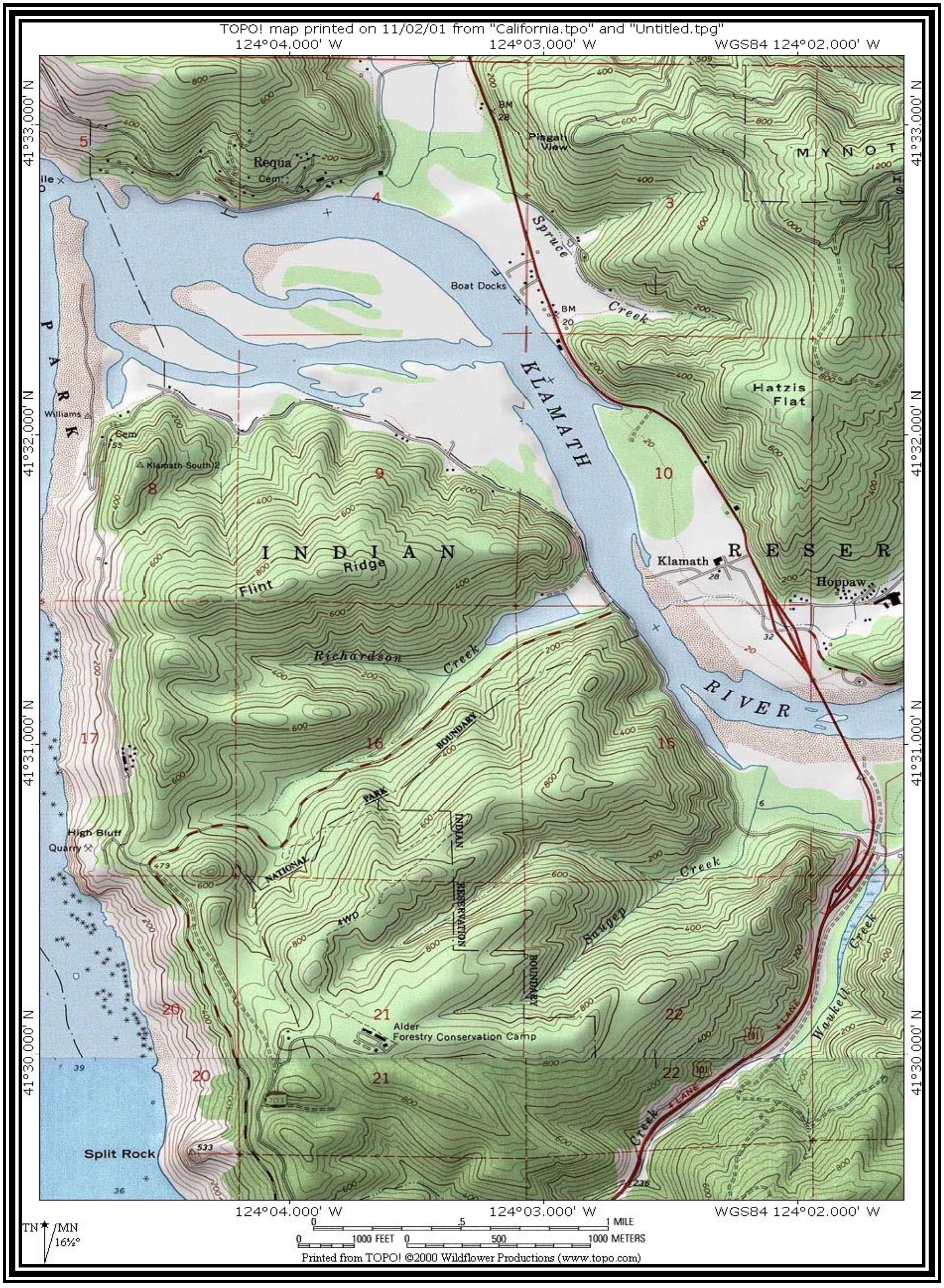


Figure 1. Location of the Klamath River Estuary, Klamath River, California

Water Quality Monitoring

Sampling locations were established using a handheld Geographic Positioning System (GPS)(Trimble, GeoExplorer 3). We divided the estuary into three main regions for sampling to remain consistent with previous CDFG studies: Lower (mouth upstream to Hunter Creek), Middle (Hunter Creek upstream to the Townsite Boat Ramp), and Upper (Townsite Boat Ramp upstream to the Highway 101 Bridge). Three sampling transects were established within each region, running perpendicular to river flow, and are abbreviated as follows: Lower (L1, L2, L3); Middle (M1, M2, M3); and Upper (U1, U2, U3). GPS Pathfinder software was used to establish five equally spaced sampling locations across each transect: a (nearest to left bank), b, c (center), d, and e (nearest to right bank)(Figure 2). It should be noted that the photograph used to depict site locations was not taken during the study period, and the location of the mouth of the Klamath River changes annually.

Sampling stations were also established in the south slough region of the estuary and lower reaches of Hunter Creek and Salt Creek that represent slough-like habitat and are tidally influenced. Five sampling locations were set-up in lower Salt Creek from the mouth upstream approximately 250 m. Six sampling locations were established in lower Hunter Creek from the mouth upstream approximately 0.6 km, ending just downstream of the bridge on Requa Rd. Sampling locations in the Hunter and Salt Creek sloughs are identified with station 1 located at the creek mouth and successively upstream locations numbered accordingly. Seven sampling locations were established in the south slough and are equally spaced from the inlet of the slough to the outlet in the lower estuary. Sampling stations in the south slough are numbered 1 through 7, with station 1 located near the inlet of the slough (approximate rkm 1.5) and station 7 located at the slough mouth in the southeast corner of the estuary bay (Figure 1).

Water quality monitoring was initiated in January 2002with bi-weekly sampling throughout the year, conditions and flow permitting. During summer months sampling occurred more frequently. Between the months of May and August, water quality data were collected during the highest (flood) and lowest (ebb) tide cycles of each month that were feasible to sample. We also sampled “mid” tide cycles, in which there is little difference between high and low tides. Monitoring during high and low tide cycles was conducted on two consecutive days (approximately 1-2 hours before the tide, during slack tide, and 1-2 hours after the tide) in order to sample the targeted tide effectively. “Mid” tide sampling was completed in one day since water levels did not fluctuate greatly.

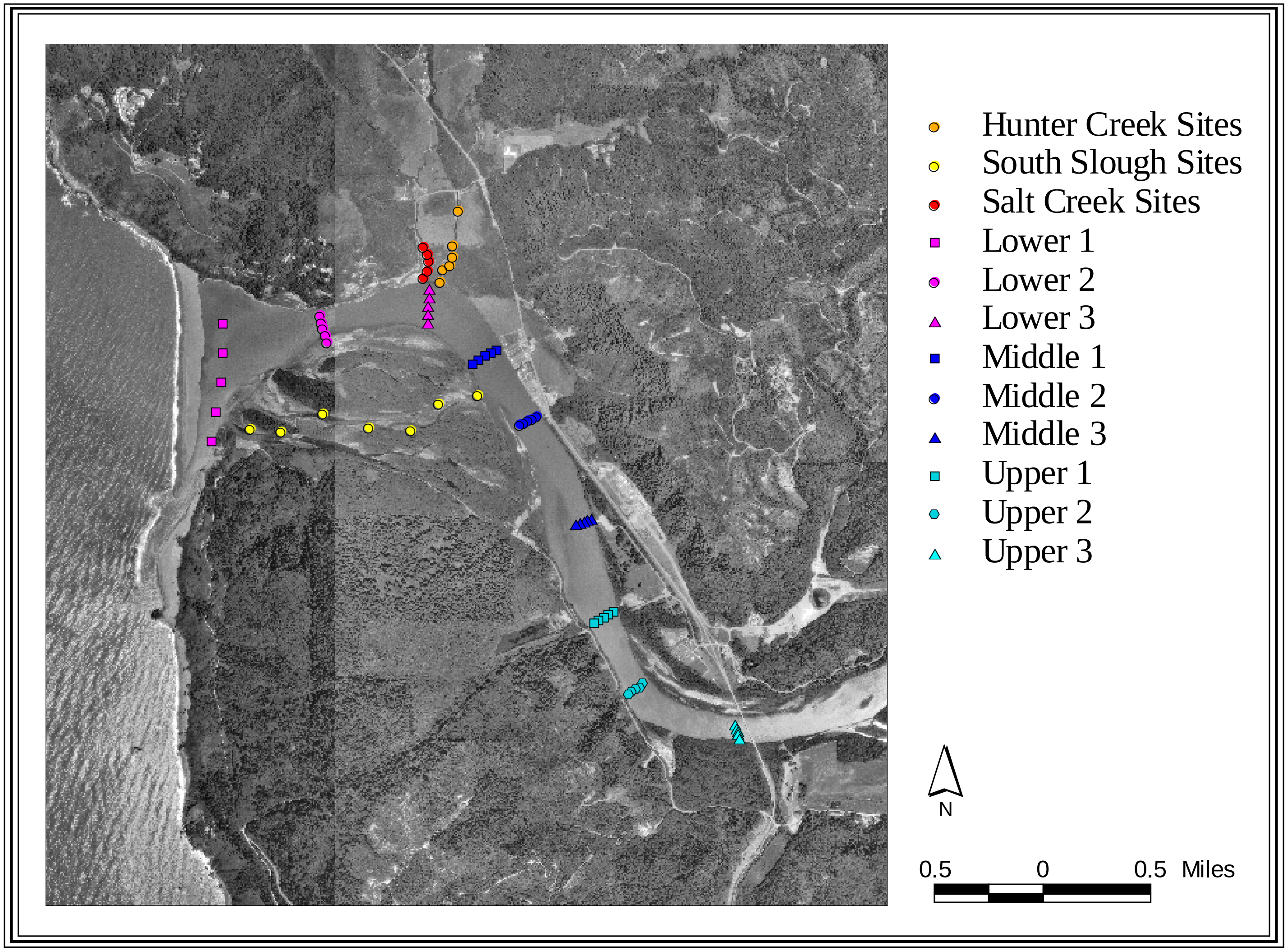


Figure 2. Water quality monitoring stations in the Klamath River Estuary and surrounding sloughs.

Water temperature (°C), dissolved oxygen (saturation and mg/L), conductivity (µS), specific conductivity (µS), and salinity (ppt) data were collected using an YSI® 85 water quality meter. At each sampling location, measurements were collected at the surface and every successive meter in the water column to the channel bottom. Water temperature was also recorded electronically using Optic StowAway TidbiT temperature recorders (Onset, -5° to 37°C Model) within each estuary region and in each slough. In the Lower estuary, temperatures were recorded at Requa; in the Middle estuary temperatures were recorded at the Townsite Boatramp; and in the Upper estuary temperature data was collected at the Highway 101 bridge. Temperature dataloggers deployed in the sloughs were at the following locations: Midway upstream in the south slough between stations 3 and 4; Lower Hunter Creek between stations 1 and 2; Salt Creek Slough at Station 5. Temperature loggers were secured to the bank using cable and anchored on the bottom substrate several meters from the bank. Temperature records from each location were used to calculate mean, minimum, and maximum daily temperature, and mean monthly temperature

GIS Aerial Photo Analysis

The Image Analysis module was used in *ArcView 3.3* to rectify each image in the project area (mouth of the Klamath River to the current location of the Highway 101 bridge) and bring it into map space. The base layer used to rectify the images was the 1993 USGS Digital Orthophoto Quad (DOQ) Requa layer. The Requa layer is actually parsed into four (4) quarter quads and is included in the deliverables of this project. The quarter quads cover an area measuring 3.75-minutes longitude by 3.75-minutes latitude and have 1-meter ground resolution. For creating estuary polygons, thirty-nine scanned images were rectified using an affine transformation. Aerial photographs were generally taken during summer months, however, differences in river flow and tidal stage may affect polygon calculations made from image measurements.

The images were scanned at 300 dpi, grayscale. Four control points were acquired in each image and the target RMS error was less than 1 (one). With an RSM error of 1, the rectified pixel is within one pixel of the desired location. The pixel size of images in this project varied from 1 to 2 meters, meaning that the RMS error ranged from 1 to 2 meters at the control points. After rectification, the rectified image was compared with the base image as to difference in distance between common points. Any distance over 12 meters was considered unacceptable, and areas with such differences were avoided during digitizing. Images with large distance differences across the majority of the photo were re-rectified until the differences were satisfactory (less than 12 meters in areas needed for digitizing). Rectification produced an IMG (*ERDAS IMAGINE* type) file, which was saved to the TIFF format, with an accompanying TFW file being generated. The TFW file contains the real world coordinates and is named the same as the TIFF file.

Empty polygon shapefiles were generated in *ArcCatalog 8.2*, one shapefile each for the following years:

Year	Shapefile Name
1936	hydro36.shp
1948	hydro48.shp
1954	hydro54.shp
1963	hydro63.shp
1969	hydro69.shp
1972	hydro72.shp
1985	hydro85.shp
1993	hydro93.shp
2001	hydro01.shp

The following attributes were added to the shapefiles:

Field Name	Data Type	Comments
TYPE	Text	The polygon-geography type. Domain: Estuary, Slough, Spit, Island
IMAGENUM	Text	Image(s) used to digitize the polygon. Concatenation of the flight line and number.
AREA	Double	Area of each polygon in square meters

The projection of each shapefile was set at UTM NAD 27, Zone 10. Digitizing was done in *ArcMap 8.2*. The view scale was set to 1500 meters for all digitizing. Of the 39 images rectified, 31 were chosen for use in digitizing. 0f those 31, five had RMS errors slightly greater than one, but again, any area of the photograph with distance differences between common points of greater than 12 meters was not used during digitizing. For polygons depicting water, the polygon boundary was digitized to be coincident with high-tide marks wherever possible for the purpose of standardization. All shapefiles have a southwestern terminus at the same point: a rocky outcrop approximately 550 meters southwest of Williams Rock. ‘Estuary’ polygons were digitized in a clockwise manner, beginning at the north side of the mouth, where the mouth meets the ocean and in all cases more than one polygon was needed to digitize the entire estuary. Consequently, the record for each polygon in the shapefile data table, for the field IMAGNUM, denotes the order of the images used in the same manner as digitizing (clockwise from same starting point). After completing each polygon, the TYPE and IMAGENUM fields were calculated. After all polygon line work was completed, the AREA field was calculated using the Field Calculator tool in *ArcMap 8.2*. A special GIS CD with all yearly coverages and calculations is accompanying this written report.

RESULTS

Timeline and Description of Historic Changes in the Lower Klamath River

Pre-1850 – For longer than can be remembered, the estuary was inhabited by Yurok People, whom depended upon the resources of the Klamath River for subsistence, commercial, and ceremonial purposes. Runs of salmon, steelhead, lamprey, sturgeon, and eulachon were abundant.

1850 – The land party from the *Cameo*, made up of Herman Ehernberg, J.T. Tyson, William Bullis, A. Heepe, and Mr. Bunus arrived at the Klamath River. They described the river as three-quarters of a mile wide with islands breaking the even flow of the water. The islands, riverbanks, and mountains were covered with thick brush and giant redwoods. Breakers off the mouth of the river outlined the sandbar, but a patch of smooth water showed an entrance three hundred yards wide (McBeth 1950).

The party was interested in establishing a city at the mouth of the river and made soundings at the river mouth and found it to be twenty feet deep at low tide. The men thought that the depth of the river would make a good harbor and city site. Mr. Ehernberg laid out the streets and lots of Klamath City, which was on the north bank of the river. He made reservations for schoolhouses, public buildings, and public squares. Twenty houses were constructed, but many were content to live in tents, and farm plots were cleared and planted. An iron house was also brought in and set up in town as a place of protection (Holland 1996, McBeth 1950).

A letter in the *Public Daily News, Klamath City, December 21, 1850* states that "the river will surely attract trade and travel to the mines. It is navigable for streamboats some sixty or eighty miles, almost to the very heart of the mining region" (McBeth 1950).

1850 – Charles Young arrived and hired Thomas Gihon and Charles Young to clear the forest and lay out a townsite on the south bank of the river, competing with Klamath City, which was on the north bank a mile upstream (Holland 1996).

1851 – The town of Klamath City was abandoned before it was a year old, having cost thousands of dollars and twenty-nine settlers had already died there (McBeth 1950).

1852 – George Gibbs says of the Klamath River mouth that no settlement can be maintained there as the shifting sands are liable during any winter storm to close it almost entirely. He sited an instance during the winter of 1850 – 1851 when a bar formed across the mouth, preventing access. However, during the summer of 1850 there was 15 ft of water at the channel entrance (Holland 1996).

1861 – Large flood in the Klamath during which time the river rose 120 feet. Bureau of

Indian Affairs at Waukell and Fort Terwar destroyed (McBeth 1950).

1864 – A letter was published in *The Alta California*, *June 9, 1864* stating that the river mouth is obstructed by a bar which shifts at every storm, and on one occasion the mouth closed up entirely and men walked across the entire spit. The river rose up until it ran over the bar and created a new outlet (McBeth 1950).

1876 – The first fishery by European settlers was established in the estuary in the fall, when Martin Jones and George Richardson started doing business by catching and salting fish for the market (McBeth 1950).

M.G. Tucker runs a toll ferry across the mouth of the Klamath, but there are records that he has difficulties persuading the Native Americans to let him continue operation.

1881 – 1890 Several sawmills and fish salteries/canneries were opened in the vicinity of the Klamath River estuary and mouth. Records also indicate that by 1894 there was a Post Office and hotel. A sawmill was also located on Hunter Creek and on the slough of Hunter's Creek near Requa. (McBeth 1950).

1887 – There was no record of M.G. Tucker's ferry, and the Native Americans now run a ferry across the river.

1890's (unknown date) – A small hatchery was established by R.D. Hume on an unspecified stream near the mouth of the Klamath River. Large quantities of eggs (from the Rogue River near Grants Pass) were successfully hatched and reared for approximately one year before releasing into Hunter Creek, High Prairie Creek, and the mainstem Klamath near the mouth (Snyder 1931).

1892 – An article from the *Del Norte Record* published on March 19, 1892 states that "trout ought to be plentiful in the Klamath River in a year or so as the Government hatchery has turned a large number into the river." (McBeth 1950).

1895 – In December, Bailey and Fortain signed a contract for running the Klamath ferry operation near the mouth of the river. The plans for the ferry included a cable system, but in February of 1896 the cable was found to be too short and further work was postponed (McBeth 1950). The cable ferry was completed, but no exact date could be found.

1912 – Three salmon canning/packing plants were in operation in the Klamath River estuary: Klamath River Canning Company, Del Norte Salmon Canning Company, and Klamath River Packing Company. Klamath River Packing Company was located on the north bank of the mainstem at the current location of the Yurok Tribe's Requa Resort. The Del Norte Salmon Canning Company and Klamath River Canning Company were located on the west bank of the Hunter Creek slough. Between the tree canneries, a total of 44,522 cases of one-pound cans were packed during the season (Snyder 1931).

1913 – The Klamath River Packing Company harvested 28,593 adult chinook between June and September (Snyder 1931).

1914 – The Klamath River Packing Company caught 63,508 adult chinook between June and 6-Sept, then caught an additional 361,184 lbs of chinook and coho (approximately 27,000 fish). The total number of adult chinook and coho harvested would have been approximately 90,000 fish (calculating average size at 13 lbs)(Snyder 1931).

1915 – The Klamath River Packers Association reportedly harvested a total of 1,232,229 lbs of chinook and coho in the estuary, totaling approximately 92,000 fish. Fish were harvested using a fleet of 40 boats (Snyder 1931).

1916 – The Klamath River Packers Association reported harvesting 668,131 lbs of salmon, totaling approximately 51,000 adult fish (Snyder 1931).

1917 – Reports to the Fish and Game Department indicate a total of 265,537 chinook and coho harvested in the estuary, along with 1,710 lbs of steelhead (Snyder 1931).

1918 – Total fish harvested by the Klamath River Packers Association and Requa Cooperative Packing Company was 672,345 lbs (approximately 51,000 adult chinook and coho)(Snyder 1931).

1919 – A new contract for the Klamath ferry operation was agreed upon with Dave Ball constructing the ferry and Stacey Fisher operating it (McBeth 1950).

1920's – Sport fishing begins to interest a large part of the State of California.

1920 – Klamath River Packers Association reportedly harvested 54,373 chinook and coho salmon (Snyder 1931).

1921 – Klamath River Packers Association reportedly harvested 42,996 chinook and coho salmon. Del Norte Packing Company reported harvesting an additional 10,148 lbs of salmon (approximately 780 fish)(Snyder 1931).

1922 – A total of 1,039,680 lbs of chinook and coho, along with 2,345 lbs of steelhead, were reportedly harvested by the Klamath River Packers Association and Del Norte Packing Company, (Snyder 1931).

1924 – Work began on the original Klamath River Bridge in July (McBeth 1950).

1926 – A total of 126 boats operated by several canneries harvested 811,714 lbs of adult salmon (approximately 62,000 fish). Numbers of returning chinook and coho are declining, as evident by the increased effort needed to catch fewer fish (comparing 1915 catch with 1926)(Snyder 1931).

1933 – The California Department of Fish and Game prohibits commercial fishing on the Klamath River and prohibits the use of gill nets on the lower 20 miles.

1936/1937 – A wing dam was constructed with rock pilings and extends approximately 400 m off the south bank of the estuary directly upstream of the estuarine embayment. This structure remained in place for many years and was washed away in three segments during 1953, 1955, and the final piece was washed out in 1964 (Chuck Williams, personal communication).

1953 – Flood in January that inundated the town of Klamath and the Klamath Glen. Approximately 500 people were evacuated and the destruction of lumber mills and other places of employment caused economic hardship (United States Committee on Public Works 1965).

1955 – Flood in December during which time approximately 700 acres of agriculture land was inundated in the delta area. The communities of Klamath and Klamath Glen were almost completely destroyed. The north approach of the Douglas Memorial Bridge crossing Highway 101 was washed out (United States Committee on Public Works 1965).

1964 – Flood in December causes total devastation of Klamath, Klamath Glen, Requa, and Camp Klamath. Huge agricultural losses due to loss of crops and pastureland from scouring and silt deposits and also considerable livestock losses. The Douglas Memorial Bridge is destroyed (United States Committee on Public Works 1965).

1972 – Construction of the Klamath River Bank Protection Project was initiated in July and completed in November. The project included installation of riprap from the town of Klamath downstream past the Requa Inn to protect against erosion due to river flows (United States Army Corps of Engineers 1997).

1977 – The Bureau of Indian Affairs issued regulations re-opening the gill net fishery on the Klamath River for subsistence and commercial harvest.

1978 – The Bureau of Indian Affairs placed a conservation moratorium on commercial fishing on the Reservation.

1987 – The conservation moratorium placed by the Bureau of Indian Affairs on Tribal commercial harvest is lifted, and the Yurok commercial gill net fishery reopens under BIA regulation.

1988/1989 – The last noticeable runs of eulachon were observed in the Klamath River estuary by Tribal fishers (Larson and Belchik 1998)

Juvenile Salmonid Sampling

<u>Purse Seine Sampling</u>

Purse seine sampling in the Klamath River estuary was relatively unsuccessful in 2002 due to sporadic sampling, weather and flow conditions, and the experimental nature of gear and sampling techniques. Fewer than ten juvenile chinook were captured during May, June, July, and early August sampling attempts, with CPUE (# chinook/set) ranging between 0 – 2.67. However, on 16-Aug, 30 chinook were captured, increasing the CPUE to 10 (Table 1). Mean fork length varied little for chinook captured between June and August, ranging between 89.20 – 94.25 mm (Figure 3). Lengths ranged between 88 – 98mm for week-ending 21-Jun; 81 – 109mm for week-ending 26-Jul; 81 – 100mm for week-ending 2-Aug; and 80 – 111mm during week-ending 16-Aug. Juvenile chinook with adipose clips were only observed during week-ending 26-Jul, when two fish with clips were captured.

Table 1. Summary of juvenile chinook catch data from purse seine sampling in the Klamath River estuary during 2002.

Week Ending	Number of Sets	Chinook N	Ad Clips N	CPUE (chinook/set)	FL Range (mm)	Mean FL +/- st dev
23-May-02	2	0	0	0.00		
31-May-02	No Sampling					
7-Jun-02	3	0	0	0.00		
14-Jun-02	No Sampling					
21-Jun-02	3	4	0	1.33	88 - 98	94.25 +/- 4.35
28-Jun-02	No Sampling					
5-Jul-02	1	0	0	0.00		
12-Jul-02	No Sampling					
19-Jul-02	No Sampling					
26-Jul-02	3	8	0	2.67	81 - 109	91.63 +/- 8.03
2-Aug-02	3	5	2	1.67	81 - 100	89.20 +/- 7.43
9-Aug-02	No Sampling					
16-Aug-02	3	30	0	10.00	80 - 109	92.33 +/- 8.85

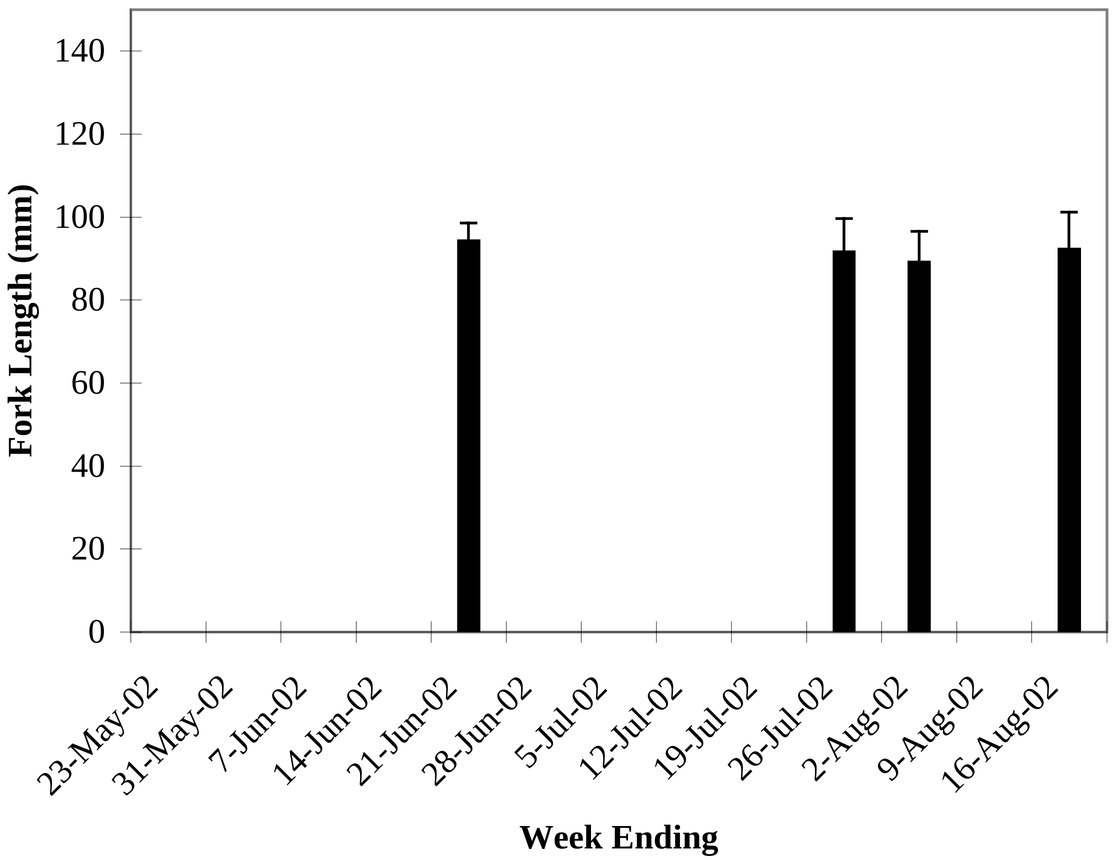


Figure 3. Mean fork length and standard deviation of chinook subyearlings captured during purse seine sampling in the Klamath River estuary during 2002.

Other salmonid species captured during purse seine sampling in 2002 included coho, cutthroat, steelhead, and brown trout. A total of five coho were captured: four during week-ending 23-May (ranging between 126 – 173mm) and one during the week-ending 21-Jun (fork length of 192mm and a right maxillary clip indicating Trinity River hatchery origin). A total of 74 cutthroat trout were captured, all during the week of 21-Jun. Of the 74 cutthroat trout captured, a subsample of 12 fish were measured and ranged in length between 145 – 265mm. A total of 65 steelhead were captured during 2002, including three “half-pounders” and two adults. Three steelhead were captured during the week-ending 23-May, ranging between 162 – 226mm, with one fish marked with an adipose clip. The majority of the juvenile steelhead observed were captured during the week-ending 21-Jun, when 57 steelhead were observed. Of the 57, ten were subsampled and ranged in length between 102 – 220mm. Five steelhead were captured during the week-ending 16-Aug—three “half-pounders” and two adults. Three juvenile brown trout were also captured, all during the week-ending 21-Jun.

Purse seine sampling in 2003 began in April, although weather and flow conditions prevented consistent weekly sampling until June. Weekly sampling was also occasionally postponed due to excessive wind or river current, and access to sites was sometimes limited during sampling due to algal abundance, tidal stage, or presence of snagging debris on the channel bottom. Catch per unit effort of chinook remained low ($\leq$ 4 chinook/set) through the week of 18-Jul (Table 2). Nine subyearling juvenile chinook were observed during sampling in April (Figure 4). No sampling occurred during the first two weeks in May, however, one yearling juvenile chinook was captured during the week-ending 16-May. Sampling was not conducted during the week of 23-May, and no chinook were observed during the following three weeks of sampling (weeks ending 30-May, 6-Jun, and 13-Jun). We began capturing small numbers of chinook during late June, with 12 captured during the week of 27-Jun and 2 captured during week-ending 4-Jul (Table 2, Figure 5). No juvenile chinook were observed during the week of 11-Jul and sampling was not conducted during the week of 18-Jul (Table 2).

The peak abundance of juvenile chinook was observed during week-ending 25-Jul (Figure 4). A total of 123 juvenile chinook were captured, increasing CPUE to 30.75 (Table 2). Juvenile chinook abundance remained relatively high through the week-ending 1-Aug, when a total of 101 fish were captured (CPUE = 25.25). Juvenile chinook abundance tapered during the week of 8-Aug, when only 35 juvenile chinook were captured (CPUE = 7). No sampling was conducted during the week of 15-Aug, but we continued to capture chinook during subsequent sampling through the week-ending 19-Sept. Catch per unit effort ranged between 1.6 – 5.6 between the weeks of 22-Aug and 19-Sept, when sampling was concluded (Table 2).

The number of adipose clipped fish observed increased as the number of juvenile chinook captured increased (Table 2, Figure 4). One chinook (of nine captured) during the week-ending 18-Apr was marked, but no additional marked chinook were observed until the week-ending 25-Jul. During the week of 25-Jul, when the peak abundance of chinook was observed, 24 adipose clipped chinook (of 123 captured) were observed. During the week-ending 1-Aug, 6 of the 101 chinook possessed an adipose clip. Two adipose clipped chinook were observed during the week-ending 8-Aug (of 35 captured), but none were observed during sampling in the weeks of 22-Aug and 29-Aug (Table 2). Subsequent sampling during the weeks ending 12-Sept and 19-Sept yielded a total of three adipose clipped chinook (Table 2).

Size trends were observed for chinook subyearling captured throughout the sampling season. Weekly mean fork length ranged between 96.67 – 98.50 mm for fish captured during the weeks of 18-Apr, 27-Jun, and 4-Jul (Table 2). Mean fork length decreased during late July and early August. During sampling prior to late July, fish size ranged between 90 – 105 mm. Fish captured during the weeks of 25-Jul, 1-Aug, and 8-Aug ranged between 82 – 108 mm, 74 – 112 mm, and 81 – 114 mm, respectively (Table 2). An increasing trend in fish length was observed beginning the week of 22-Aug, when mean fork length was 100.50 mm and individual fish ranged between 89 – 108 mm. Fish size increased progressively through the end of the sampling season, and by the week-ending

19-Sept, chinook fork length ranged between 102 – 135 mm and mean fork length was 115.32 mm (Table 2, Figure 5).

Trends in subyearling chinook weight data were similar to trends in fork length data, but more pronounced (Figure 6). Weekly mean weight was 10.46 g for the week of 18-Apr, with fish ranging between 8.9 – 15.0 g. Mean weights for the weeks of 27-Jun, 4-Jul, and 25-Jul were 9.84, 12.00, and 9.94 g, respectively (Table 2). Fish weight was the lowest overall during the week of 8-Aug, ranging between 5.6 – 16.3 g with a mean value of 8.83 g (Figure 6, Table 2). Similar to fish length, however, fish weight began to increase for fish captured during the week of 22-Aug and increased progressively through the end of the sampling season (Figure 6). Fish weight was highest during September, with fish captured during the week of 12-Sept ranging between 9.5 – 40.9 g, and chinook captured during the succeeding week ranged between 11.1 – 22.4 g (Table 2). Mean weight for fish captured during the weeks of 12-Sept and 19-Sept was 16.52 g and 16.56 g, respectively (Table 2).

Table 2. Summary of juvenile chinook catch data from purse seine sampling in the Klamath River estuary during 2003.

Week Ending	Number of Sets	Chinook N	CPUE (chinook/set)	FL Range (mm)	Mean FL (mm) +/- st dev	Wt Range (g)	Mean Wt (g) +/- st dev
18-Apr-03	4	9	2.25	94 - 104	98.22 +/- 3.56	8.9 - 15.0	10.46 +/- 1.86
25-Apr-03	No Sampling						
2-May-03	No Sampling						
9-May-03	No Sampling						
16-May-03	2	1	0.5	172	172	No Data	
23-May-03	No Sampling						
30-May-03	3	0	0				
6-Jun-03	4	0	0				
13-Jun-03	3	0	0				
20-Jun-03	No Sampling						
27-Jun-03	3	12	4	90 - 105	96.67 +/- 4.72	8.2 - 13.5	9.84 +/- 1.82
4-Jul-03	5	2	0.4	96 - 101	98.50 +/- 3.53	10.5 - 13.5	12.00 +/- 2.12
11-Jul-03	3	0	0				
18-Jul-03	No Sampling						
25-Jul-03	4	123	30.75	82 - 108	92.90 +/- 5.40	7.3 - 15.3	9.94 +/- 1.80
1-Aug-03	4	101	25.25	74 - 112	89.93 +/- 5.97	No Data	
8-Aug-03	5	35	7	81 - 114	92.66 +/- 5.93	5.6 - 16.3	8.83 +/- 1.99
15-Aug-03	No Sampling						
22-Aug-03	5	8	1.6	89 - 108	100.50 +/- 5.98	8.5 - 14.4	11.60 +/- 2.00
29-Aug-03	5	12	2.4	93 - 119	104.00 +/- 7.54	9.4 - 20.4	13.49 +/- 2.83
5-Sep-03	No Sampling						
12-Sep-03	5	28	5.6	94 - 142	110.89 +/- 9.91	9.5 - 40.9	16.52 +/- 6.06
19-Sep-03	5	22	4.4	102 - 135	115.32 +/- 3.57	11.1 - 22.4	16.56 +/- 3.57

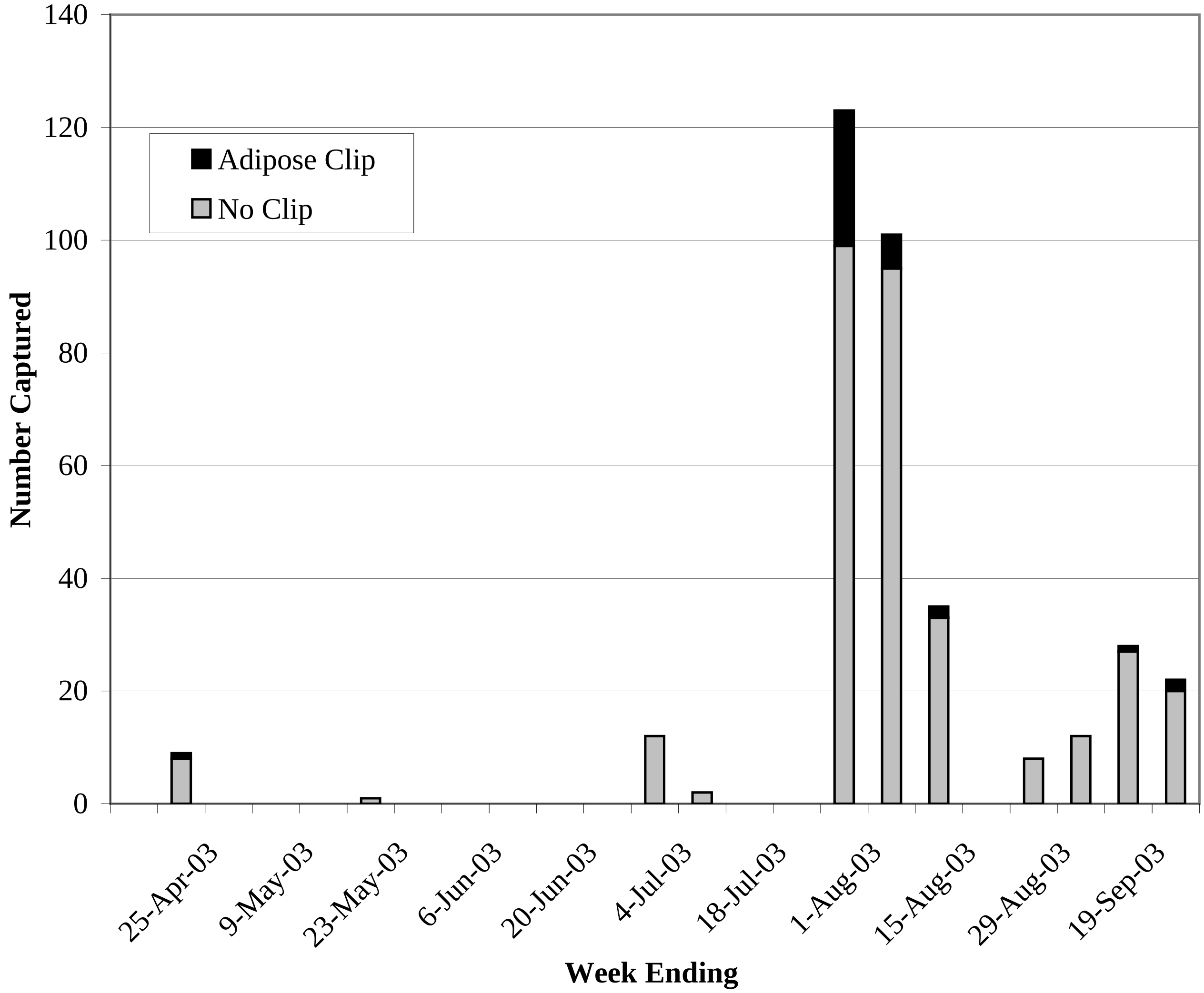


Figure 4. Total chinook subyearlings captured (adipose clip vs. no clip) during purse seine sampling in the Klamath River estuary during 2003.

South Slough Sampling

Juvenile chinook, coho, steelhead, and cutthroat trout were captured using various sampling techniques, but most commonly via hook and line and beach seining. Minnow trapping was conducted during 2002 (February – October), but was not continued in 2003 due to poor performance. No sampling occurred during late spring and summer months because of inaccessibility due to low flow conditions in the slough. Seining resumed in the south slough in Feb-03 and sampling occurred on an intermittent basis throughout the year.

Steelhead and cutthroat trout were commonly observed in the south slough, and were the only salmonids documented to inhabit the slough during winter months (Table 3). Juvenile chinook were observed during beach seine sampling on 11-Apr-02, 9-Jul-03, and 11-Aug-03. Wild coho young of the year (YOY) were also observed in the slough during sampling on 8-May-03 (Table 3).

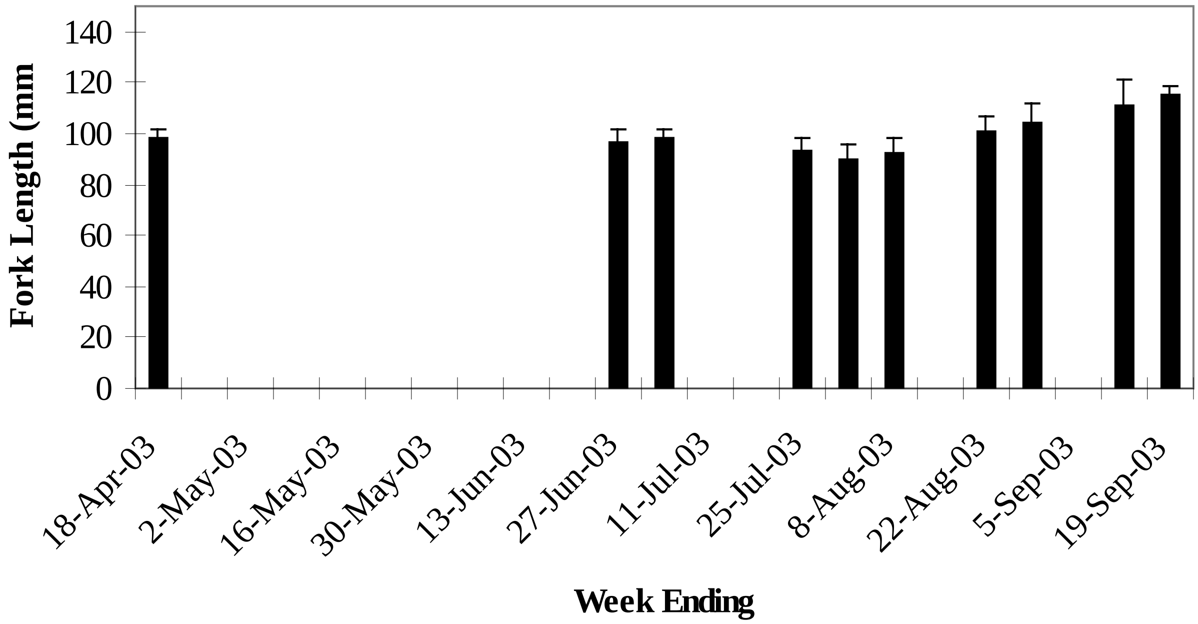


Figure 5. Mean fork length and standard deviation of subyearling chinook captured during purse seine sampling in the Klamath River estuary during 2003.

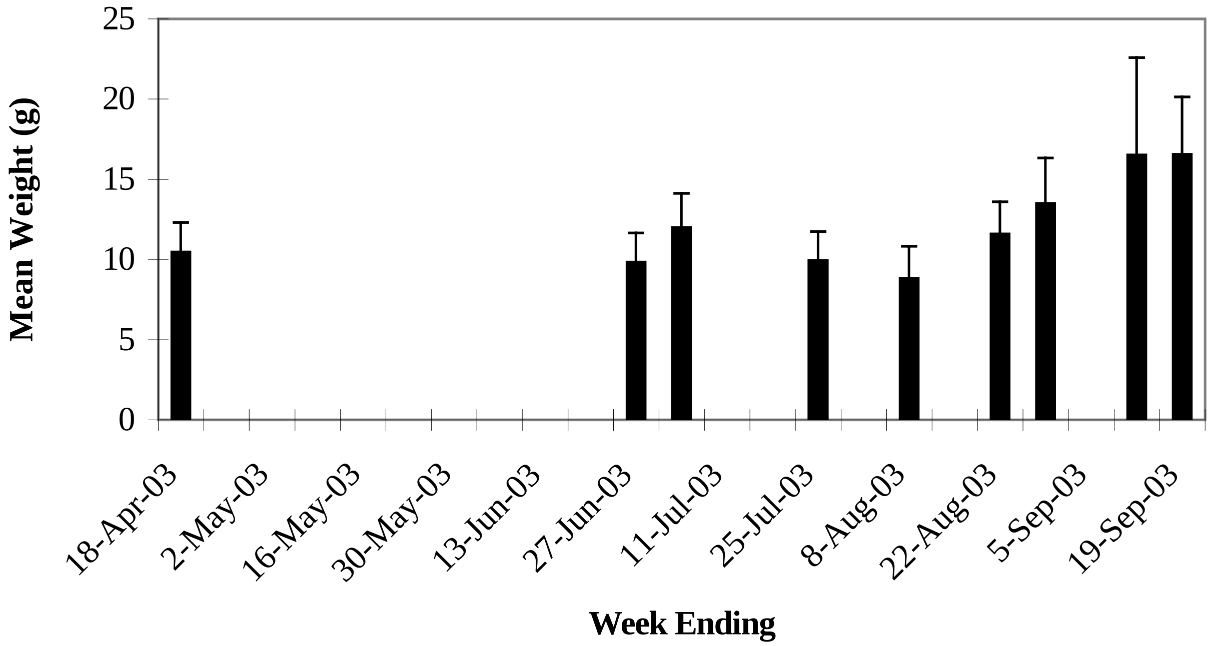


Figure 6. Mean wet weight and standard deviation of subyearling chinook captured during purse seine sampling in the Klamath River estuary during 2003.

Table 3. Results of hook and line, beach seine, and minnow trap sampling in the south slough of the Klamath River estuary during 2002 and 2003.

Date	Survey Method	Species	Number Captured	FL Range (mm)	Wt Range (g)
5-Feb-02	Hook and Line	Steelhead	4	170 - 400	
6-Feb-02	Hook and Line	Steelhead	1	250	
8-Feb-02	Hook and Line	Cutthroat	12	187 - 435	
		Steelhead	5	185 - 232	
19-Feb-02	Hook and Line	Steelhead	2	247 - 248	
22-Feb-02	Minnow Trap	No Salmonids Captured			
28-Feb-02	Minnow Trap	No Salmonids Captured			
28-Feb-02	Hook and Line	No Salmonids Captured			
10-Apr-02	Hook and Line	Steelhead	1	191	
10-Apr-02	Beach Seine	No Salmonids Captured			
11-Apr-02	Beach Seine	Chinook	1	140	
		Cutthroat	8	114 - 176	
28-Oct-02	Beach Seine	No Salmonids Captured			
22-Nov-02	Beach Seine	No Salmonids Captured			
5-Dec-02	Beach Seine	Cutthroat	9	260 - 370	
		Steelhead	2	180 - 260	
11-Feb-03	Beach Seine	Steelhead	7	167 - 182	
4-Mar-03	Beach Seine	No Salmonids Captured			
8-May-03	Beach Seine	Cutthroat	2	66 - 70	
		Coho	2	54 - 56	
24-May-03	Beach Seine	No Salmonids Captured			
9-Jul-03	Beach Seine	Chinook	4	95 - 100	8.8 - 9.7
		Cutthroat	2	145 - 149	26.1 - 34.9
		Trout Fry	1	54	1.7
8-Aug-03	Beach Seine	Cutthroat	5	128 - 163	19.6 - 34.1
		Steelhead	2	138 - 169	38.8 - 52.4
11-Aug-03	Beach Seine	Chinook	4	93 - 102	9.5 - 13.0
		Cutthroat	1	132	25.0
		Steelhead	1	90	8.0

Water Quality Monitoring, Klamath Estuary

Temperature

Due to equipment failure during 2002, the only electronic temperature data retrieved was from our upper estuary Onset Tidbit recorder. Records from water quality monitoring show that water temperature remained below 10°C through mid-March, with mean monthly temperatures of 6.84°C, 7.56°C, and 8.29°C calculated from electronic temperature data for January, February, and March, respectively. Mean monthly temperatures during April and May were 11.27°C and 13.35°C, respectively. Temperatures in the upper estuary began warming significantly in June, when the minimum and maximum temperatures recorded were 15.73°C and 23.37°C, respectively (Figure 7). Mean monthly temperatures in the upper estuary during June, July and August were 17.89°C, 20.97°C, and 20.19°C, respectively. Maximum temperatures recorded during July and August were 24.74°C and 23.88°C, respectively.

Temperatures in the upper estuary began cooling in September, when the mean monthly temperature dropped to 18.84°C and minimum and maximum temperatures were 16.68°C and 23.37°C (respectively). Water temperatures were averaging between 16-17.45°C in early October, were cooled to 14°C by mid-month and had dropped to 10°C by the end of the month. Average daily temperature during November and December were 9.52°C and 7.99°C, respectively (Figure 7).

Temperature is most variable in the lower region of the estuary due to saltwater intrusion and the formation of a salt wedge, which stratifies the water column. During winter months, stratification of the water column results in warmer ocean waters on the bottom of the channel with cooler freshwater on top. During sampling in December of 2001, there was a 0.8°C difference between surface and bottom temperatures. During January of 2002, temperature differences ranged between 0.1 – 1.2°C, and during November 2002 water on the bottom of the channel was between 0.4 – 1.6°C warmer than surface temperatures.

During summer months, the presence of a salt wedge in the estuary forms a cooler saltwater layer along the bottom of the channel, which may provide thermal refugia from warm surface temperatures. During June, July, and August of 2002, differences of 0.7-5.6°C were observed between surface and bottom temperatures in the lower estuary, except on 3-Jul (Figure 8). During Jul-3, uniform temperatures were observed throughout the water column except at sampling stations L2a and L2b. At these stations, bottom temperatures were 14.1°C and 14.6°C (respectively) and surface temperatures were 20.9°C.

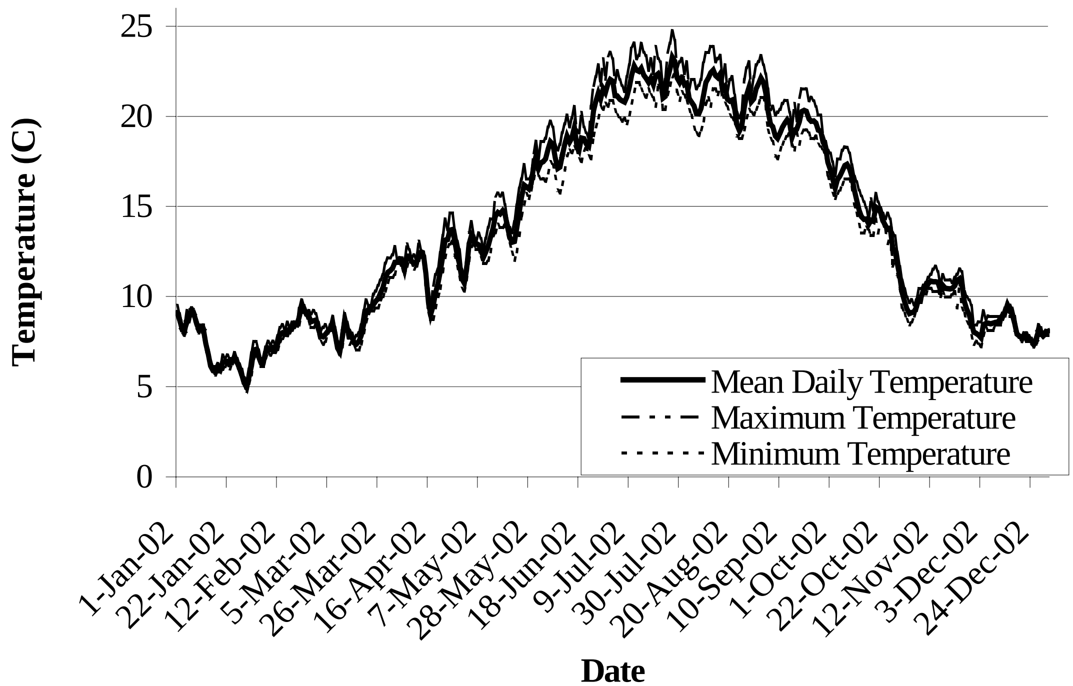
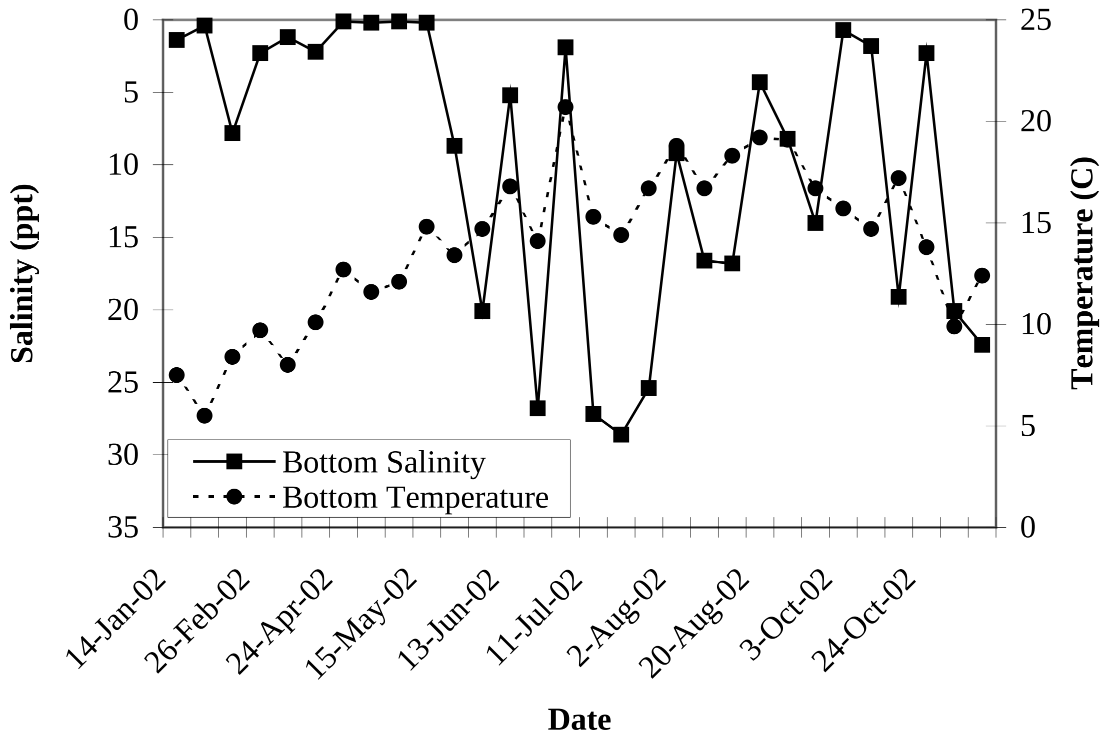


Figure 7. Minimum, maximum, and mean daily temperatures recorded in the Upper Klamath River estuary at the Highway 101 Bridge during 2002.

Salinity

Stratification in the estuary varies seasonally, but to some extent is almost always present due to tidal influence. Between January and mid-June, saltwater intrusion was only present at the sampling transect closest to the ocean (L1), probably due to increased freshwater flow prohibiting tidal influx. Salinity measurements collected in the L1 during those months were between 0.0 – 0.1ppt in surface readings and ranged between 0.2 – 25.1ppt along the river bottom. The saltwedge moved upstream beyond Transect 1 during June, at which time low salinity levels between 0.3-0.5ppt were observed upstream to Transect M3 (Townsite Boatramp; Figure 2).

The presence of a saltwedge in the middle and upper estuary occurs mainly during summer months when freshwater flows are lowest. The first substantial salinity observation above Transect L1 occurred on 18-Jun, when salinity measurements of 24.5ppt were observed along the bottom of the channel at Transect M1 (Figure 9). Sampling on 3-Jul showed that the saltwedge did not extent beyond L2, however, a saltwedge was reestablished by sampling on 11-Jul up to Transect M3 and was persistent into the middle transects through October. Sampling on 3-Oct only detected saltwater intrusion up to Transect L2, where a salinity measurement of 20.7 was observed along the bottom of the channel. Subsequent sampling during October and early November showed that the saltwedge reestablished up to Transects M2 and/or M3 until 13-Nov, when it was only detected upstream to Transect L3 (Figure 9).



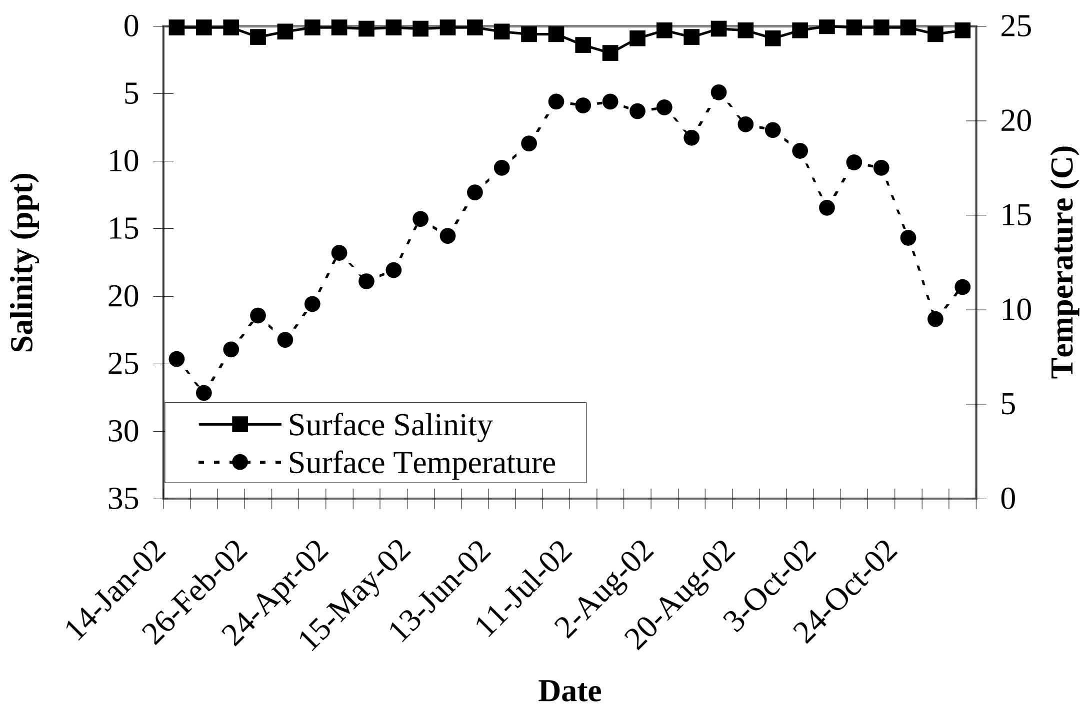


Figure 8. A comparison of bottom temperature/salinity (top graph) and surface temperature/salinity (bottom graph) observed during water quality monitoring at Station L1d during 2002.

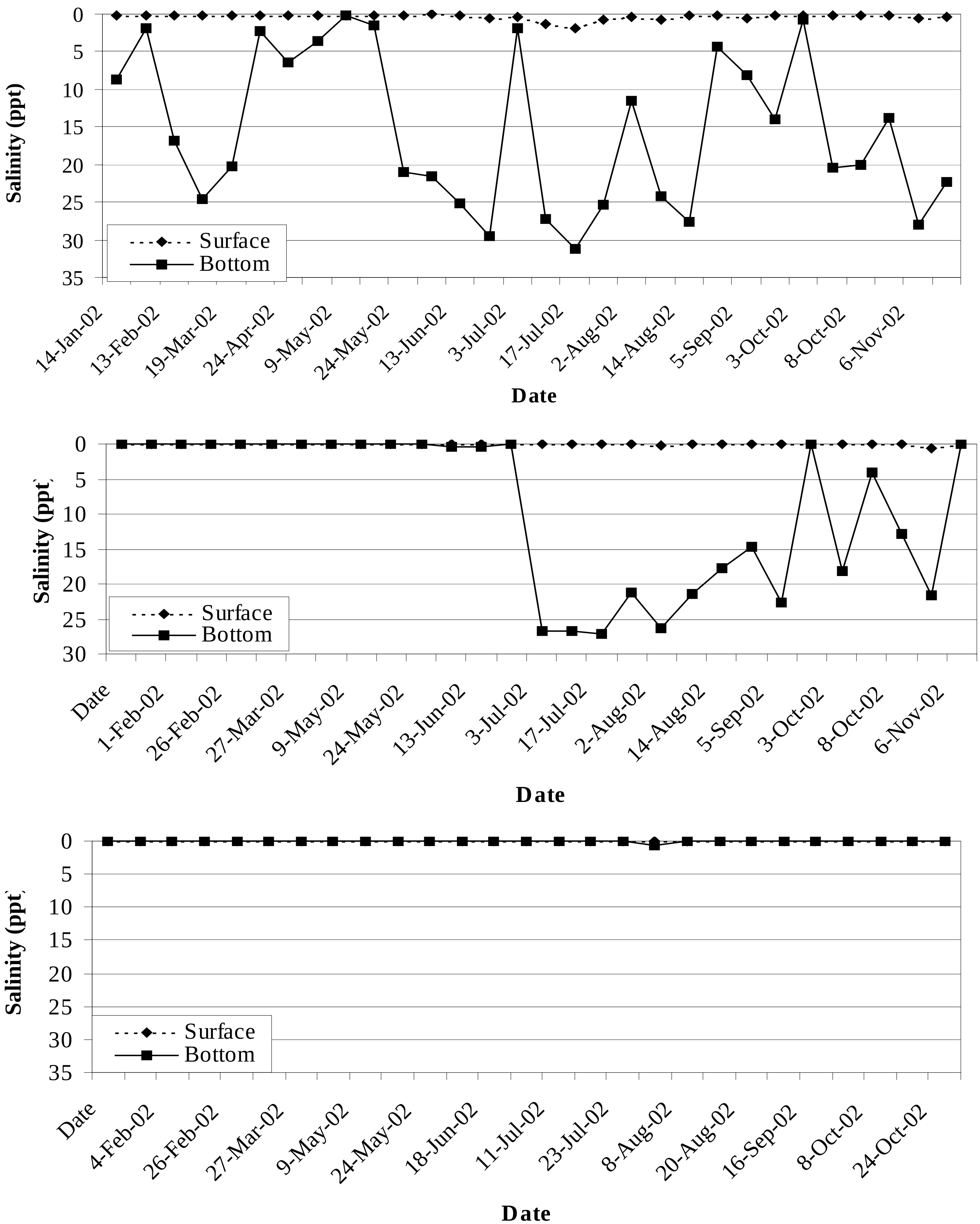


Figure 9. Surface and bottom salinity measurements observed during water quality monitoring at Transects L1 (top graph), M1 (middle graph), and U1 (bottom graph) during 2002.

Dissolved Oxygen

Dissolved oxygen (DO) levels were lowest in the lower most estuary transects, especially Transect 1, where levels were frequently observed to be less than 6 mg/L near the channel bottom (Figure 10). DO measurements ranged between 0.06 – 12.78 mg/L during sampling between January and mid-June (13-Jun). Measurements below 6 mg/L were always observed at stations a, d, and e, which are embayment areas to the north (station a) and south (stations d and e) of the main channel (Figure 2). Dissolved oxygen levels observed between July and mid-September (16-Sept) were generally between 6 – 10 mg/L, however, ten measurements at stations d and e were below 6 mg/L during this period (Figure 10). Dissolved oxygen levels at Transect 1 increased during October and November, ranging between 6.74 – 15.53 mg/L.

Dissolved oxygen values observed at Transect M1 were generally higher compared with Transect L1. Between January and mid-June (14-Jun), DO observations ranged between 8 – 12.5 mg/L, except on 14-Feb when dissolved oxygen was observed as low as 4.08 mg/L (Figure 10). Dissolved oxygen during summer and early fall (18-Jun – 8-Oct) at Transect M1 was generally between 5 – 10.5 mg/L, except on five occasions when levels dropped below 6 mg/L (range 4.45 – 5.99) and once when levels were as high as 13.31 at Station a on 17-Jul. During October and November, DO values ranged between 6.5 – 15 mg/L (Figure 10).

Dissolved oxygen levels were consistently higher in the Upper Transects of the estuary sampling stations, where dissolved oxygen levels were never observed below 6 mg/L (Figure 10). Measurements observed at Transect U1 ranged between 8 – 13 mg/L between January and mid-June (14-Jun) sampling. During the summer and early fall months (late June through early October), dissolved oxygen at Transect U1 ranged between 6 – 10 mg/L and increased to between 10 – 15 mg/L during the months of October and November (Figure 10).

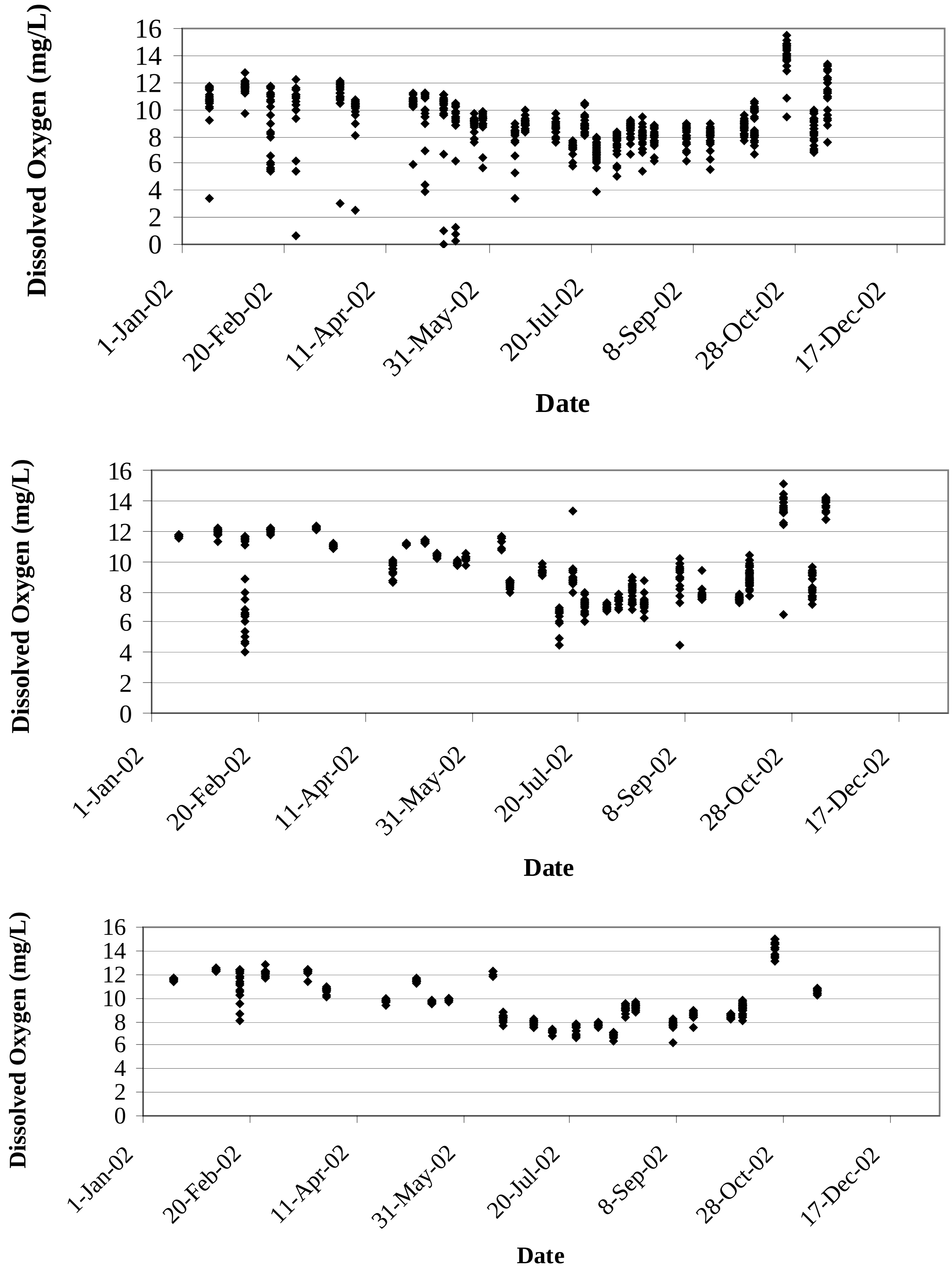


Figure 10. Dissolved oxygen measurements observed throughout the water column during water quality monitoring at Transects L1 (top graph), M1 (middle graph), and U1 (bottom graph) during 2002.

Water Quality Monitoring, South Slough

Temperature

Electronic temperature records from the south slough indicate that mean daily temperatures stayed below 10°C through mid-March, when temperature began gradually increasing (Figure 11). Mean daily temperatures during April and May were 14.28°C and 16.74°C, respectively. Through May, temperature records exceeding 20°C were not observed. Temperatures warmed during June, with average daily temperatures ranging between 18.13°C on 1-Jun and 21.45°C on 30-Jun. Temperatures peaked between 30-Jun and 2-Jul, with maximum daily temperatures above 23°C and mean daily temperatures between 21-44 – 21.73°C (Figure 11). Mean daily temperature observed between 3-Jul and 11-Jul ranged from 19.81 – 21.68°C, with a maximum temperature of 22.89°C observed on 8-Jul. Water temperatures during late July were significantly cooler, with temperatures ranging between 15 - 17°C. Another warming event was observed in mid-September, when mean daily temperatures ranged between 17.38 – 18.55°C and a maximum temperature of 18.94°C was observed on 27-Sept. In October, a progressive cooling trend began and continued for the remainder of the year. Mean monthly temperatures calculated for October, November, and December were 15.18°C, 11.08°C, and 10.13°C (respectively).

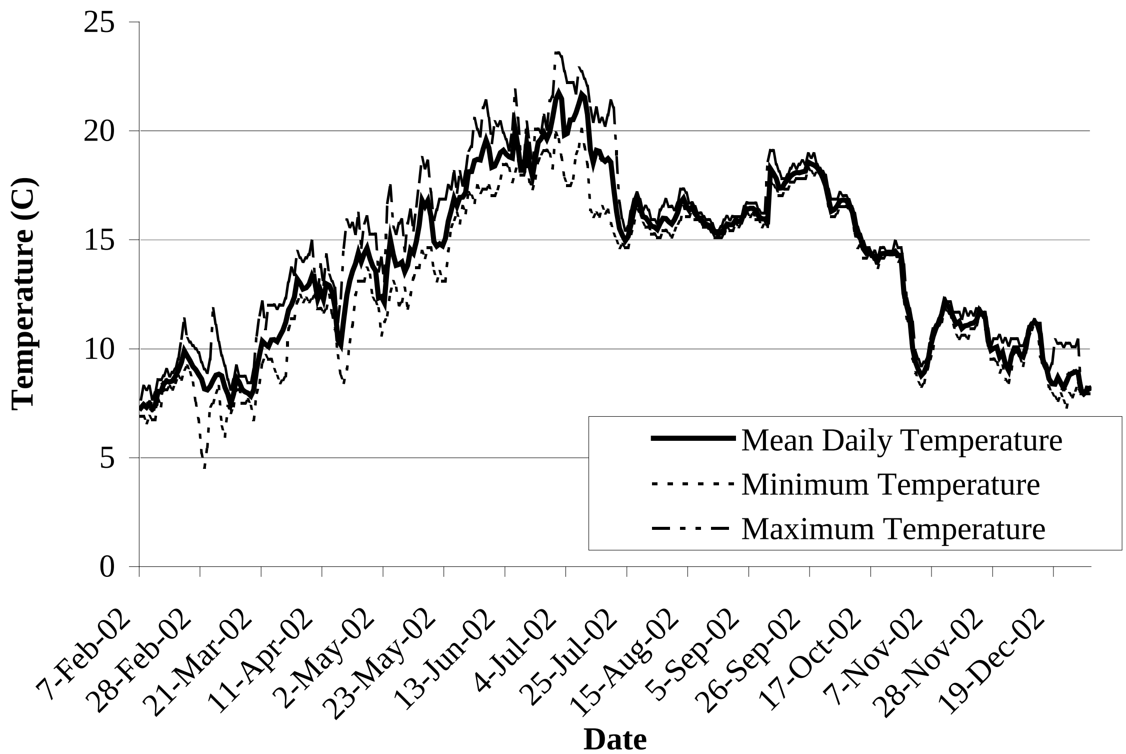


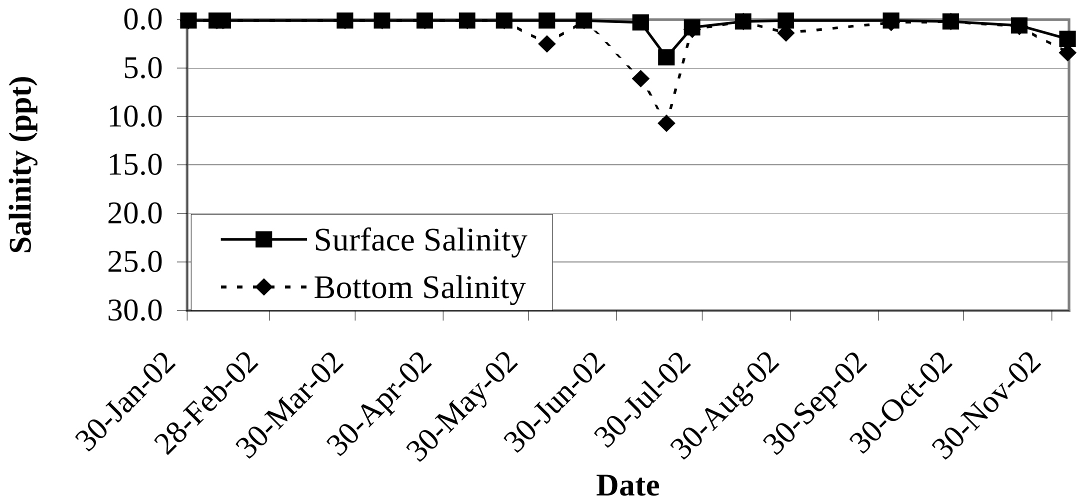
Figure 11. Minimum, maximum, and mean daily water temperatures recorded in the south slough of the Klamath River estuary during 2002 (7-Feb – 31-Dec).

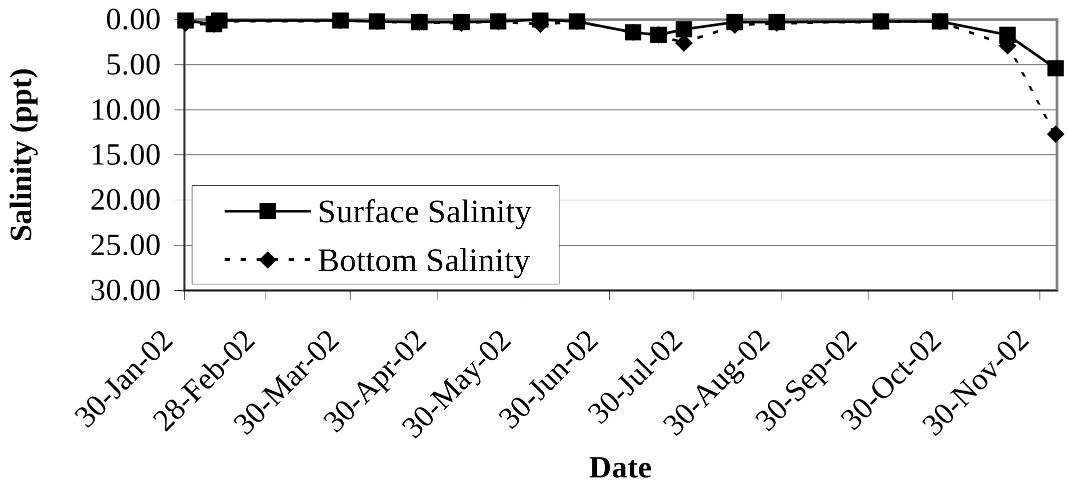
Salinity

Surface salinity in the slough was always less than or equal to salinity measurements observed on the channel bottom. Salinity in the slough ranged between 0.0 – 0.9 ppt through late May across all sampling stations and depths (Figure 12). During June, surface salinity ranged between 0.0 – 0.5 ppt and bottom salinity was observed between 0.2 – 2.5 ppt. Salinity increased during July, when surface measurements up to 3.9 ppt and bottom measurements up to 10.7 ppt were observed. Salinity observations between August and October ranged between 0.0 – 0.7 ppt for surface readings and 0.2 – 3.6 at the bottom of sampling locations. Salinity increased during November and December, especially at Station 7, which is closest to the river mouth (Figure 12). During these winter months, surface salinity measurements ranged between 0.6 – 2.8 ppt and bottom salinity ranged between 3.4 – 23.4 ppt (Figure 12).

Dissolved Oxygen

Dissolved oxygen measurements in the south slough were always above 6.0 mg/L for surface and mid-channel readings, although bottom readings were frequently below 6.0 mg/L, especially during summer months. At Station 1 (farthest upstream at the slough inlet), bottom readings during sampling on 5-Jun, 18-Jun, and 8-Jul were 4.63 mg/L, 3.94 mg/L, and 4.60 mg/L (respectively). At Station 2, bottom readings observed on 18-Jun, 8-Jul, and 17-Jul were 0.19 mg/L, 3.15 mg/L, and 4.78 mg/L (respectively). Low DO was observed along the channel bottom during October at Station 2. Sampling on 4-Oct and 25-Oct resulted in dissolved oxygen measurements of 0.18 mg/L and 4.90 mg/L. Low measurements were observed at Station 3 during sampling conducted in June, October, and November. On 18-Jun, dissolved oxygen was 3.99 mg/L along the channel bottom, and on 25-Oct and 18-Nov readings were 0.46 mg/L and 4.17 mg/L (respectively). Dissolved oxygen readings along the channel bottom at Station 4 were below 6 mg/L on 13-Aug, and 4-Oct when readings were 3.54 mg/L and 5.85 mg/L (respectively). Results from the channel bottom at Station 5 show that DO dropped below 6 mg./L during sampling on 23-Apr, 18-Jun, and 17-Jul. Dissolved oxygen measurements for those dates were 3.29 mg/L, 5.95 mg/L, and 5.87 mg/L (respectively). At Station 6, DO was only observed below 6 mg/L on the channel bottom once, during sampling on 18-Jun when a measurement of 4.81 mg/L was observed. Dissolved oxygen was never less than 6 mg/L at Station 7, which is the outlet of the slough (Figure 13).





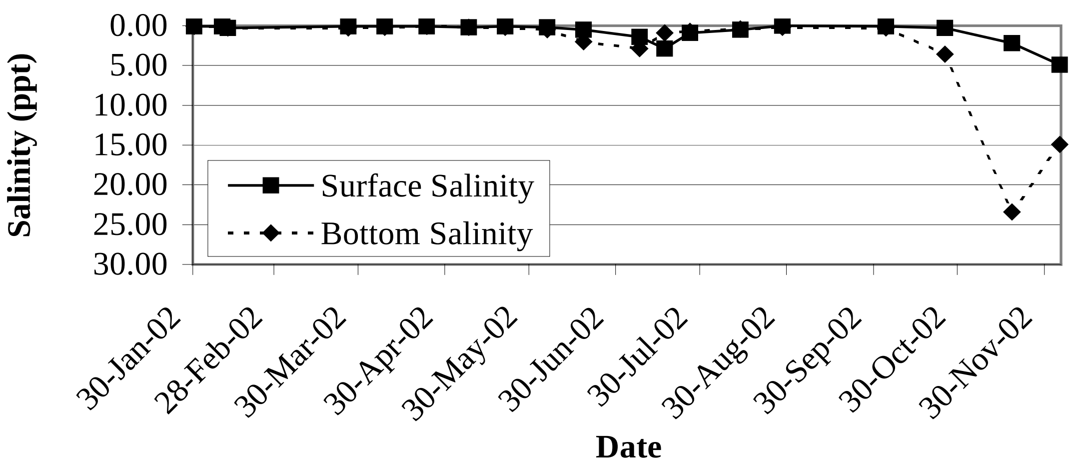


Figure 12. Surface and bottom salinity (ppt) measurements observed in the south slough of the Klamath River estuary at Station 1 (top graph), Station 4 (middle graph) and Station 7 (bottom graph) during 2002.

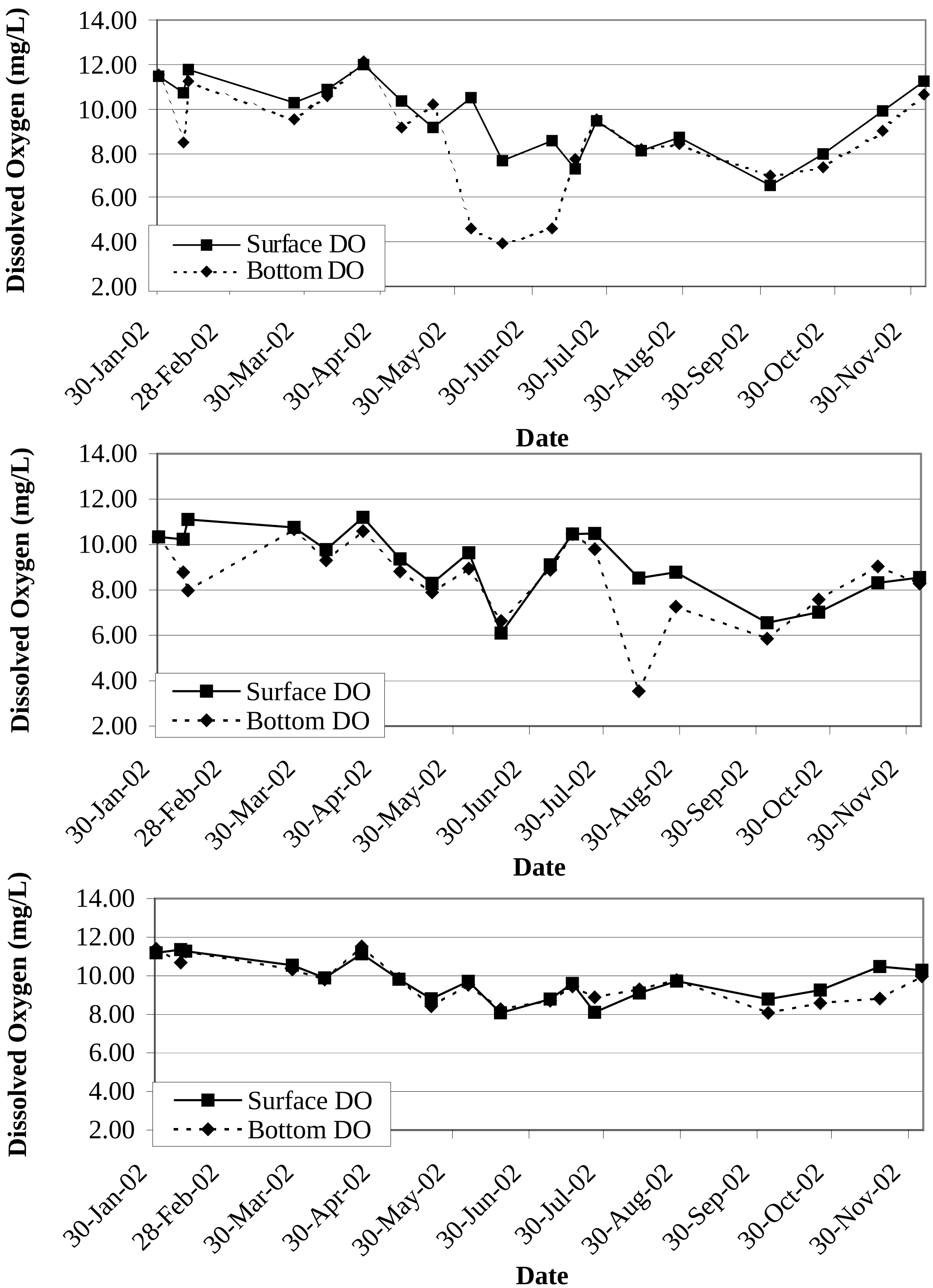


Figure 13. Surface and bottom dissolved oxygen (mg/L) measurements observed in the south slough of the Klamath River estuary at Station 1 (top graph), Station 4 (middle graph) and Station 7 (bottom graph) during 2002.

Temperature

Electronic temperature records from lower Salt Creek indicate that bottom temperatures remain fairly cool, even during summer months (Figure 14). Mean daily temperature fluctuated between 8 - 11°C during February and March. A small peak in temperature was observed between 1-Apr – 15-Apr, during which time mean daily temperatures were between 11.26 – 12.79°C. During late April through mid May, mean daily temperatures remained between 9.5 - 12°C. Temperatures began increasing during late May, but generally remained between 12 - 15°C through the end of September (Figure 14). The highest temperature observed was 15.58°C on 1-Jul. Temperatures began cooling in October and continued through the end of the year, with mean daily temperatures ranging between 8 – 11.5°C.

Results from water quality monitoring show that surface temperatures in the lower portion of the slough are much warmer during summer months, likely due to estuarine influence. Noticeable decreases in surface temperatures are observed at each subsequent monitoring station upstream from the estuary (Figure 15).

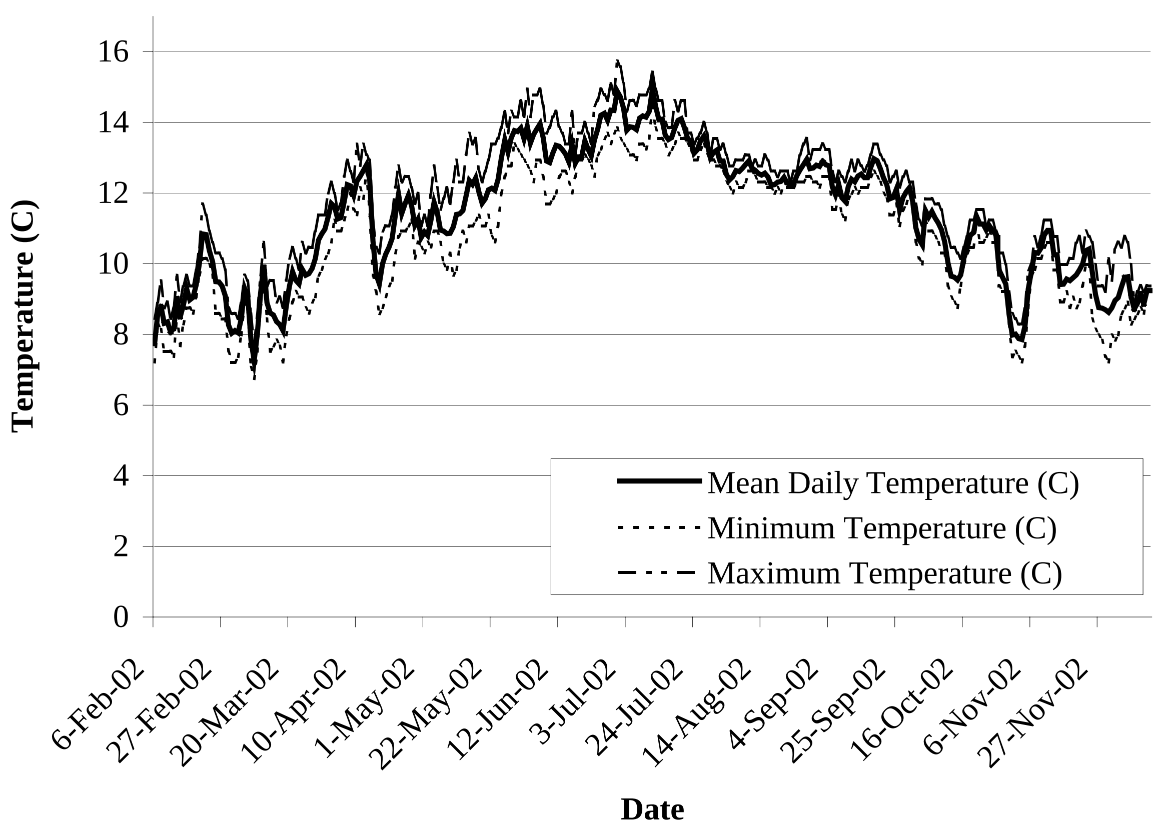


Figure 14. Minimum, maximum, and mean daily temperatures recorded in the Salt Creek Slough during 2002 (6-Feb – 13-Dec).

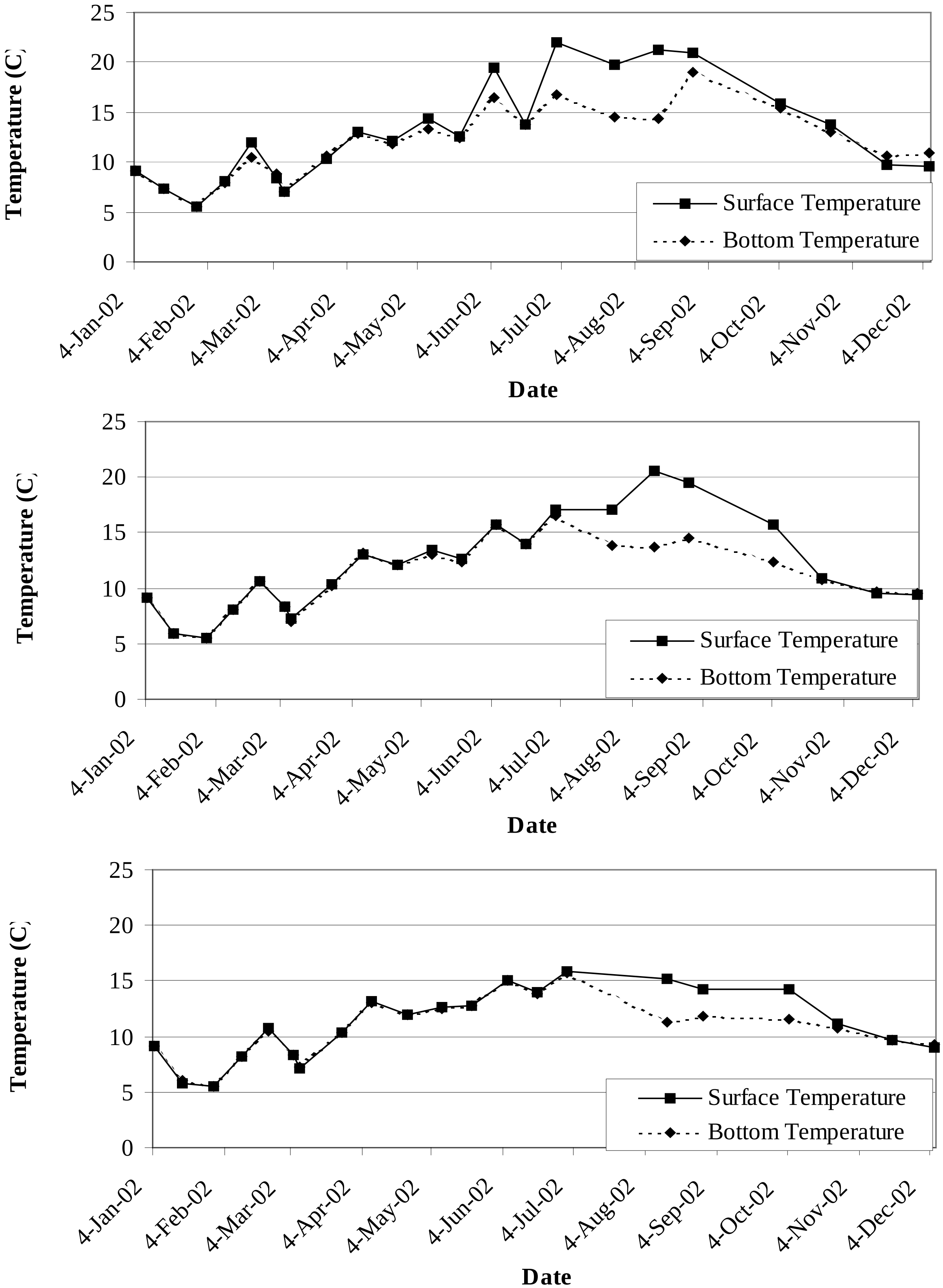


Figure 15. Surface and bottom temperatures observed in the Salt Creek Slough at Station 1 (top graph), Station 3 (middle graph), and Station 5 (bottom graph) during 2002.

Salinity

Salinity was observed in the highest concentration at Station 1 (creek mouth) and generally decreased at each successively upstream monitoring station. Observations were between 0.0 – 0.3 at all stations during sampling through 4-Oct. On 26-Jul, surface salinity at the downstream sites (Stations 1-3) was slightly more concentrated ranging between 0.2 – 0.3ppt compared with bottom measurements of 0.1ppt. Sampling at Station 1 on 25-Oct indicated a stratified water column, with surface measurements of 0.2ppt and bottom measurements of 17.1ppt recorded. Observations at all other sites ranged between 0.0 – 0.2ppt. Measurements taken on 18-Nov were 0.2ppt and 1.7ppt for surface and bottom readings at Station 1 (respectively). Surface and bottom observations at Station 2 were 0.1ppt and 0.4ppt (respectively), and salinity ranged between 0.0 – 0.2ppt at Stations 3-5. Salinity concentrations were greatest during sampling on 6-Dec, with surface and bottom measurements of 0.6ppt and 24.9ppt observed at Station 1. Surface salinity measurements for Stations 2-5 were 0.7ppt, 0.8ppt, 0.8ppt, and 0.9ppt (respectively). Bottom salinity concentrations observed on 6-Dec at Stations 2-5 were 23.7ppt, 7.5ppt, 3.2ppt, and 3.8ppt (respectively).

Dissolved Oxygen

Dissolved oxygen levels in Salt Creek were variable during the year and among the sites. Surface and mid-channel observations were nearly always above 6.0 mg/L, although bottom measurements were frequently below 6 mg/L and were observed as low as 1.09 mg/L. During sampling on 4-Jan, DO values ranging between 6.7 – 8.09 mg/L. Observations between mid January (16-Jan) and early March (8-Mar) were generally between 8 – 10 mg/L. During sampling on 26-Mar, DO at the bottom of Station 2 was 4.08 mg/L and subsequent sampling on 8-Apr showed similar results, with 1.09 mg/L observed at the bottom of Station 2 and 3.00 mg/L observed at the bottom of Station 1 (creek mouth). Conditions improved through early July, with readings ranging between 9.11 – 10.51 mg/L on 23-Apr; 8.38 – 10.04 mg/L on 8-May; 6.55 – 9.16 mg/L on 21-May; 7.41 – 9.97 mg/L on 5-Jun; 6.13 – 7.48 mg/L on 18 Jun; and 7.59 – 9.83 mg/L on 1-Jul.

Consistently low DO levels were observed from late July through late October near the channel bottom (Figure 16). During sampling on 26-Jul, DO levels at the bottom of Stations 1 and 5 were 5.73 and 5.63 mg/L (respectively). On 13-Aug, DO was <6mg/L at all five sampling stations on the channel bottom, dropping as low as 2.28 mg/L at Station 5. Conditions were also poor at Station 5 on 28-Aug, when levels near the channel bottom were 3.83 mg/L. Subsequent sampling on 4-Oct indicated that dissolved oxygen levels at the channel bottom were < 6mg/L at Stations 2 through 5, ranging between 4.24 – 5.42 mg/L. Sampling on 25-Oct revealed that DO levels throughout the water column were below 6 mg/L at Stations 3, 4, and 5, and bottom measurements at 1 and 2 were 3.91 and 5.93 mg/L (respectively). Conditions improved during November and December sampling, with observations ranging between 6.95 – 9.51 mg/L on 18-Nov and 7.3 – 11.12 mg/L on 6-Dec.

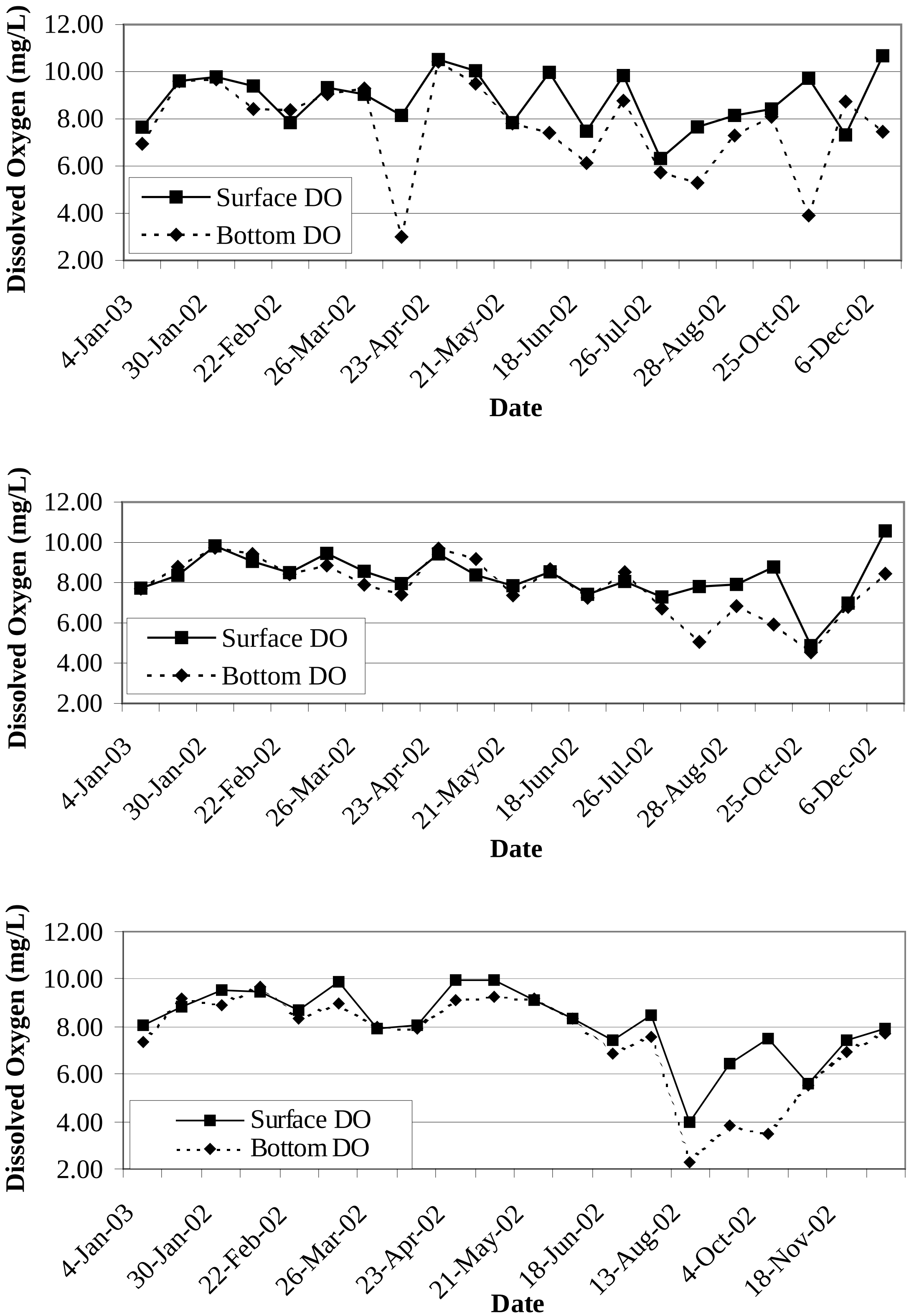


Figure 16. Surface and bottom dissolved oxygen (mg/L) measurements observed in the Salt Creek Slough at Station 1 (top graph), Station 3 (middle graph) and Station 5 (bottom graph) during 2002.

Water Quality Monitoring, Hunter Creek

Temperature

Mean daily water temperature calculated from electronic records ranged between 7.80 – 16.18°C, with the warmest temperatures occurring during September (Figure 17). Bottom temperatures generally remained below 14°C through 26-May, with the exception of maximum temperatures recorded on 2-Apr, 11-May, and 15-May of 15.67°C 14.57°C, and 15.04°C (respectively). Mean daily temperature remained below 12°C through 26-May (Figure 17). Mean daily temperatures between 27-May – 25-Jun ranged between 11.23 – 12.92°C, during which time the minimum/maximum temperatures observed were 8.37°C (8-Jun) and 15.99°C (16-Jun). Temperatures gradually warmed through the summer months. Mean daily temperatures reached a high of 14.34°C on 11-July, corresponding with the maximum daily temperature of 18.06°C. A slight cooling event occurred during early August, when a mean daily temperature of 12.60°C was observed on 5-Aug (min 11.47°C / max 13.79°C).

Gradual warming occurred during late summer and temperatures peaked in the Hunter Creek slough during September (Figure 17). Mean daily temperatures from electronic records ranged between 13.47 – 16.18°C, with minimum daily temperatures varying between 10.85 – 14.1°C and maximum temperatures between 15.20 – 18.06°C. Water quality monitoring showed that surface temperatures at downstream sampling stations was much higher than bottom temperatures during summer months (Table 4). During monitoring in late July and August, surface temperatures at Station 1 exceeded 21°C, while bottom temperatures were between 13.6 – 15.8°C (Table 4).

Temperatures in the Hunter Creek slough cooled significantly through October (Figure 17) and the thermograph during November and December resembled temperatures from January through March. During November and December, all electronic temperature records ranged between 7.76 – 11.78°C.

Table 4. Surface and bottom temperatures (°C) observed during water quality monitoring in the Hunter Creek Slough during 2002 at Stations 1 (mouth) through 6 (site furthest upstream) on 26-Jul, 13-Aug, and 28-Aug.

Site	26-Jul Surface / Bottom	13-Aug Surface / Bottom	28-Aug Surface / Bottom
Station 1	21.0 / 15.3	21.4 / 13.6	21.1 / 15.8
Station 2	15.6 / 14.1	21.3 / 13.2	20.5 / 13.0
Station 3	12.6 / 12.5	19.9 / 13.1	18.6 / 13.0
Station 4	12.6 / 12.5	14.4 / 13.9	14.9 / 14.8
Station 5	12.6 / 12.5	14.5 / 14.1	14.7 / 14.6
Station 6	12.6 / 12.3	13.6 / 13.6	14.2 / 14.0

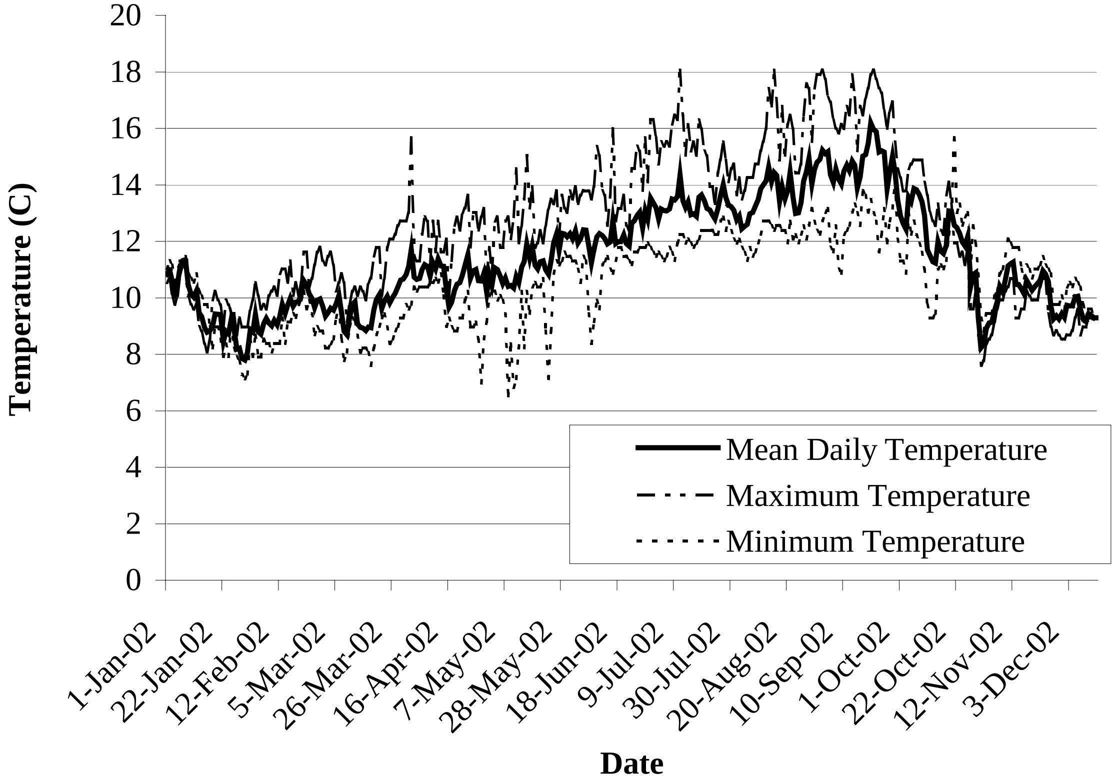


Figure 17. Minimum, maximum, and mean daily temperatures recorded in the Hunter Creek slough during 2002 (1-Jan – 13-Dec).

Salinity

Salinity was observed in the highest concentration at Stations 1 (creek mouth) and generally decreased at each successively upstream monitoring station. Salinity was never observed during sampling at the uppermost station and was not detected at the lower stations until 26-Jul. Salinity measurements ranged between 0.0 – 0.3ppt between 26-Jul and 4-Oct sampling. During sampling on 25-Oct, surface and bottom observations at Station 1 were 0.2ppt and 1.0ppt (respectively), and measurements were 0.0ppt throughout the water column at Stations 2 through 6.

Salinity was most prevalent in the Hunter Creek slough during November sampling. On 6-Nov, surface / bottom salinity observations were 0.9 / 3.0ppt at Station 1; 0.9 / 1.6ppt at Station 2; 0.7 / 1.7ppt at Station 3; 0.4 / 3.1ppt at Station 4; and 0.1 / 1.0ppt at Station 5. No salinity was observed at Station 6 on 6-Nov. Surface and bottom measurements observed on 18-Nov were 0.7 / 1.0ppt at Station 1; 0.9 / 1.0ppt at Station 2; 0.6 / 0.6ppt at Station 3; and 0.4 / 0.5ppt at Station 4. Salinity was not observed at Stations 5 or 6 on 18-Nov.

Dissolved Oxygen

Dissolved oxygen levels were highest during late winter and spring and declined during summer and fall months. Measurements during January through March ranged between 9 – 11 mg/L at all stations during every monitoring event, except during sampling on 6-January, when measurements at Station 4 were 7.79 – 8.73 mg/L and observations at Station 5 were 7.98 – 8.67 mg/L. Between April and mid-July, DO measurements were greater than 8.5 mg/L at all stations throughout the water column during all sampling events. Dissolved oxygen measurements on 26-Jul ranged between 7.69 – 9.79 mg/L at all stations, and observations on 13-Aug were similar, ranging between 7.65 – 9.99 mg/L. On 28-Aug, observations ranged between 6.98 – 10.19mg/L.

Dissolved oxygen levels began to drop in early October, when measurements were frequently below 7 mg/L and several times were observed below 6 mg/L. A measurement of 3.93 mg/L was recorded at Station 3 on 4-Oct, and observations at Station 2 were as low as 6.54 mg/L. All measurements from Station 4 ranged between 6.35 – 6.85 mg/L, and dissolved oxygen at Stations 1, 5, and 6 ranged between 7 – 10 mg/L. Observations on 25-Oct ranged between 5.64 – 9.06 mg/L, with the lowest measurements taken at Stations 1 (5.64 mg/L), Station 3 (6.14 – 6.92 mg/L throughout the water column), and Station 6 (6.90 mg/L). Measurements at Stations 2, 4, and 5 ranged between 7 – 8.5 mg/L. Readings observed on 6-Nov ranged between 7.25 – 10.01 mg/L at all sampling stations and water depths. Observations on 18-Nov were similar, with most measurements ranging between 7.06 – 10.27 mg/L, except DO near the channel bottom of Station 5, which was 5.92 mg/L. No sampling occurred during December.

GIS Aerial Photo Analysis

Dramatic changes have occurred in the Klamath River estuary during the past 65 years, as evident from aerial photos obtained for this project. However, there is no way to measure the estuary's habitat under pristine conditions since the earliest photos indicate habitat alteration. Island habitat in the estuary was most prevalent in records from 1936, 1948, 1954, and 1963, ranging between 221,203 – 772,150 m^2. Island habitat in 1969 photos encompassed 64,004 m^2 and 56,968 m^2 in 1972. Photographic records from 1985, 1993, and 2001 show island habitat ranging between 10,559 – 15,822 m^2 (Figure 18). Overall surface area of estuarine waters ranged between 1,624,511 – 2,545,812 m^2 among aerial photo records (Figure 18). Slough surface area varied, with very little slough area present in 1936 (40,691 m^2), and the most slough area present in 1969 (541,953 m^2; Figure 18). The size of the estuary spit ranged between 197,873 – 416,417 m^2 among photographic records (Figure 18). In general, the upper bend of the estuary moved slightly to the south and the lower bend of the estuary (just upstream of Hunter/Salt Creeks) drastically eroded the north bank, finally capturing the mouths of Hunter and Salt Creeks upstream of their confluence. The erosion was controlled after riprap was installed along the bank in the early 1970's. Deposition on the south bank downstream of the Hunter Creek/Salt Creek mouths has occurred over time, especially after large flood events.

<u>1936 Aerial Photos</u>

The land surrounding the estuary was largely used for agriculture purposes, especially on the south bank. Local elders convey that this has been farmland for as long as they can remember, and two farmhouses and a barn were present (Chuck Williams, personal communication). The south slough flowed east into the agriculture land from the embayment of the estuary and appeared to be an artificial channel, most likely an irrigation canal. The widest point in the south slough is approximately 25 m, and there does not appear to be continuous flow linking the slough with the upper estuary.

Within the estuary, there were three mid-channel islands between the mouth of Salt/Hunter Creek and the current Townsite Boatramp (Figure 19) with well-established vegetation. Salt Creek flowed into Hunter Creek approximately 440 m upstream of their confluence with the Klamath River (Figure 19). The mouth of the river was configured to the south, with Williams Rock located on the south shore on the bank adjacent to where the river enters the narrowed channel commonly referred to as the "chute".

<u>1948 Aerial Photos</u>

Agriculture continued to dominate lands directly surrounding the estuary in 1948. The south slough and Salt Creek slough remained relatively unchanged. The lower portion of Hunter Creek changed substantially, and a reach approximately 340 m long migrated westward towards Salt Creek. A small island was formed immediately upstream of the Hunter Creek/Salt Creek mouth, increasing available slough habitat.

There were also several changes in the mainstem of the Klamath River noted in the 1948 photographs. In 1948, the mouth configuration was to the north. Scouring immediately upstream of the Hunter Creek/Salt Creek mouth eroded approximately 78 m of previously existing bank (Figure 20). Deposition of riverine sediments between the eastern portion of he lower mainstem island and the south bank prevented downstream flow and created backwater slough habitat that was probably highly variable depending on tidal stage. Closure of this channel also resulted in a constricted channel running to the north of the lower island (Figure 20).

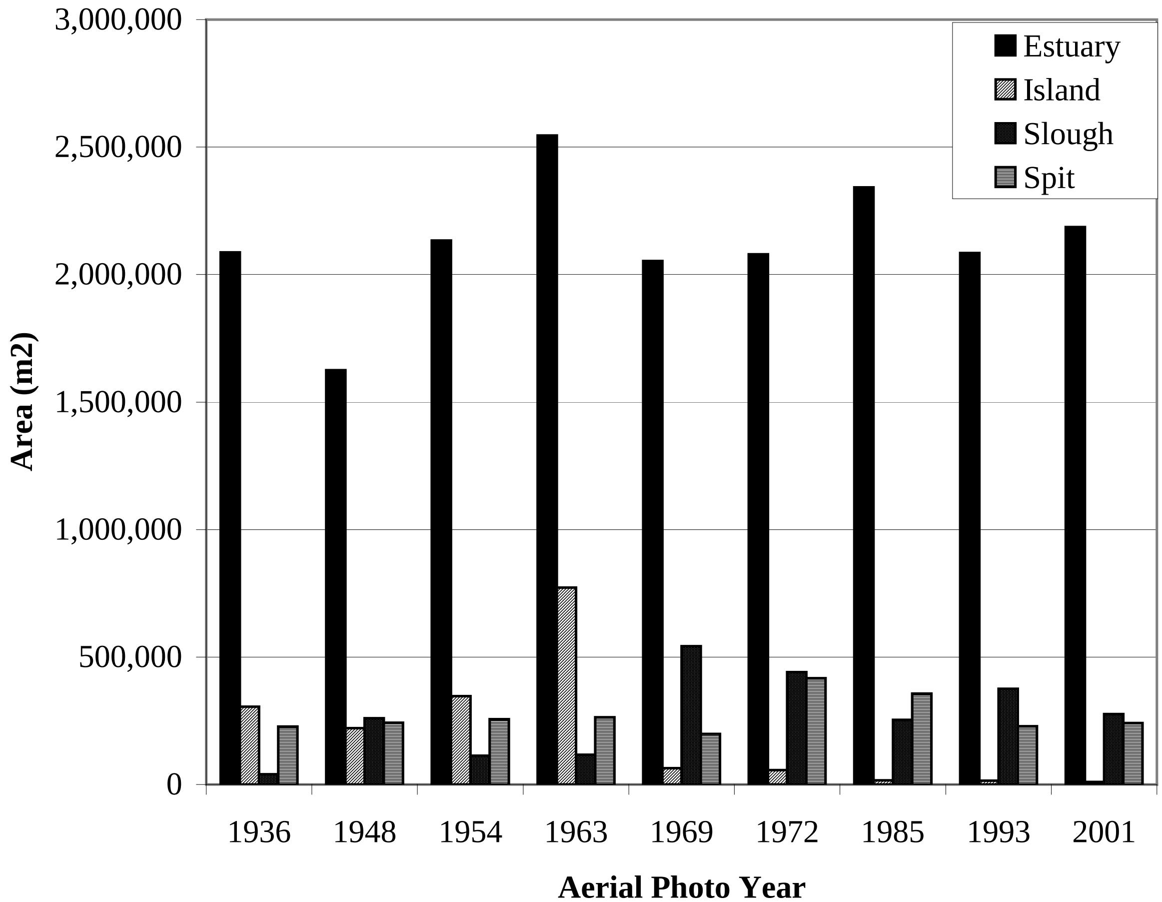


Figure 18. Surface area measurements (m^2) for estuary water (from river mouth to current Highway 101 bridge), island habitat, slough habitat, and spit calculated from 1936, 1948, 1954, 1963, 1969, 1972, 1985, 1993, and 2001 aerial photos.

1954 Aerial Photos

Landscapes reflected in the 1954 aerial photographs reflect that agriculture was less prevalent surrounding the estuary, specifically on the south bank surrounding the south slough. The south slough channel was wider than in 1948 and an additional slough inlet approximately 125 m north of the south slough mouth was present (Figure 21). Scouring visible in the aerial photographs between the top of the slough and the main channel, in addition to the widening of the slough channel, indicate that a large flow event created continuous flow through the south slough at some point. Records from the USGS gaging station at Terwer show an event of approximately 297,000 cfs on 18-Jan-53, which may have raised the stage height enough to create flooding of the slough and scour the channel.

The configuration of the river mouth was similar in 1954 as depicted in aerial photographs from previous years, emptying from the north side of the estuary. Flow was re-established on the south side of the mid-channel islands, with complex braiding visible and mature vegetation on the islands. Approximately 120 m of previously existing river bank was eroded from the north bank of the last bend, located immediately upstream of the Hunter Creek/Salt Creek mouth (Figure 21). The lower reach of Hunter Creek meanders back to the east and captures the mouth of Salt Creek slightly upstream of the previous confluence (compared to 1936 and 1948 images).

1963 Aerial Photos

Aerial photos from 1963 indicate major changes in the lower estuarine and slough regions when compared to 1954 photographs. Similar to previous years for which aerial photos are available, the river mouth is located on the north side of the estuary (Figure 22). Mid-channel islands were more prevalent in 1963, with extensive channel braiding between them, including regions of the south slough. The south slough region was much wider than in 1954 and appears to have continuous freshwater flow through it (Figure 22). A small embayment of water was present to the south of the south slough mouth between what is referred to as ‘Dad’s Camp’ and the estuary spit (Figure 22). Another noteworthy change is that a large log pond was present behind the mill adjacent to Highway 101 near the mouth of Richardson Creek. This pond was actively used during1963 and several hundred logs were visibly floating on its’ surface in the aerial photos.

Channel morphology was also changed during the 1955 flood and reflected in 1963 photographs. The uppermost bend of the estuary (as described in our project; Figure 22) shifted to the south, eroding approximately 100 m of previously existing riverbank on the south bank and depositing approximately 65 m of material on the north bank. The sandy point bar immediately upstream of the town of Klamath, present in 1954, is now gone, also presumably washed away during the 1955 flood. The south bank of the river directly across from the town of Klamath and the existing bridge remains unchanged due to bedrock walls. The westward bend of the river immediately upstream of the mouth of Hunter/Salt Creek, which has been actively eroding for at least as long as aerial photos will document, has moved an additional 165 meters to the north. This resulted in part of the

Hunter/Salt Creek channel being lost, and the mainstem Klamath now captures the creek approximately 234 m upstream of their mouth as documented in 1954 aerial photographs.

<u>1969 Aerial Photos</u>

Extensive changes occurred in the Klamath River estuary between 1963 and 1969, likely due to the December 1964 flood event (557,000 cfs at Terwer Gage). Sediment depositions are widespread throughout the south slough region, and the islands present in 1963 are one continuous land mass with several main slough channels extending westward toward the estuary's lower embayment (Figure 23). The small embayment between 'Dad's Camp' and the south spit is gone, presumably filled with sediment during the flood.

Widespread changes in the main river channel were also evident in 1969 when compared with 1963 aerial photos. In the upper estuary, the main channel encroached approximately 100 m of the south bank at the site of the new Highway 101 Bridge (Figure 23). The lowermost bend of the estuary adjacent to Hunter and Salt Creeks eroded an additional 115 m of the north bank, capturing the final bend of Hunter Creek before it joins with Salt Creek and resulting in two separate creek confluences with the mainstem Klamath. The creek channels of Salt and Hunter changed very little upstream of their mouth at the Klamath, despite the large flood of 1964. A new point bar was visible downstream of Requa, and a small embayment was also present between the north spit and Oregos (north of the river mouth). Similar with all previous photographic records, the river mouth was on the north side of the estuary in 1969.

<u>1972 Aerial Photos</u>

The Klamath River estuary as depicted in 1972 aerial photos is very similar to 1969 images. The river mouth was in the middle of the channel, with a small embayment on the north side between the spit and Oregos (Figure 24). While the upper region of the estuary near the Highway 101 Bridge appears narrower, this may be due to decreased river flow. The lowermost bend appears to still be shifting north, cutting the north bank back an additional 80 m at the mouths of Hunter and Salt Creek. This erosion resulted in 80 m of Hunter Creek and 180 m of Salt Creek being lost to the main channel (Figure 24). The region of the south slough remains relatively unchanged.

<u>1985 Aerial Photos</u>

Aerial photographs from 1985 show little changes from 1972 records, except for changes in the configuration of the river mouth. The mouth has migrated to the south end of the estuary via a long chute that originates near the middle of the channel and runs diagonally to the south between two sand spits (Figure 25). The small embayment on the north side of the lower estuary between the spit and Oregos is much smaller in 1985 compared with 1972 due to the location of the mouth and shape of the north spit. The land between the main river channel and the south slough shows increased vegetation with mature trees present. This is the first year of photographic records that land on the north bank of the lowermost bend has not been lost to the river (adjacent to the mouths of Salt and Hunter

Creeks) due to the installation of riprap in 1972 (United States Army Corps of Engineers 1997). In addition, car bodies were buried along the channel of Hunter and Salt Creeks to prevent further erosion (Don De Vol, personal communication).

1993 Aerial Photos

The Klamath River estuary shows very little change between 1985 and 1993. This is presumably due to the extensive sections of riprap along the north bank. Low flows in the late 1980's and early 1990's may have also contributed to the lack of physical change in the estuary, although a flood event of 459,000 cfs occurred in February of 1986. A small peninsula has formed on the south bank across the channel from the Townsite Boatramp, creating backwater habitat (Figure 26). The small embayment on the north side of the estuary between Oregos and the north spit is gone, most likely because the sand spit has encroached approximately 200 m from the ocean into the estuary. The lower reaches of Hunter and Salt Creek show no changes, and very little change has occurred in the south slough except increasing riparian habitat with mature canopy cover.

2001 Aerial Photos

The Klamath River estuary changed very little between 1993 and 2001 despite a flood event of 505,789 cfs in January of 1997. The only noticeable difference is the location of the mouth, which was to the south in 1993 and is situated in the center with a long narrow chute to the south in 2001. The south slough appears to have connectivity with the upper river channel, and the inlet is directly below the peninsula that first appeared in 1993 photographs (across the channel from the Townsite Boatramp).

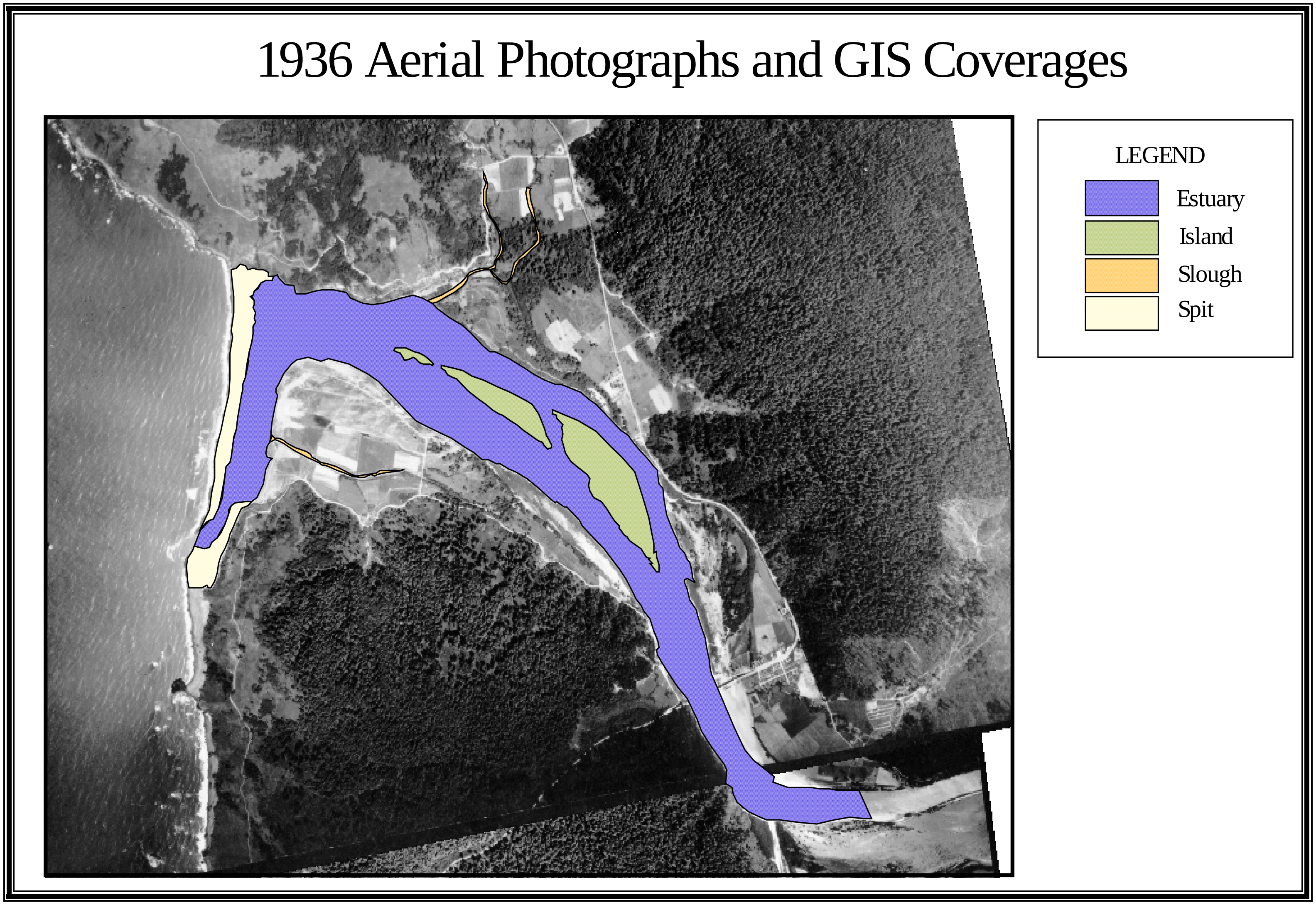


Figure 19. ArcView 3.2 GIS layout of estuary, island, slough, and spit coverages for 1936 aerial photographs.

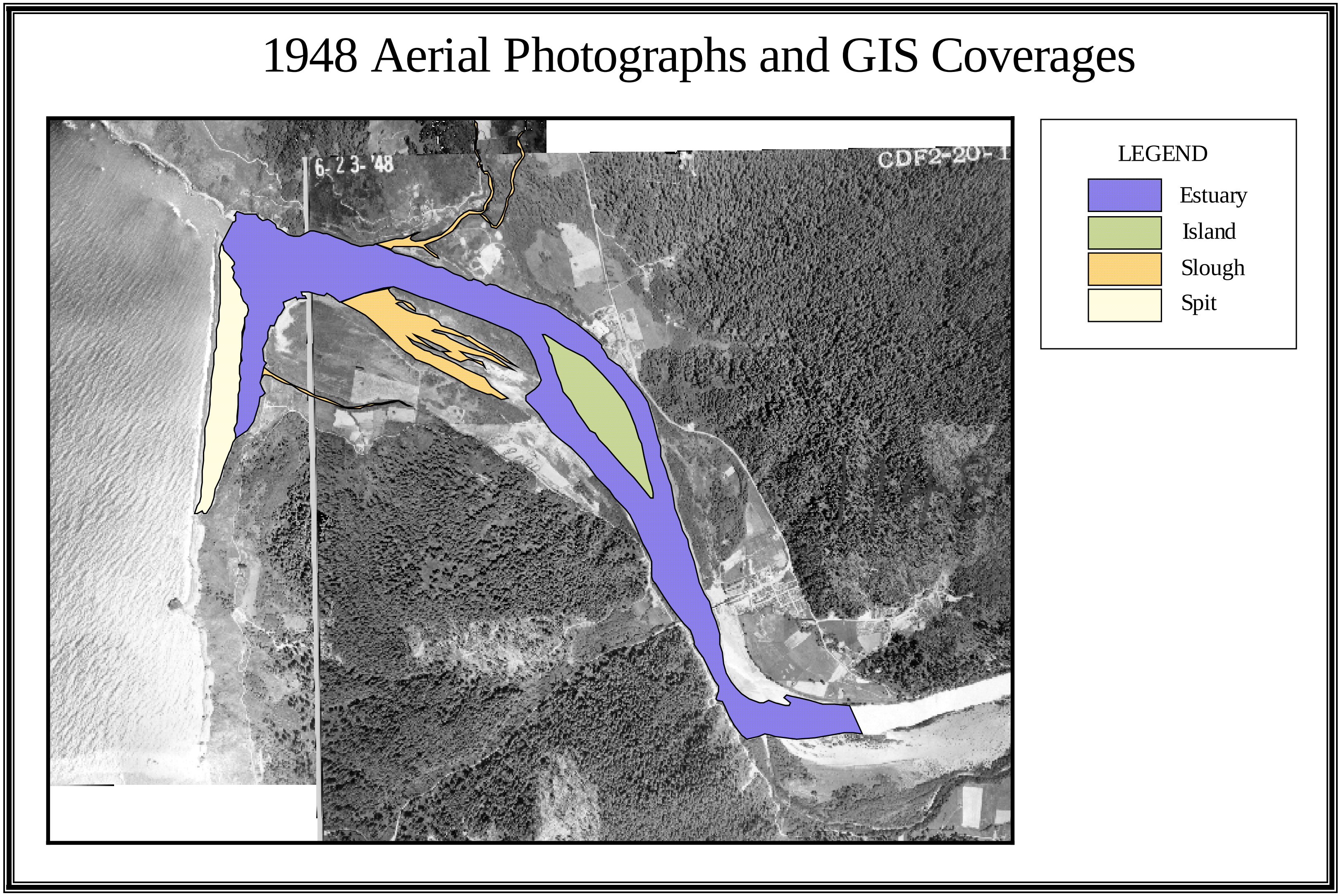


Figure 20. ArcView 3.2 GIS layout of estuary, island, slough, and spit coverages for 1948 aerial photographs.

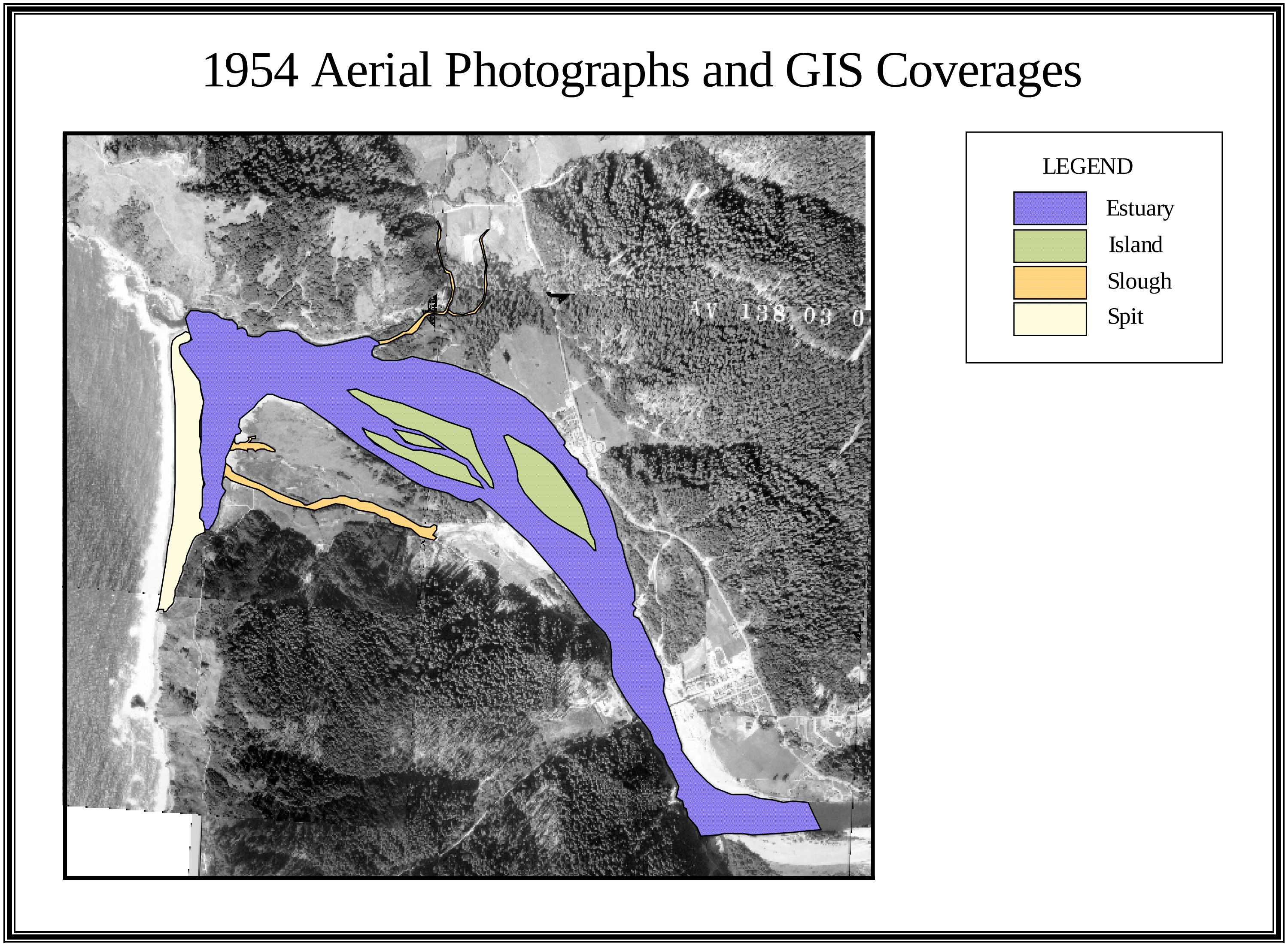


Figure 21. ArcView 3.2 GIS layout of estuary, island, slough, and spit coverages for 1954 aerial photographs.

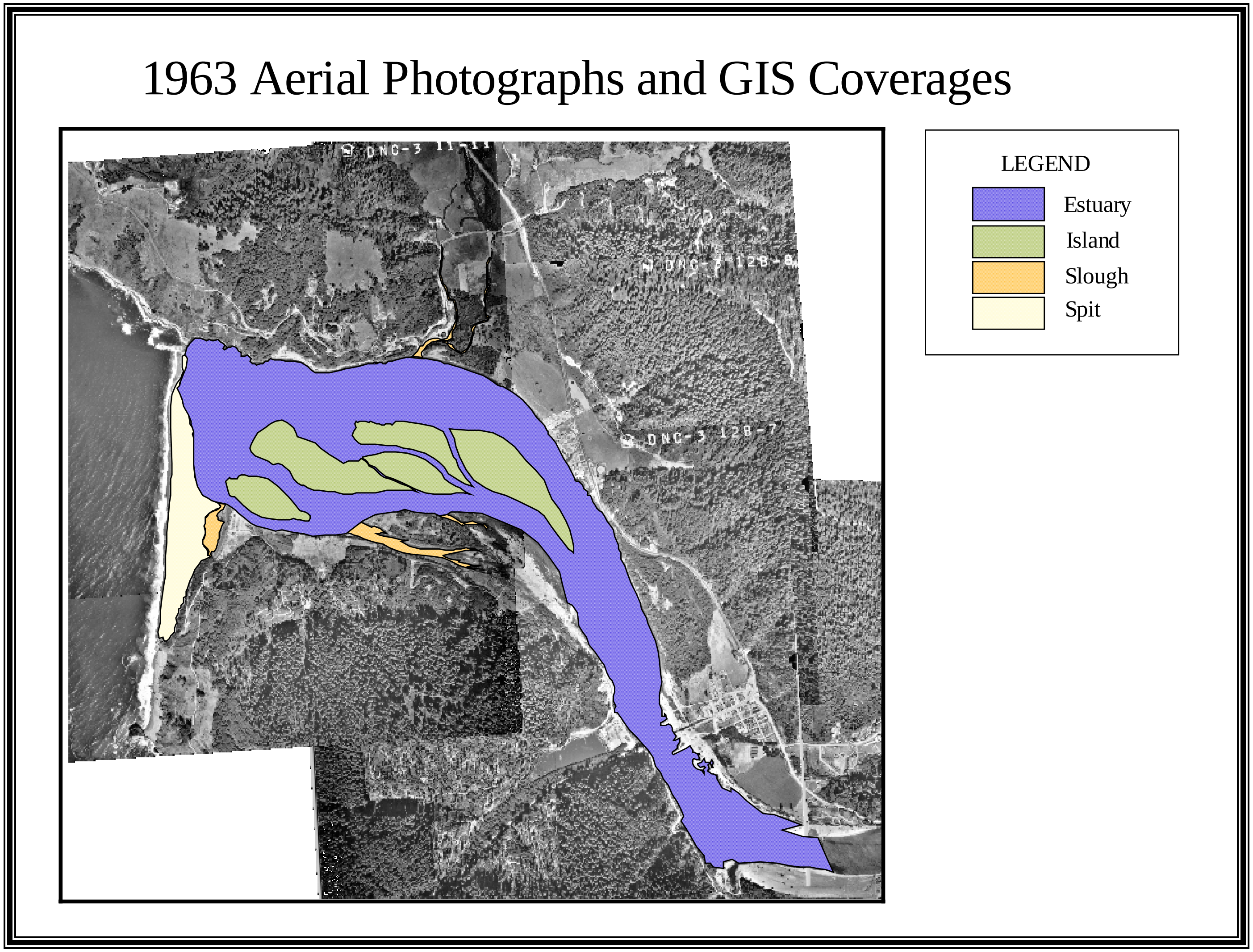


Figure 22. ArcView 3.2 GIS layout of estuary, island, slough, and spit coverages for 1963 aerial photographs.

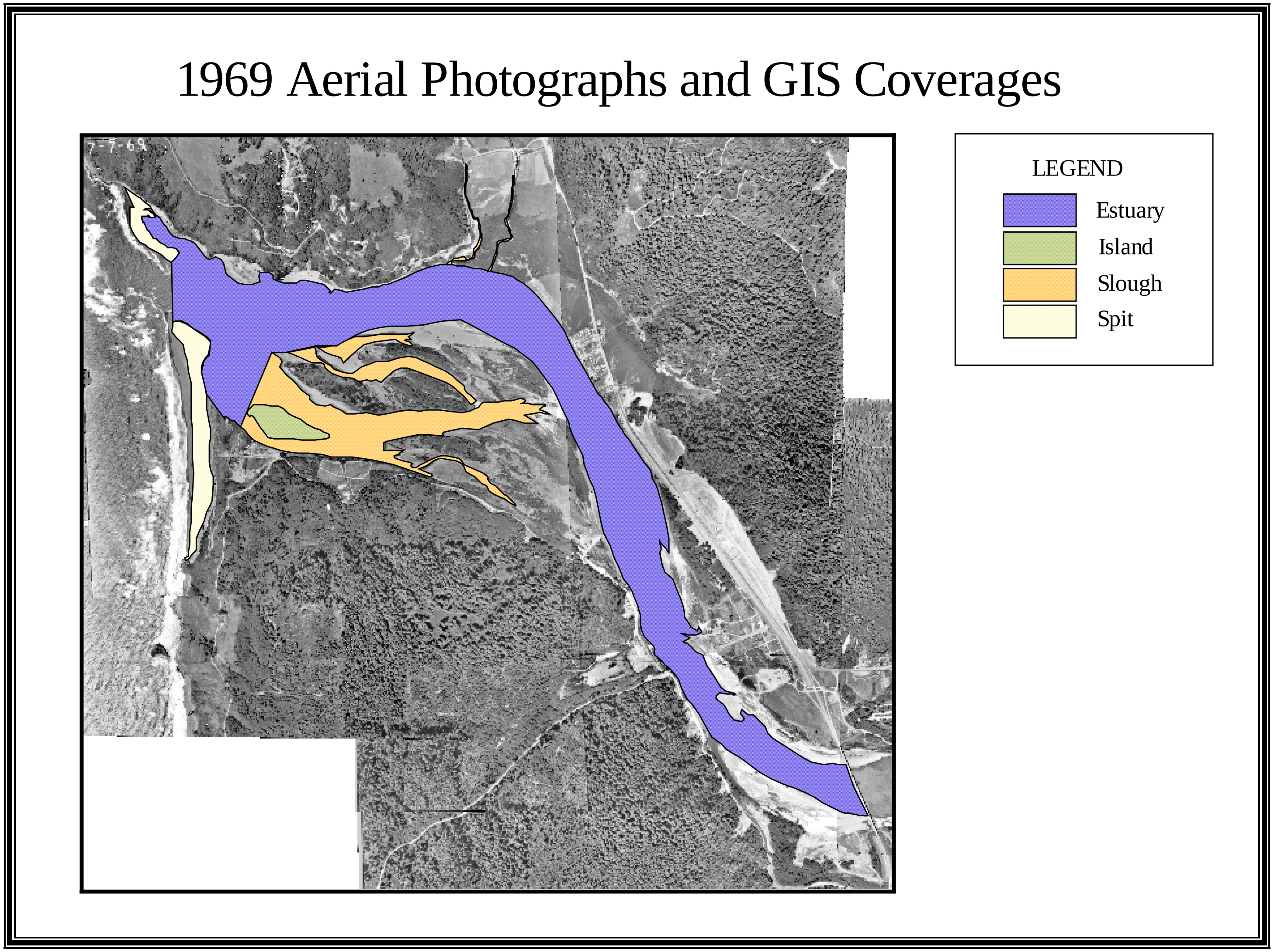


Figure 23. ArcView 3.2 GIS layout of estuary, island, slough, and spit coverages for 1969 aerial photographs.

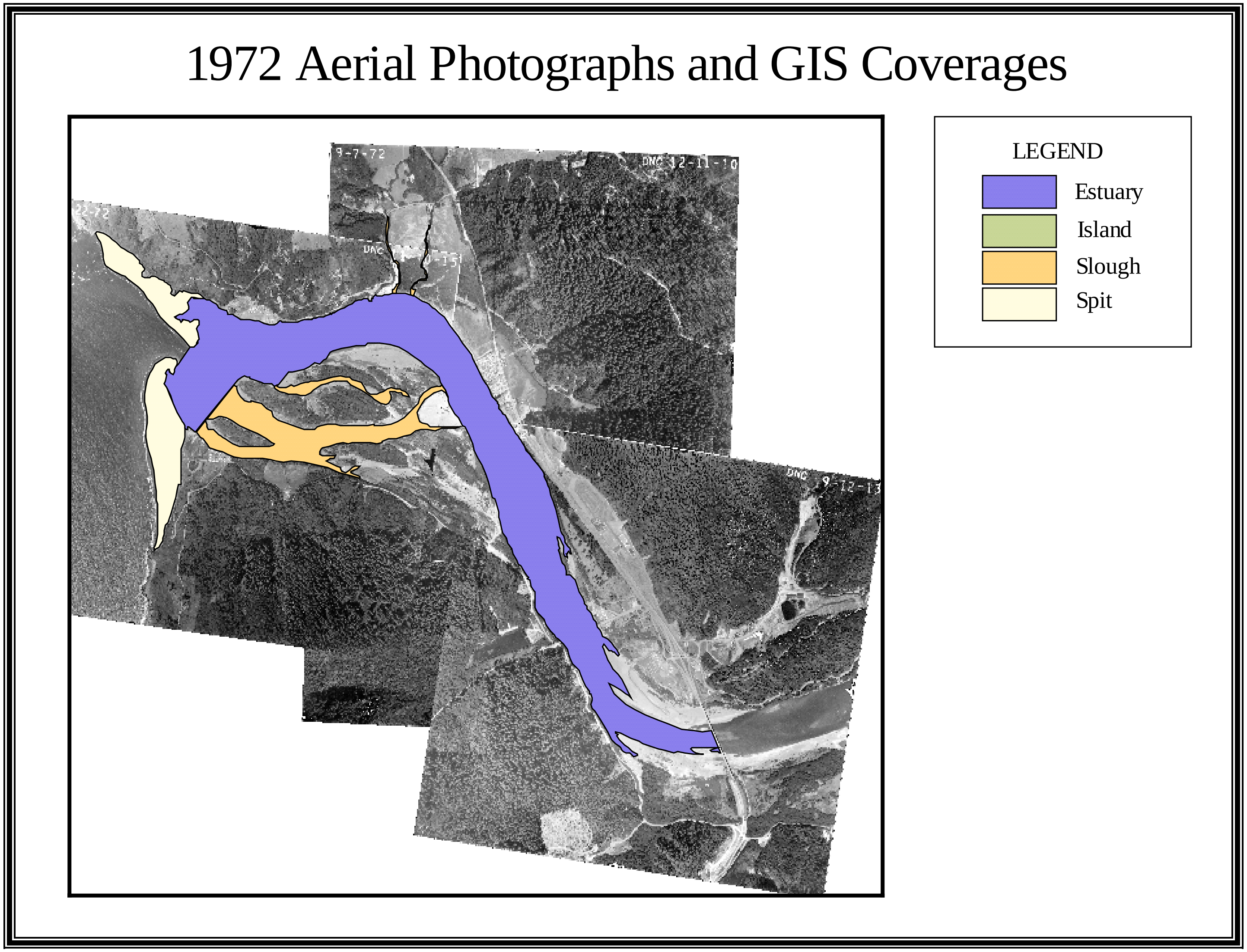


Figure 24. ArcView 3.2 GIS layout of estuary, island, slough, and spit coverages for 1972 aerial photographs.

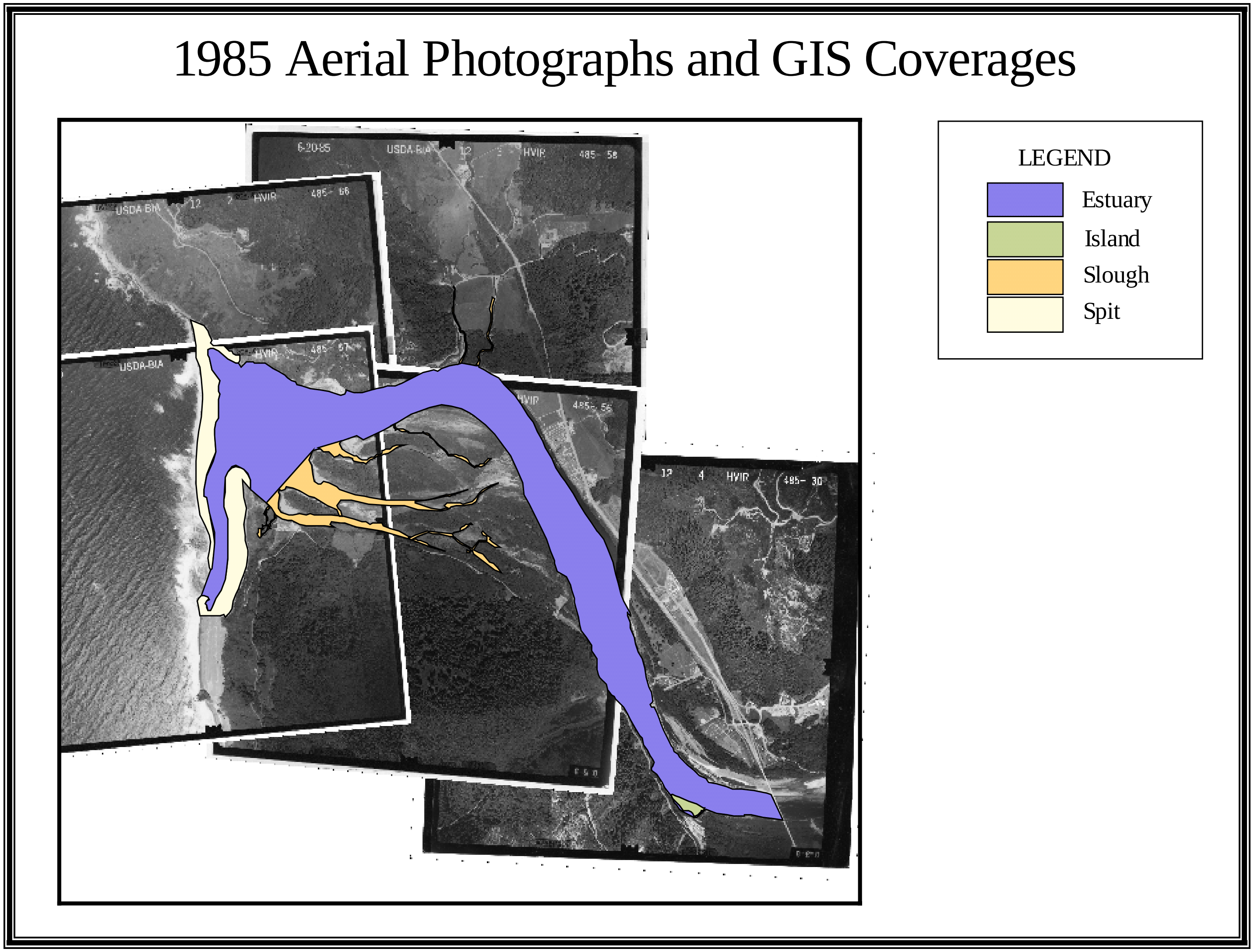


Figure 25. ArcView 3.2 GIS layout of estuary, island, slough, and spit coverages for 1985 aerial photographs.

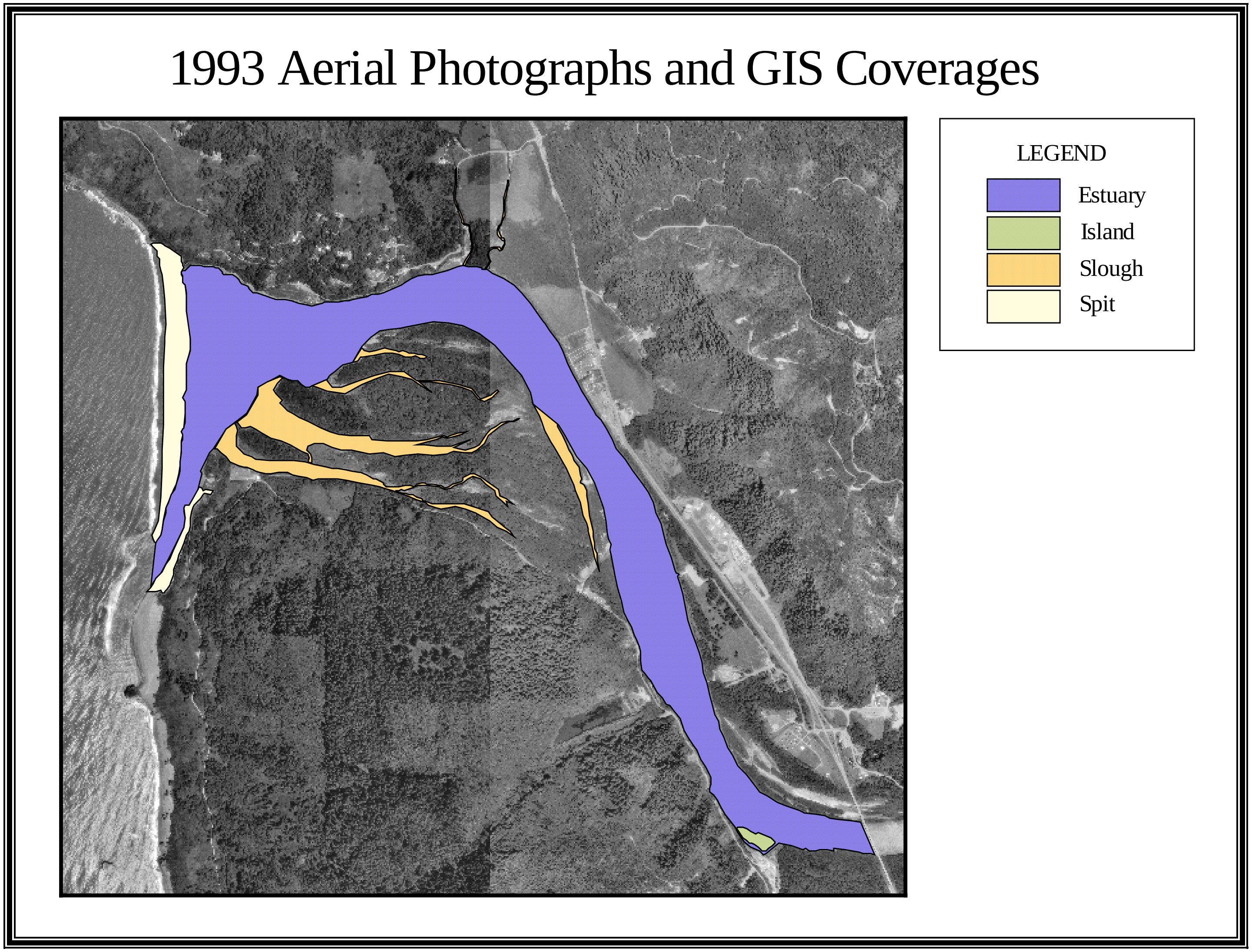


Figure 26. ArcView 3.2 GIS layout of estuary, island, slough, and spit coverages for 1993 aerial photographs.

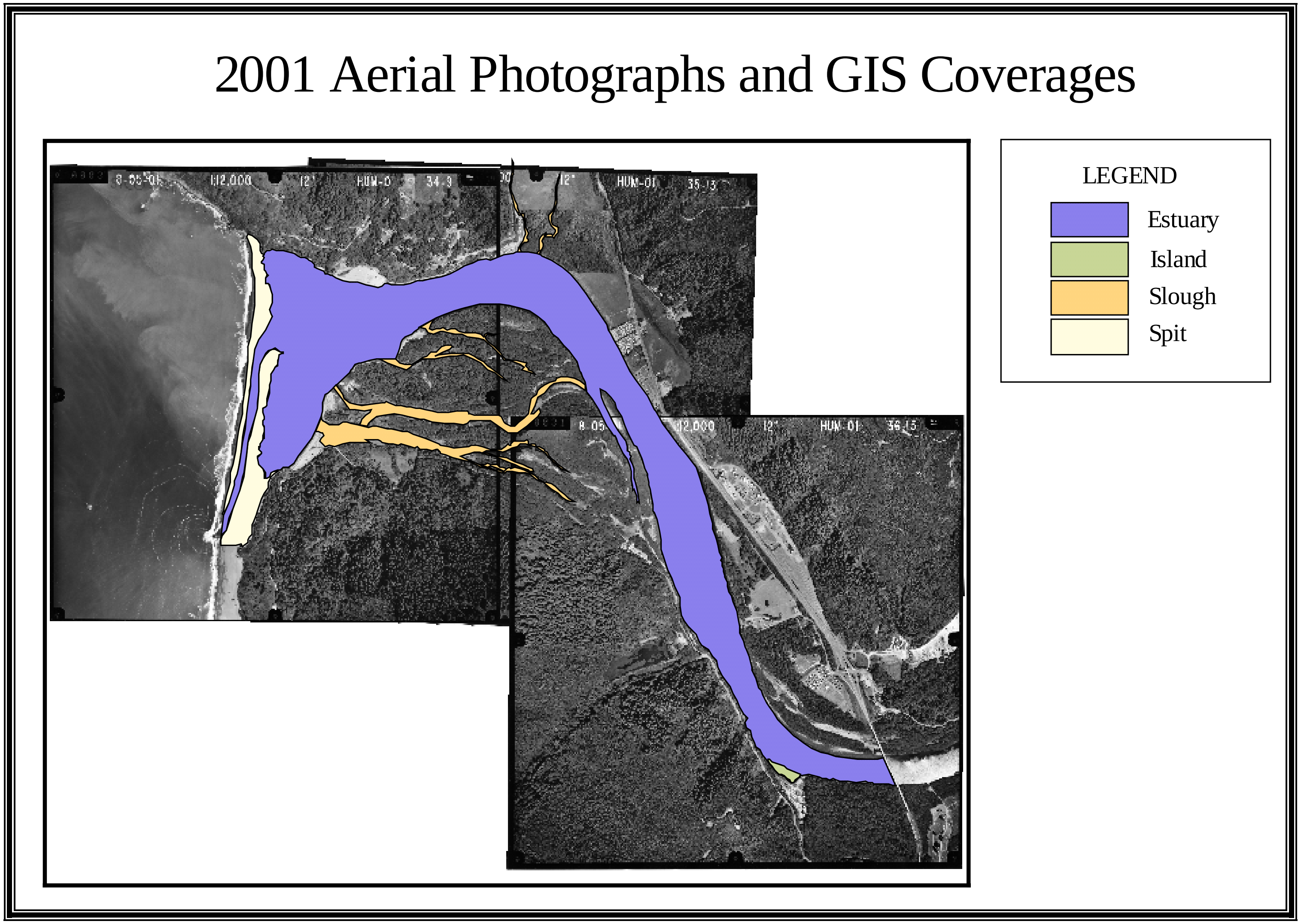


Figure 27. ArcView 3.2 GIS layout of estuary, island, slough, and spit coverages for 2001 aerial photographs.

DISCUSSION

The Klamath River estuary, like most rivers and estuaries, has been extensively influenced since European settlement due to a myriad of causes including (but certainly not limited to) water diversion, development, timber practices, dam construction, and habitat and channel alteration. In addition, native fish populations within the Klamath River basin have been influenced by interactions with hatchery fish, non-native introductions, inability to access historical ranges due to human development, and decreased water quality and quantity compared with conditions they have evolved with. Fish runs in the Klamath have been declining since European settlers began commercial fishing in the 1870's. As Snyder wrote in 1931, the "depletion of Klamath salmon is not only apparent, but seems to be progressing at an alarming rate" (Snyder 1931). In light of the importance of estuaries to juvenile and adult anadromous salmonids, it is likely that alterations to habitat within the estuary has contributed to the decline of anadromous fishes of the Klamath Basin.

Historically, habitat change in the Klamath River estuary was likely driven by large flood events. Since aerial photographic records available to us only go as far back as 1936, it is difficult to speculate long-term changes that have occurred in the estuary. For example, agricultural development along the south side of the estuary was prevalent in the earliest of these photographs and has probably been an influence since white settlement. Analysis of the aerial photographs available to us indicates that the most extensive changes appeared in the 1963 and 1969 photographic records, presumably due to the 1955 flood (425,000 cfs) and 1964 flood (557,000 cfs; USGS public data from Terwer). Erosion on the lowermost bend of the river adjacent to Hunter and Salt creeks resulted in the loss of 550 m of riverbank. Salt Creek was historically a tributary to Hunter Creek, but erosion that occurred during the 1964 flood captured the mouth of Hunter Creek upstream of its confluence with Salt Creek. Aerial photos from 1972, 1985, 1993, and 2001 show very little change to the morphology of the estuary, Salt Creek slough, and Hunter Creek slough due to the installation of levees and riprap as bank stabilization measures. It should be noted that several flood events larger than 1955 (529,000 cfs in 1974; 459,000 cfs in 1986; 505,000 cfs in 1997) have occurred since the levees and riprap were installed and no morphological changes were evident in subsequent aerial photos of the estuary or Hunter and Salt Creek sloughs.

The south slough of the estuary has expanded in size over time. The first documented aerial photographs taken in 1936 show the slough to be little more than an irrigation/drainage ditch surrounded by agricultural lands. Unfortunately, historic records were unavailable to us regarding habitat conditions of the slough prior to the arrival of non-natives and the subsequent conversion of this area to agriculture. Large-scale scouring events, primarily the 1964 flood, appear to have broadened the channel. Juvenile chinook, coho, cutthroat, and steelhead were all captured during sampling in the south slough, and it appears to provide quality overwintering habitat for steelhead and cutthroat during winter and early spring months, although sampling techniques were inadequate to determine anything except presence/absence.

Sampling in the south slough was sporadic due to access problems during low flows in the summer and also the lack of suitable sampling gear. Minnow trapping was attempted frequently but was not successful, and snorkeling was ineffective due to poor visibility. Beach seining was the only method that seemed to work; however, seining locations were limited due to the deep waters and steep banks through most of the slough. Boat electrofishing may be the most effective way to sample the slough for fish. We have recently acquired a small electrofishing boat that we are in the process of renovating for use in the estuarine sloughs.

Dissolved oxygen in the upper reach of the south slough, which frequently fell below 6mg/L, may limit salmonid utilization. DO levels were improved at each successively downstream station in the slough and never dropped below 6mg/L at the lowermost sampling station (Station 7). This is probably due to swifter currents in the lower slough, which limits the accumulation of algae and aquatic macrophytes, which are quite thick in the upper slough. Dense accumulations of algae and macrophytes can cause oxygen sags in the early morning hours, creating intolerable conditions for aquatic species (Horne and Goldman 1994). Evidence of this was observed during overnight minnow trapping, when threespine stickleback recovered from the upper region of the slough were all mortalities, yet fish captured in the lower slough did not suffer any mortalities (YTFP, unpublished data).

The Hunter Creek and Salt Creek sloughs likely provide overwintering habitat for juvenile salmonids, as well as provide thermal refugia areas for fish during summer months. Summer temperatures in Salt Creek ranged between 12 - 15°C in 2002, while daily summertime minimum temperature in Hunter Creek ranged between 11 - 14°C and maximum temperature ranged between 14 - 18°C. During beach seining in the lower estuary, CDFG observed that most of the subyearling chinook were captured from sites adjacent to the mouth of Hunter Creek, along with juvenile steelhead, cutthroat, and coho (Wallace 2003). While Salt Creek may provide thermal refugia for salmonids during warm summer months, it is probably not utilized as much as Hunter Creek due to DO limitations.

Water quality within the estuary is highly variable throughout the year and is greatly influenced by time of year, river flow, tidal cycle, and configuration and location of the mouth. Temperature is most variable in the lower estuary due to saltwater intrusion and formation of a salt wedge along the bottom portion of the river channel. Water temperature between June and August is apparently the water quality parameter most stressful to juvenile salmonids. We frequently observed daily maximum temperatures between 23 – 25°C during the summer of 2002, and Wallace (1998) observed similar results during previous water quality monitoring. Water temperatures in the Klamath River were likely historically high, as data from 1926 documented river temperatures near the channel bottom between 20.5 – 22.0°C (Snyder 1931).

Water quality monitoring by CDFG in the estuary similarly concluded that high water temperature was likely the most serious problem faced by juvenile salmonids during summer months (Wallace 1998). A study by Beacham and Withler (1991) indicated that ocean-type chinook (fall chinook) may be better adapted for warmer temperatures due to their limited residency in freshwater, and the their UILT (Upper Incipient Lethal Temperature) may vary by population depending on their history of adaptation to temperature regimes. That said, numerous other studies have shown that temperatures such as those observed in the Klamath River estuary may limit juvenile chinook growth (Armour 1990, Marine and Cech 1998). In addition to increasing the metabolic demand of outmigrating juvenile salmonids, increased temperatures may cause poor feeding. A study by Brett (1958) showed that subyearling fall chinook in the Columbia River inhibited feeding when temperatures were between 18 - 20°C. Utilization of cooler refugia areas such as the mouths of Hunter and Salt Creek, along with the cooler saltwedge in the estuary, may provide juvenile salmonids with relief from high water temperatures observed in the Klamath River estuary during summer months. In juvenile salmonid surveys conducted in the estuary, chinook appeared to be more abundant near the freshwater/saltwater interface, probably seeking thermal refugia (Wallace 1995a).

The original objective of purse seine sampling in the deeper waters within the estuary was to compare results with concurrent CDFG beach seine sampling and determine whether there were size differences or peak catch differences for subyearling chinook. Unfortunately, due to the experimental nature of the gear, we had difficulty effectively using the gear prior to July of 2003. Interestingly, this is when peak catches of juvenile chinook were captured in the deeper waters of the estuary. Beach seining results also indicate a pulse of juvenile chinook moving through the estuary during that time, in addition to a pulse of fish moving through in late June (CDFG, unpublished data).

Adipose clipped fish were captured throughout the sampling season, but gave us little information on the number of hatchery fish captured in relation to total catch due to differences in fractional marking between Trinity River Hatchery and Iron Gate Hatchery. The only method for determining peak hatchery emigration would be to sacrifice adipose clipped fish, remove CWTs, determine origin and extrapolate rates for each hatchery group. Future hatchery plans should consider marking a constant fraction of all fish released, similar to the 25% constant fractional marking rate currently used at Trinity River Hatchery so that the extent of hatchery utilization and rearing below the Klamath-Trinity confluence can be more easily calculated without sacrificing all ad-clipped fish.

The sizes of juvenile chinook captured in beach seines by CDFG and our purse seine were similar during June, July, and August of 2002 and June and July of 2003, although no statistical analyses were carried out due to small sample sizes and the sporadic nature of sampling. Subyearling chinook in August and September of 2003 showed increased growth compared with earlier months, with mean fork length increasing approximately 5mm during each subsequent weekly sampling through mid-September, when mean fork length reached 115.32 mm. Beach seine sampling was not conducted by CDFG during September, so data is not available for comparison. However, fish were substantially smaller than observations by Snyder (1931), who described juvenile chinook commonly captured in the estuary during late summer and early fall ranging between 6 – 7 inches (152 – 177 mm). Scale samples from these fish show increased growth during estuarine residence, and scales from returning adults showed that fish with this scale pattern had a higher ocean survival rate (Snyder 1931). Numerous other studies also indicate that chinook that are successful in utilizing estuaries for rearing have higher survival rates (Reimers 1971, Nicholas and Hankin 1989). Future work is needed to determine factors that may be limiting chinook growth and residency in the Klamath River estuary so that restoration activities can be implemented to increase the success of juvenile chinook leaving the Klamath Basin.

RECOMMENDATIONS

1. Continue monitoring juvenile salmonid utilization, emigration, distribution, and abundance in the Klamath River estuary. The California Department of Fish and Game (Mike Wallace) has been collecting this data since 1986, and it is important monitoring information needed to understand the health of anadromous salmonid stocks, especially juvenile chinook, emigrating from the Klamath River Basin.

2. Implement standardized constant fractional marking rates for hatchery fish released throughout the Klamath River Basin. Currently, the extent of hatchery utilization and rearing below the Klamath-Trinity confluence is difficult to determine due to differences in marking techniques between Iron Gate Hatchery and Trinity River Hatchery.

3. Conduct research to assess factors that may be minimizing the use of the estuary by juvenile salmonids. This should include an assessment of potential density dependent factors including food availability, presence and abundance of hatchery outmigrants, water quality, and habitat availability/suitability. If lack of preferred habitat is found to be limiting estuarine residence, a restoration plan should be designed. Future plans should assess the feasibility of increasing habitat complexity through the re-introduction of large woody debris and re-establishment of natural edge-type habitat.

4. Determine the extent of overwintering that occurs in the south slough of the Klamath River estuary by juvenile salmonids. The use a small electrofishing boat or raft would likely be the most effective sampling technique for this habitat.

5. Assess the feasibility of addressing water quality issues that are limiting salmonid utilization of the south slough of the estuary during summer months. If deemed practicable, conduct habitat restoration measures that may increase habitat suitability, such as eliminating dense aquatic macrophytes and algae in the upper reaches and/or increasing flow into the slough.

6. Determine the extent of non-natal rearing that occurs in lower Salt and Hunter Creeks to assess their importance as thermal refugia areas, as well as providing off-channel habitat during periods of high flow. This would need to be a multi-year effort conducted year-round to understand and quantify the usage of these areas by various salmonid species and life stages over a wide range of water quality and flow conditions.

7. Improve water quality in the lower reach of Salt Creek, where low dissolved oxygen may currently limit salmonid utilization of a large thermal refugia area. Assess the feasibility of working with current landowners to fence the reach for cattle exclusion, stabilize eroding banks, and re-establish the riparian canopy.

8. Assess the feasibility of restoring slough habitat within the Salt and Hunter Creek sloughs. This should include assessing the possibility of reconnecting the Salt and Hunter Creek drainages, re-establishing the historic natural meanders in the lower reaches of these drainages (pre-farm field and grazing conversion) and possibly constructing off-channel ponds and/or sloughs. The objective would be to increase the quantity and complexity of habitat available for non-natal rearing.

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Personal Communications

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Wallace, M. April 17, 2001. Development of Yurok Tribal Fisheries Program Klamath River Estuary study plan.

Williams, Chuck. April 7, 2004. Longtime resident and previous owner of Dad's Camp.