FINAL PERFORMANCE REPORT

As Required By

FEDERAL AID IN SPORT FISH RESTORATION ACT

INLAND AND ANADROMOUS SPORT FISH AND MANAGEMENT AND RESEARCH

Federal Aid Project F-51-R

Inland and Anadromous Sport Fish Management and Research

Category: Surveys and Inventories

Project No. 32: Klamath River Basin Juvenile Salmonid Investigations

Job No. 6: Food Habits and Preferences of Juvenile Chinook
Salmon in the Klamath River Estuary

California Department of Fish and Game

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Period Covered: July 1, 1991 through June 30, 1995

I. Summary:

The California Department of Fish and Game's Natural Stocks Assessment Project conducted this study to determine the diets of juvenile salmonids related to prey availability in the Klamath River estuary. During 1991-1992 in the lower Klamath estuary, isopods, amphipods, insects, mostly dipterans (true flies), and mysidaceans (opossum shrimp) were the most numerous organisms captured in pelagic and epibenthic tows, while amphipods, oligochaets (worms), and isopods were the most numerous items collected in benthic samples. In the upper estuary, insects, mostly dipterans, gastropods, isopods, and arachnids (spiders and mites) were the most numerous organisms captured in pelagic tows; ostracods (seed shrimp), insects, and isopods were the most common items captured in epibenthic tows; insects, amphipods, and oligochaets comprised most of the items in Surber samples; and amphipods dominated catches in Ekman dredge samples. There was at least an order of magnitude increase in the density of organisms captured progressing from pelagic to epibenthic to benthic sampling. Statistical tests usually showed no significant differences in the abundance of major taxonomic groups between habitats. The exceptions were isopods from upper estuary pelagic tows, amphipods from lower estuary epibenthic tows, and insects from upper estuary epibenthic tows. Insects, mostly dipterans, and amphipods were the most numerous prey items found in all juvenile salmonid stomachs. However, chinook collected from the lower estuary preferred homopterans (aphids), ephemeropterans (mayflies), hymenopterans (ants) and mysidaceans while chinook collected from the upper estuary preferred trichopterans (caddisflies),

ephemeropterans, lepidopterans (butterflies), and mysidaceans. Also, preferred prey of juvenile chinook from upper estuary pelagic tows were significantly different between habitats from March through July (when juvenile chinook abundance was highest) with gravel flat habitat having by far the highest average rank of preferred prey. From April through June chinook and coho salmon exhibited significant diet overlap due to their high reliance on dipterans and ephemeropterans. In contrast, steelhead contained a higher proportion of amphipods, trichopterans, isopods, and fish, while cutthroat contained predominately amphipods. However, from June through August there was significant diet overlap between chinook and steelhead and chinook and cutthroat, due primarily to high numbers of amphipods in the diets of all three species. During 1992-1993 the most numerous items captured in the Klamath estuary were insects, arachnids, mysidaceans, and amphipods in pelagic tows; isopods, insects (mostly dipterans), amphipods, and mysidaceans in epibenthic tows; and amphipods, isopods, bivalves, and insects (mostly dipterans) in benthic samples. Epibenthic tows from 1991-1992 and 1992-1993, pelagic tows from 1991-1992, and Ekman dredge samples from 1992-1993 showed that the abundance of juvenile chinook preferred prey was lowest in the summer and early fall during times of peak chinook abundance. These results suggest that the food supply in the Klamath River estuary was taxed by high chinook abundance. However, it appears that significant chinook rearing occurs upstream of the estuary in the mainstem river and it is not known if, or how far upstream the lowered prey abundance occurs. Therefore until we answer these questions it will be impossible to determine if the lowered prey abundance of preferred prey in the estuary limits salmonid production from the Klamath basin.

II. Background:

Numerous estuaries on the West Coast of North America have been shown to be important rearing areas for some species of juvenile salmonids (Reimers 1971; Healey 1980a; Kjelson et al. 1982; Levy and Northcote 1982; Myers and Horton 1982). Two reasons for this is that estuaries provide nursery habitat for juvenile salmonids and an environment for productive foraging (Simenstad et al. 1982) . Juvenile salmonids, especially chinook salmon, may rear and therefore concentrate in estuaries during their seaward migration. Here they are more likely to deplete their food supply and compete for food than after they disperse to sea (Feller and Kaczynski 1975). Some studies have suggested that juvenile salmonid growth and survival are possibly limited by the availability of prey (Reimers 1971; Healey 1979; Kjelson et al. 1982; Simenstad et al. 1982; Neilson et al. 1935).

Other studies have shown that juvenile salmonids seem to prefer some estuarine habitats over others (MacDonald et al. 1987; McCabe et al. 1986). This may be due, in part, to the amount or type of food available to them in each habitat.

It is likely that tens of millions of juvenile salmonids migrate through the Klamath estuary on their way to the ocean. Based on this and the tendency of chinook to rear in estuaries, the Klamath River Task Force (1991) stated that the Klamath River estuary appears to be an area where density dependent rearing mortality could be decreasing the survival of salmonid stocks and that this problem may be heightened by the large release of hatchery chinook from basin hatcheries. Simenstad and Wissmar (1984) stated that in some cases the estuary may limit the potential summer rearing production of a watershed despite the potential freshwater production of chinook fry. Reimers (1971) suggested, and was later supported by Neilson et al. (1985), that high juvenile chinook salmon abundances reduced their growth rates in the Sixes River estuary, Oregon. He theorized that it was a density dependent growth reduction related to prey availability. Wallace (1993), noted a similar pattern in the weekly mean fork lengths (FL) of juvenile chinook salmon in the Klamath River estuary that Reimers described for the Sixes River estuary in which the size of the chinook did not increase during the summer months when their abundance was high.

Many studies have described the diet of juvenile salmonids within estuaries, but relatively few, such as Busby (1991), MacDonald et al. (1990), Craddock et al. (1976), Sibert (1979), and Congleton (1978) have attempted to compare the diet of juvenile salmonids to the abundance of prey items available at the time of their capture. Studies of food habits of fishes are more meaningful if they determine not only what the fishes eat but also measure the prey that are potentially available to them (Chesson 1979). Investigators have long noted the importance of comparing fish diets to the availability of potential prey when trying to determine not only prey preference, but whether prey availability may be limiting fish growth (Hess and Rainwater 1939; Allen 1941). With this in mind, the California Department of Fish and Game (CDFG) initiated a study of juvenile salmonids in the Klamath River estuary to: 1) determine their diet; 2) determine the type and abundance of prey available to them; 3) determine if their diets are different between selected habitat types; 4) assess whether some habitats have higher abundance of prey items and in turn support higher salmonid abundance; 5) determine if there is competition for food between salmonid species; and 6) assess whether their high abundance taxed the available food supply and caused their apparent slower growth. By documenting the type of prey consumed by juvenile salmonids in various estuarine habitats, determining the prey preference of juvenile chinook, and comparing chinook diets to the diets of other juvenile salmonid species in the Klamath estuary to look for signs of competition, this study may show if the rearing capacity of the estuary is being taxed, possibly limiting the juvenile salmonid production from the basin.

Study Area - The Klamath River is within the Columbian Province which extends along the Northern Pacific coast from Cape Mendocino to Vancouver Island. Mountainous Shorelands and rocky foreshores are prevalent. Estuaries in this province are strongly influenced by freshwater runoff and the tidal range *is* large to moderate (USFWS 1981) . The Klamath estuary is short and small especially when compared to the large size of the watershed. The estuary provides numerous habitat types and a passage way for anadromous fishes but lacks the extensive tide flats and tidal marshes found in most larger estuaries. Tidal penetration varies greatly seasonally and is effected by freshwater flow and sand berm which forms in the late summer at the river mouth.

III. Objectives:

1) Describe the food items eaten seasonally by juvenile salmonids within the Klamath River estuary.
2) Determine the type and abundance of prey available to juvenile salmonids in the Klamath River estuary.
3) Assess whether the apparent slow summer growth of juvenile chinook salmon, which we have previously observed, might be caused by high juvenile abundance which taxes the available food supply in the estuary.
4) Assess the potential competition for food between salmonid species.
5) Determine if juvenile salmonid diets are different among selected habitat types.
6) Assess food preferences of juvenile salmonids within the Klamath River estuary.

IV. Procedures:

For this study the Klamath River estuary was defined as the lower four miles of river subject to tidal fluctuation (Figure 1). The lower estuary (river miles 0-1.5) is characterized by broad open water 2 to 4 meters deep with primarily sand/gravel substrate. This area experiences tidal fluctuation up to 2 meters, and brackish water 15 to 30 ppt is usually present along the bottom during most tide levels from May through October. The deepest portion of the estuary occurs near river mile (RM) 1 where water depth exceeded 10 meters at high tide. The few

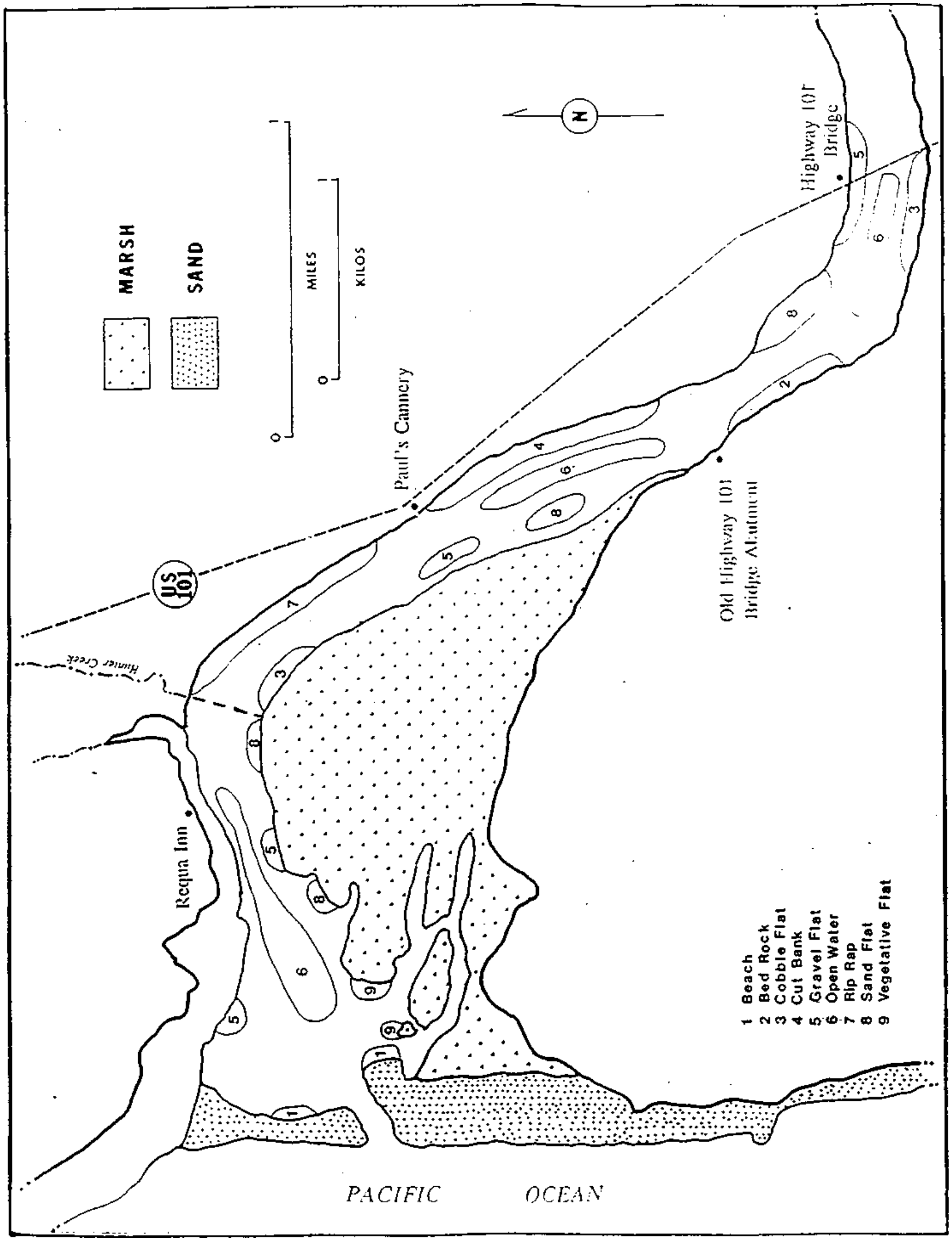

Figure 1. Approximate locations and habitat types of Klamath River estuary prey item sampling sites.

tidal flats that occur in the estuary are found in the lower estuary. In the upper estuary the river channel gradually narrows as it proceeds upstream and begins to take on more riverine characteristics. Brackish water usually extends upstream to about KM 3 at high tide, but has been detected as far upstream as RM 4 during high tide coupled with extreme low river flow conditions. The substrate in the upper estuary is also mostly sand/gravel. A layer of freshwater 1 to 2 meters deep is found along the surface of the water column throughout the entire estuary rendering littoral areas, even in the lower estuary, primarily freshwater habitat.

The amount and type of habitat found in the Klamath estuary varies with season and between years. Historical photographs and older aerial photographs show that the lower estuary has been very dynamic in regards to its scour and deposition points throughout the last 50 to 100 years. Seasonal habitat changes within the estuary consisted primarily of an increase in plant growth, especially algae, along the river margins and shallow water areas, and the accumulation of fine sediment throughout the estuary during summer as flows dropped and water temperatures rose (CDFG 1993b). During the summers of 1991 and 1992 many shallow water habitats such as mud, sand, gravel, or cobble flats gradually became smaller in area and eventually became vegetative flats due to the formation of a thick algal mat or in some cases due to the extensive growth of aquatic vascular plants. Winter river flows tend to scour vegetation and fine sediments out of the estuary. For example we noted a decrease in the amount of vegetated areas and fine substrate areas in the spring of 1993 compared to the spring of 1992, probably due to the high river flows during the winter of 1992-93.

Prey Item Collection - From March 1991 to March 1992 we attempted to collect prey items biweekly from seven habitat types in the upper estuary (river miles 1.5 to 4.0) and five habitats in the lower estuary (river miles 0 to 1.5) in order to determine if prey availability differed between these habitats (Appendix 1). Habitats were classified following the method described by Bottom et al. (1979) and Starr (1979) in which estuarine habitats are separated essentially by substrate type (Figure 2). All sampling was attempted within a consistent water height range (approximating 4 to 6 ft. tide levels during late spring and summer river flows) to minimize the effect of river flow and tidal stage on the distribution and abundance of prey items. Relative water height was determined from graduated tide staffs located throughout the estuary.

Because of the wide variety of prey items eaten by juvenile salmonids (Shapovalov and Taft 1954; Sasaki 1966; Healey 1980a and 1982; Simenstad

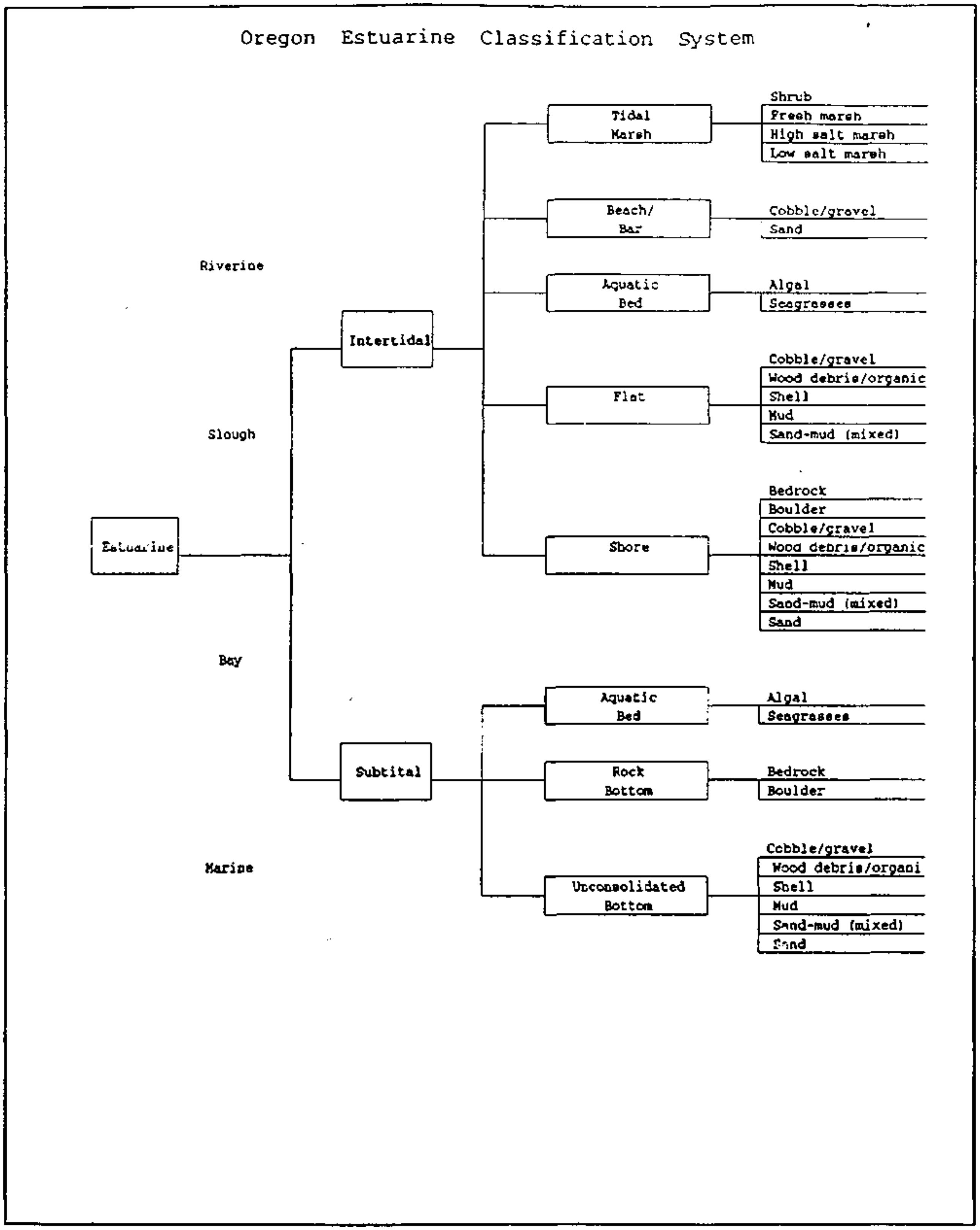

FIGURE 2. Habitat Classification system developed by Oregon Department of Fish and Wildlife to describe habitats found in Oregon estuaries (after Starr 1979).

et al. 1982) we attempted to collect surface, epibenthic, and benthic samples in each habitat type. However, we were not able to conduct epibenthic or benthic sampling in all habitats due to excessive water depths, swift currents, or armored substrate (Appendix 1). We also suspended prey item sampling in habitats which had changed from their original designation. For example, we discontinued sampling cobble flat habitat when extensive plant growth changed it into a vegetative flat habitat during the study.

Pelagic samples were collected by towing a 0.5 meter (m), or 0.3 m plankton net and cod end bottle with 0.5mm mesh for five minutes. The net was towed along side the boat so as not to stir up benthic or epibenthic prey items in front of the net with the boat motor. A General Oceanics manual flow meter was suspended in front of the opening of the net to allow us to calculate the volume of water sampled. The catch-per-unit-effort (CPUE) was calculated as the number of organisms per m^3. The sample collected and a field tag containing the date, habitat type, sampling method, and location of the sample were placed into one quart jars.

Epibenthic samples were collected with a 0.3 m plankton net and cod end bottle with 0.5 mm mesh attached to a 30.48 m length of rope. When deployed, the net was allowed to sink to the bottom and was then retrieved slowly allowing the net to bounce along the substrate for 100 feet, usually parallel to the shoreline. The sample was then washed through two screens; a 6.4 mm screen mesh to remove large debris, and a 0.5 mm screen to collect prey items. The sample on the screen was then washed into one quart jars containing a completed field tag. CPUE was calculated as the number of organisms per m^3.

Benthic samples were collected with a 0.0232 m^2 Ekman Dredge in soft substrate. A 0.0929 m^2 Surber Sampler was used to collect benthic samples from habitats in the upper estuary when water depths and currents were adequate to use this method (Appendix 1). In the upper estuary benthic samples were collected by a Surber Sampler in gravel flat habitat from March through July and by an Ekman Dredge in sand flat habitat from August to March 1992. The change in sampling gear was forced by lower river flows and reduced tidal fluctuation which created "standing water" in the estuary and rendered the Surber Sampler useless. The change in habitats was due to the inability of the Ekman Dredge to successfully grab gravel substrate. Sample sites were arbitrarily chosen within each habitat type. Benthic samples from the Ekman Dredge and Surber Sampler were washed through two screens and placed into sample jars as described above for the epibenthic samples. CPUE was calculated as the number of organisms per m^2.

Field samples were brought back to the laboratory and transferred into 10% formalin for 1 to 3 days, and then transferred to and stored in 45% alcohol until they were processed. All samples were rough sorted to remove debris and substrate and organisms were placed into vials containing "like organisms". Labels containing the information on the field tags were inserted into each vial. Organisms were identified to a major taxonomic group and counted. Heads and nearly complete organisms were included in the count.

Beginning in April 1992 we shifted our project's goals from describing prey abundance by habitat to describing prey abundance in the estuary as a whole. We did this to look for trends in prey item abundance relative to juvenile salmonid abundance and hopefully to establish a long-term prey item abundance data set. We gathered pelagic, epibenthic, and benthic prey item samples from fixed stations throughout the estuary (Appendix 1). We collected samples biweekly from April 1992 through January 1993, and occasionally from January through May 1993 whenever water conditions allowed . The samples were processed the same way as in the previous year except that they were preserved and stored only in 45% alcohol.

<u>Fish Diet Collection</u> - Juvenile salmonids were collected from March 1991 to March 1992 by electrofishing in the upper estuary and seining in the lower estuary. Each week we attempted to retain up to two fish per species per habitat to determine their stomach contents. We injected 10% formalin into the body cavity of each fish and placed them into a jar of 10% formalin with a field tag containing the date, habitat, method of capture, species, fork length, and weight of each fish.

Once in the laboratory the fish were kept in formalin for 3 to 10 days and then transferred to and stored in 45% alcohol until they were processed. We removed the stomachs (esophagus to pylorus) and emptied the contents of each into a small dissecting pan. The contents were rough sorted and placed into vials of 45% alcohol containing "like organisms". Organisms were identified to a major taxonomic group and counted. Heads and nearly complete organisms were included in the count.

<u>Data Analysis</u> - Prey item data from March 1991 through March 1992 were stratified by upper and lower estuary, habitat type, and collection method. We wanted to test whether prey item abundance for selected groups differed by habitat and to determine whether we could combine habitat types to describe

overall estuary prey abundance. Because of the relatively small number of samples, the non normal distribution of the number of prey items captured, and the extremely large variation in the number of prey items per sample, we decided to use non parametric statistical tests. Usually only pelagic samples were tested because other collection methodologies were normally not conducted a sufficient number of times in multiple habitats (Appendix 1). We used Kruscal-Wallis analysis to test for differences in the number of organisms of the most abundant taxonomic groups by habitat type. We used the Mann-Whitney U-test when only two habitats were compared.

From April 1992 to May 1993 we collected pelagic, epibenthic, and Ekman dredge (benthic) samples using the same equipment as in 1991-1992. However, pelagic and benthic samples were each collected from three standard locations in the estuary (Appendix 1) and the data was pooled for each collection method to look for trends in abundance of potential prey items throughout the course of the year. Epibenthic tows from the same time period were also collected from three stations, however due to sample spoilage and missed sampling dates at some sites due to high current velocities, we only analyzed data from one site (lower estuary gravel flats, the same site sampled in 1991).

To assess possible food competition between juvenile salmonid species we used the Morisita-Horn Index developed by Morisita (1959) and modified by Horn (1966) as presented in Magurran (1988):

$$c = \frac{2\ (\ an\ X\ bn\ )}{(\ da + db\ )\ aN\ X\ bN}$$

where C = overlap coefficient

aN = the number of prey items in species A

bN = the number of prey items in species B

an = the number of individuals in the prey in species A

bn = the number of individuals in the prey in species B

$$da = \frac{an^2}{aN^2}$$

$$db = \frac{bn^2}{bN^2}$$

Values of C range from 0 to 1, with 0 indicating no overlap and 1 indicating complete diet overlap. A value of 0.6 is considered significant diet overlap (Zaret and Rand as cited by McCabe et al 1983).

Prey preferences of juvenile chinook were determined by the method described by Johnson (1980) whereby the difference in the average rank of a prey group in the diet compared to its' average rank in the environment is calculated. We assumed that a taxonomic group was a preferred prey item if the calculated difference was greater than zero and avoided if less than zero.

V. Findings:

Prey Item Abundance 1991-1992 - Isopods (sub samples were exclusively Gnorimosphaeroma lutea), amphipods (primarily Corophium spinicorne), and insects (primarily dipterans) were the most numerous organisms captured in the Klamath River estuary from March 1991 through March 1992. Isopods and amphipods dominated catches in the lower estuary (Table 1), while the composition of organisms captured in the upper estuary was more diverse (Table 2). There was at least an order of magnitude increase in the density of organisms captured progressing from pelagic to epibenthic to benthic sampling (Tables 1 and 2). The number of organisms captured per sample varied greatly within all habitats for all sampling methodologies.

Prey Item Abundance by Habitat, 1991-1992 - In the lower estuary we started to sample five habitats with pelagic tows by June. We were also able to complete epibenthic tows from April 1991 to March 1992 in gravel and vegetative flat habitats. However due to sand routinely completely filling the net during epibenthic tows we were only able to successfully complete epibenthic tows in sand flat habitat from June through August 1991 and in beach habitat from May through July 1991. Also, due to small amounts of gravel present in the substrate which repeatedly jammed open the Ekman dredge, we were only able to successfully conduct benthic sampling in lower estuary sand flat habitat from August 1991 until March 1992 and in lower estuary beach habitat from September 1991 to February 1992 (Appendix 1).

In the lower estuary, the most numerous organisms captured in sand flat habitat were isopods and amphipods in pelagic tows; amphipods and insects in epibenthic tows; and amphipods and oligochaets (worms) in Ekman dredge (benthic) samples (Table 1). In beach habitat, we captured mostly isopods in pelagic tows; isopods and amphipods in epibenthic tows; and amphipods and oligochaets in Ekman dredge samples (Table 1). In gravel flat habitat, pelagic and epibenthic tows captured mostly isopods and amphipods (Table 1). Pelagic and epibenthic tows from vegetative flat habitat were dominated by isopods (Table 1). Open water pelagic tows captured mostly isopods, amphipods, and insects (Table 1).

TABLE 1. Most numerous organisms captured by pelagic, epibenthic and benthic sampling in the lower Klamath River estuary habitats, 4/2/91 to 3/9/92.

Pelagic Samples

Gravel Flat (Effort = 420.11m^3)

Group	No.	% Catch	CPUE (#/m^3)
Isopod	517	78.7	1.23
Amphipod	66	10.0	0.16
Insect	38	5.8	0.09
Other	36	5.5	0.09
Total	657	100	1.56

Sand Flat (Effort = 326.00m^3)

Group	No.	% Catch	CPUE (#/m^3)
Isopod	438	63.6	1.34
Amphipod	129	18.7	0.40
Insect	51	7.4	0.16
Mysidacea	42	6.1	0.13
Other	29	4.2	0.09
Total	689	100	2.11

Vegetative Flat (Effort = 286.43m^3)

Group	No.	% Catch	CPUE (#/m^3)
Isopod	275	79.5	0.96
Insect	33	9.5	0.11
Other	38	11.0	0.13
Total	346	100	1.21

Beach (Effort = 421.75m^3)

Group	No.	% Catch	CPUE (#/m^3)
Isopod	1,248	89.8	2.96
Insect	68	4.9	0.16
Other	74	5.3	0.18
Total	1,390	100	3.30

Open Water (Effort = 287.01m^3) (with sample 7/2)

Group	No.	% Catch	CPUE (#/m^3)
Isopod	1,435	63.1	5.00
Amphipod	502	22.1	1.75
Insect	325	14.3	1.13
Other	12	0.5	0.04
Total	2,274	100	7.92

Open Water (Effort = 274.14m^3) (without sample 7/2)

Group	No.	% Catch	CPUE (#/m^3)
Isopod	324	89.8	1.18
Insect	17	4.7	0.06
Other	20	5.5	0.07
Total	361	100	1.32

Epibenthic Samples

Gravel Flat (Effort = 47.88m^3)

Group	No.	% Catch	CPUE (#/m^3)
Isopod :	10,410	70.7	217.42
Amphipod	3,555	24.2	74.25
Other	750	5.1	15.66
Total :	14,715	100	307.33

Vegetative Flat (Effort = 47.88m^3)

Group	No.	% Catch	CPUE (#/m^3)
Isopod	9,087	87.0	189.79
Mysidacea	835	8.0	17.44
Other	521	5.0	10.88
Total	10,443	100	218.11

Sand Flat (Effort = 15.96m^3)

Group	No.	% Catch	CPUE (#/m^3)
Amphipod	3,015	53.1	188.91
Insect	1,137	20.0	71.24
Isopod	553	9.7	34.65
Mysidacea	432	7.6	27.07
Oligochaet	310	5.5	19.42
Other	230	4.1	14.41
Total	5,677	100	355.70

Beach (Effort = 13.30m^3)

Group	No.	% Catch	CPUE (#/m^3)
Isopod	347	41.1	26.09
Amphipod	268	31.7	20.15
Mysidacea	98	11.6	7.37
Oligochaet	62	7.3	4.66
Insect	58	6.9	4.36
Other	12	1.4	0.90
Total	845	100	63.53

Benthic (Ekman) Samples

Sand Flat (0.28m^2)

Group	No.	% Catch	CPUE (#/m^2)
Amphipod	905	60.0	3,770.83
Oligochaet	357	23.3	1,487.50
Isopod	148	9.6	616.67
Bivalve	96	6.3	400.00
Other	29	1.9	120.83
Total	1,535	100	6,395.83

Beach (0.14m^2)

Group	No.	% Catch	CPUE (#/m^2)
Amphipod	1,194	66.6	9,950.00
Oligochaet	356	19.9	2,966.67
Isopod	210	11.7	1,750.00
Other	33	1.8	275.00
Total	1,793	100	14,941.67

TABLE 2. Most numerous organisms captured by pelagic, epibenthic and benthic sampling in the upper Klamath River estuary habitats, 3/26/91 through 3/16/92.

Pelagic Samples

Open Water (Effort = 481.01m^3)

Group	No.	% Catch	CPUE(#/m^3)
Isopod	99	31.2	0.21
Arachnid	97	30.6	0.20
Insect	75	23.7	0.16
Other	46	14.5	0. 10
Total	317	100	0.66

Cut Bank (Effort = 528.17m^3)

Group	No.	% Catch	CPUE(#/m^3)
Isopod	344	45.9	0.65
Insect	286	38.1	0.54
Other	120	16.0	0.23
Total	750	100	1.42

Rip Rap (Effort = 480.54m^3)

Group	No.	% Catch	CPUE(#/m^3)
Cladocera	347	30.1	0.72
Insect	245	21.3	0.51
Arachnid	242	21.0	0.50
Isopod	196	17.0	0.41
Other	123	10.6	0.26
Total	1,153	100	2.40

Bed Rock (Effort = 511.18^3)

Group	No.	% Catch	CPUE(#/m^3)
Isopod	206	28.4	0.40
Insect	205	28.4	0.40
Gastropod	97	13.4	0.19
Arachnid	96	13.3	0.19
Amphipod	68	9.4	0.13
Other	51	7.1	0.10
Total	723	100	1.41

Sand Flat (Effort = 451.68m^3)

Group	No.	% Catch	CPUE(#/m^3)
Arachnid	295	29.4	0.65
Insect	227	22.6	0.50
Oligochaet	176	17.5	0.39
Isopod	137	13.7	0.30
Cladocera	97	9.7	0.21
Other	71	7.1	0.16
Total	1,003	100	2.22

Gravel Flat (Effort = 437.18m^3)

Group	No.	% Catch	CPUE(#/m^3)
Gastropod	1,026	49.5	2.35
Insect	541	26.1	1.24
Ostracod	285	13.7	0.65
Other	221	10.7	0.51
Total	2,073	100	4.74

Epibenthic Samples

Gravel Flat (Effort = 37.24m^3)

Group	No.	% Catch	CPUE (#/m^3)
Ostracod	2,490	45.7	66.86
Gastropod	944	17.3	25.35
Isopod	593	10.9	15.92
Insect	584	10.7	15.68
Arachnid	289	5.3	7.76
Other	543	10.0	14.58
Total	5,443	100	146.16

Benthic Samples

Gravel Flat (Effort = 0.74m^2) Surber Samples

Group	No.	% Catch	CPUE (#/m^2)
Insects	460	60.0	621.62
Oligochaet	176	22.9	237.84
Gastropod	102	13.3	137.84
Other	29	3.8	39.19
Total	767	100	1,036.49

Sand Flat (Effort =0.26m^2) Ekman Dredge

Group	No.	% Catch	CPUE (#/m^2)
Amphipod	3,461	79.2	13,572.55
Isopod	674	15.4	2,643.14
Other	234	5.4	917.64
Total	4,369	100	17,133.33

Due to sampling procedures and problems discussed above, we can only report on prey item abundance in upper estuary habitats using pelagic tows, except for epibenthic and benthic samples from gravel flat habitat and benthic sampling from sand flat habitat.

In the upper estuary, the most numerous organisms captured in gravel flat habitat were gastropods, insects, and ostracods (seed shrimp) in pelagic tows; ostracods, gastropods, isopods, and insects in epibenthic tows; and insects and oligochaets in the Surber (benthic) samples (Table 2) . In sand flat habitat, the most numerous organisms captured were arachnids (spiders and mites), insects, oligochaets, and isopods in pelagic tows, and amphipods and isopods in Ekman dredge samples (Table 2). The most numerous items captured in pelagic samples in other upper estuary habitats were isopods, arachnids, and insects in open water habitat; isopods and insects in bed rock habitat; cladocerans (water fleas), insects, arachnids, and isopods in rip rap habitat; and isopods and insects in cut bank habitat (Table 2).

The majority of Kruscal-Wallis and Mann-Whitney U-tests showed no significant differences in the abundance of prey groups between habitats at the 95% level (Table 3). The exceptions were isopods in pelagic tows from upper estuary habitats from 4/9/91 to 7/9/91; insects in pelagic tows from upper estuary habitats from 3/26/91 to 3/16/92; and amphipods in lower estuary epibenthic tows between gravel and vegetative flat habitats from 4/2/91 - 3/9/92.

Salmonid Diets - Overall, insects and amphipods were the most numerous prey items found in all juvenile salmonid stomachs (Table 4). In the upper estuary from May through July insects were by far the most numerous prey in chinook, coho, and steelhead stomachs, while amphipods dominated the contents of cutthroat stomachs (Table 4). Dipterans (true flies), ephemeropterans (mayflies) , and trichopterans (caddisflies) made up over 90% of the insects found in the salmonid stomachs. Dipterans were the most numerous insect found in chinook, coho, and cutthroat stomachs while ephemeropterans were the most numerous insects found in steelhead stomachs. Steelhead also had markedly higher proportions of trichopterans, fish, and isopods in their stomachs compared to the other salmonid species (Table 4).

In the lower estuary we only captured enough chinook and cutthroat to be used to compare stomach contents. In July and August amphipods were the most numerous items in chinook stomachs and dominated the contents of cutthroat

TABLE 3. Results of data analysis comparing abundance of organisms between selected habitats.

Group	Sampling Period	Habitats Compared	Test Statistic	Sig Level
LOWER PELAGIC (Kruscal-Wallis Test)				
Isopods	06/20/91 - 03/09/92	Vegetative, Sand & Gravel Flats, Open Water, Beach	0.753	0. 945
Amphipods	06/20/91 - 03/09/92	Vegetative, Sand & Gravel Flats, Open Water, Beach	5.036	0.284
Insects	06/20/91 - 03/09/92	Vegetative, Sand & Gravel Flats, Open Water, Beach	8.355	0.079
LOWER EPIBENTHIC (Mann-Whitney U-test)				
Amphipods	04/02/91 - 03/09/92	Gravel & Vegetative Flats	- 2.150	0.032
Insects	04/02/91 - 03/09/92	Gravel & Vegetative Flats	1.052	0.293
Isopods	04/02/91 - 03/09/92	Gravel & Vegetative Flats	- 0-	1
Mysids	04/02/91 - 03/09/92	Gravel & Vegetative Flats	- 0.143	0.887
LOWER EPIBENTHIC (Kruskal-Wallis Test)				
Isopods	06/06/91 - 07/19/91	Vegetative, Sand & Gravel Flats, Beach	4.501	0.212
Amphipods	06/06/91 - 07/19/91	Vegetative, Sand & Gravel Flats, Beach	4.586	0.205
Insects	06/06/91 - 07/19/91	Vegetative, Sand & Gravel Flats, Beach	1 .099	0.777
Mysids	06/06/91 - 07/19/91	Vegetative, Sand & Gravel Flats, Beach	2.709	0.439
LOWER EPIBENTHIC (Kruskal-Wallis Test)				
Isopods	06/06/91 - 08/15/91	Vegetative, Sand & Gravel Flats	3.176	0.204
Amphipods	06/06/91 - 08/15/91	Vegetative, Sand & Gravel Flats	0.558	0.757
Insects	06/06/91 - 08/15/91	Vegetative, Sand & Gravel Flats	0.336	0.845
Mysids	06/06/91 - 08/15/91	Vegetative, Sand 4 Gravel Flats	3.782	0.151
UPPER PELAGIC (Kruskal-Wallis Test)				
Amphipods	04/09/91 - 07/09/91	Cobble, Gravel & Sand Flats, Rip-Rap, Open Water, Cut Bank, Bed Rock	10.678	0.099
Insects	04/09/91 - 07/09/91	Cobble, Gravel 4 Sand Flats, Rip-Rap, Open Water, Cut Bank, Bed Rock	10.463	0.106
Isopods	04/09/91 - 07/09/91	Cobble, Gravel & Sand Flats, Rip-Rap, Open Water, Cut Bank, Bed Rock	18.823	0.004
Gastropods	04/09/91 - 07/09/91	Cobble, Gravel 4 Sand Flats, Rip-Rap, Open Water, Cut Bank, Bed Rock	5.098	0.531
Arachnids	04/09/91 - 07/09/91	Cobble, Gravel & Sand Flats, Rip-Rap, Open Water, Cut Bank	1.934	0.925

TABLE 3. Results of data analysis comparing abundance of organisms between selected habitats. (Continued)

UPPER PELAGIC (Kruskal-Wallis Test)				
Group	Sampling Period	Habitats Compared	Test Statistic	Sig Level
Amphipods	03/26/91 - 03/16/92	Gravel & Sand Flats, Rip-Rap, Cut Bank, Open Water, Bed Rock	7.351	0.196
Isopods	03/26/91 - 03/16/92	Gravel & Sand Flats, Rip-Rap, Cut Bank, Open Water, Bed Rock	7.207	0.206
Insects	03/26/91 - 03/16/92	Gravel & Sand Flats, Rip-Rap, Cut Bank, Open Water, Bed Rock	19.489	0.002
Gastropods	03/26/91 - 03/16/92	Gravel & Sand Flats, Rip-Rap, Cut Bank, Open Water, Bed Rock	10.463	0.063
Arachnids	03/26/91 - 03/16/92	Gravel & Sand Flats, Rip-Rap, Cut Bank, Open Water, Bed Rock	3.361	0.645
LOWER PELAGIC (Kruskal-Wallis Test)				
Preferred Prey	06/20/91 - 03/09/92	Vegetative, Sand & Gravel Flats, Beach, Open Water	6.199	0.185
LOWER EPIBENTHIC (Kruskal-Wallis Test)				
Preferred Prey	06/06/91 - 07/19/91	Vegetative, Sand & Gravel Flats, Beach	4.125	0.248
Preferred Prey	06/06/91 - 08/15/91	Vegetative, Sand & Gravel Flats	1.304	0.521
UPPER PELAGIC (Kruskal-Wallis Test)				
Preferred Prey	03/26/91 - 03/16/92	Open Water, Rip-Rap, Bed Rock, Cut Bank, Sand & Gravel Flats	3.968	0.554
Preferred Prey	03/26/91 - 07/23/91	Open Water, Rip-Rap, Bed Rock, Cut Bank, Sand & Gravel Flats	11.225	0.047

TABLE 4. Comparison of diets between juvenile chinook salmon, coho salmon, steelhead trout, and cutthroat trout in the Klamath estuary for selected months in 1991.

Upper Estuary (May-July)

Chinook (n = 39)

Prey Item	No.	%	0 No. per Stomach
Insect *	1,335	75.6	34.2
Amphipod	344	19.5	19.5
Other	88	5.0	2.3
Total	1,767	100	45.3

* Diptera 70.8%;
Ephemeroptera 22.8%;

Coho (n = 9)

Prey Item	No.	%	0 No. per Stomach
Insect *	716	92.6	79.6
Amphipod	54	7.0	6.0
Other	3	0.4	0.3
Total	773	100	85.9

* Diptera 51.7%;
Ephemeroptera 36.0%;
Trichoptera 9.9%

Steelhead (n = 17)

Prey Item	No.	%	0 No. per Stomach
Insect *	608	66.3	35.8
Amphipod	135	14.7	7.9
Fish	71	7.7	4.2
Isopod	62	6.8	3.6
Other	41	4.5	2.4
Total	917	100	53.9

* Ephemeroptera 45.4%;
Trichoptera 36.5%;
Diptera 12.0%

Cutthroat (n = 18)

Prey Item	No.	%	0 No. per Stomach
Amphipod	884	78.5	49.1
Insect *	139	12.3	7.7
Mysidacea	66	5.9	3.7
Other	37	3.3	2.1
Total	1,126	100	62.6

* Diptera 60.4%;
Trichoptera 21.6%;
Ephemeroptera 11.5%

Lower Estuary (July-August)

Chinook (n = 36)

Prey Item	No.	%	0 No. per Stomach
Amphipod	324	56.9	9.0
Insect *	187	32.9	5.2
Mysidacea	18	3.2	0.5
Fish	13	2.3	0.4
Other	27	4.7	0.8
Total	569	100	15.8

* Homoptera 75.4%;
Diptera 18.7%

Cutthroat (n = 9)

Prey Item	No.	%	0 No. per Stomach
Amphipod	357	92.5	39.7
Isopod	8	2.1	0.9
Other	21	5.4	2.3
Total	386	100	42.9

stomachs (Table 4). Homopterans (aphids) and dipterans were the most common insects found in the chinook stomachs.

From June to August chinook diets in the upper estuary shifted from one dominated by insects to one in which amphipods composed a majority of their prey (Table 5). In the fall and winter, mysidaceans and isopods became more numerous in their diets (Table 5). In the lower estuary, chinook diets were composed of primarily amphipods in July and August, but dominated by insects, primarily ephemeropterans, in September (Table 6). We collected too few stomach samples from the lower estuary after September to provide any meaningful results.

The degree of diet overlap between salmonids varied between species and time of year. From April through June 1991 juvenile chinook and coho salmon exhibited significant diet overlap (0.91), while the diet overlaps between chinook and steelhead (0.47) and chinook and cutthroat (0.26) were not significant. The high diet overlap between chinook and coho was due to their high reliance on dipterans and ephemeropterans. In comparison, steelhead diets contained fewer dipterans and a higher proportion of amphipods, trichopterans, isopods, and fish, while cutthroat diets were made up of primarily amphipods. However, when we compared diet overlap from June through August 1991 for chinook and steelhead (0.72) and chinook and cutthroat (0.68) both were significant. This was due primarily to the high numbers of amphipods in the diet of all three species.

We were able to capture enough chinook from May through August to compare their diets from various habitats in the upper estuary. Insects, (usually dipterans), were their most numerous prey in all sampled habitats except for sand flats where amphipods dominated their diet (Table 7). Ephemeropterans were also numerous in their diet especially those collected from cobble and gravel flat habitats. During October through January insects and amphipods remained their most numerous prey, but isopods and mysidaceans (opossum shrimp) comprised a higher proportion of their diet than May through August especially in rip rap habitat (Table 8).

In the lower estuary we captured only enough chinook to compare diets from July through September in three habitats. Insects, primarily homopterans and ephemeropterans were the most numerous food item found in chinook stomachs (Table 9), though most were consumed in September (Table 6). Amphipods and to a lesser extent fish and mysidaceans were also common organisms found in chinook stomachs.

TABLE 5. Monthly summary of juvenile chinook salmon diet from the upper Klamath estuary.

June

Prey Item	No.	%	0 No. per Stomach
Insect*	827	86.4	37.6
Amphipod	102	10.7	4.6
Other	28	2.9	1.3
Total	957	100	43.5

n = 22 (0 empty stomachs)
Mean FL = 96 mm
Mean Wt = 11.3 gm
* Diptera 68.9%;
Ephemeroptera 25.2%

July

Prey Item	No.	%	0 No. per Stomach
Insect*	508	62.7	29.9
Amphipod	242	29.9	14.2
Acarina	49	6.0	2.9
Other	11	1.4	0.6
Total	810	100	47.6

n = 17 (2 empty stomachs)
Mean FL = 86 mm
Mean Wt = 8.1 gm
* Diptera 74.2%;
Ephemeroptera 18.9%

August

Prey Item	No.	%	0 No. per Stomach
Amphipod	597	59.1	33.2
Insect*	320	31.7	17.8
Trematoda	71	7.0	3.9
Other	22	2.2	1.2
Total	1,010	100	56.1

n = 18 (1 empty stomach)
Mean FL = 97 mm
Mean Wt = 11.6 gm
* Diptera 70.6%;
Ephemeroptera 10.9%

October/November

Prey Item	No.	%	0 No. per Stomach
Isopod	182	58.7	10.1
Insect*	80	25.8	4.4
Amphipod	39	12.6	2.2
Other	9	2.9	0.5
Total	310	100	17.2

n = 18 (3 empty stomachs)
Mean FL = 137 mm
Mean Wt = 27.0 gm
* Hemiptera 52.5%;
Homoptera 15.0%;
Hymenoptera 15.0%

December

Prey Item	No.	%	0 No. per Stomach
Mysidacea	188	38.4	15.7
Insect*	185	37.8	15.4
Amphipod	71	14.5	5.9
Isopod	34	6.9	2.8
Other	12	2.4	1.0
Total	490	100	40.8

n = 12 (1 empty stomach)
Mean FL = 156 mm
Mean Wt = 45.9 gm
* Trichoptera 56.2%;
Diptera 21.1%

January

Prey Item	No.	%	0 No. per Stomach
Insect*	882	50.6	46.4
Amphipod	653	37.5	34.4
Mysidacea	166	9.5	8.7
Other	41	2.4	2.2
Total	1,742	100	91.7

n = 19 (0 empty stomachs)
Mean FL = 167 mm
Mean Wt = 64.3 gm
* Diptera 85.3%;
Trichoptera 9.2%

TABLE 6. Monthly summary of juvenile chinook salmon diet from the lower Klamath estuary.

July

Prey Item	No.	%	0 No. per Stomach
Amphipod	235	53.9	13.8
Insect *	178	40.8	10.5
Other	23	5.3	1.4
Total	436	100	25.6

n = 17 (1 empty stomachs)
Mean FL = 90 mm
Mean Wt = 8.1 gm
* Homoptera 79.2%; Diptera 15.7%

August

Prey Item	No.	%	0 No. per Stomach
Amphipod	89	66.9	4.7
Mysidacea	12	9.0	0. 6
Fish	12	9.0	0.6
Insect*	9	6.8	0.5
Other	11	8.3	0.6
Total	133	100	7.0

n = 19 (4 empty stomachs)
Mean FL = 99 mm
Mean Wt = 10.8 gm
* Diptera 77.8%

September

Prey Item	No.	%	0 No. per Stomach
Insect *	674	89.7	84.3
Amphipod	46	6.1	5.8
Other	31	4.6	3.9
Total	751	100	93.9

n = 8 (0 empty stomachs)
Mean FL = 105 mm
Mean Wt = 13.3 gm
* Ephemeroptera 74.2%;
Homoptera 19.1%

TABLE 7. Comparison of diets of juvenile chinook salmon from different habitat types in the upper Klamath estuary from May through August, 1991.

Sand Flat (n = 14)

Prey Item	No.	%	0 No. per Stomach
Amphipod	809	70.0	57.8
Insect *	287	24.8	20.5
Acarina	44	3.8	3.1
Other	18	1.6	1.3
Total	1,158	100	82.7

* Diptera 86.1%;
Ephemeroptera 9.8%

Gravel Flat (n = 24)

Prey Item	No.	%	0 No. per Stomach
Insect *	642	85.0	26.8
Trematoda	44	5.8	1.8
Amphipod	35	4.5	1.5
Other	34	4.5	1.4
Total	755	100	31.5

* Diptera 52.3%;
Ephemeroptera 30.8%;
Trichoptera 7.0%

Open Water (n = 4)

Prey Item	No.	%	0 No. per Stomach
Insect *	154	100.0	38.5
Total	154	100.0	38.5

*Diptera 87.7%; Trichoptera 6.5

Cut Bank (n = 7)

Prey Item	No.	%	0 No. per Stomach
Insect *	335	86.8	47.9
Amphipod	29	8.7	4.1
Trematoda	20	5.2	2.9
Other	2	0.5	0.3
Total	386	100	55.1

*Diptera 97.0%

Cobble Flat (n = 7) (Includes 2 yearling chinook)

Prey Item	No.	%	0 No. per Stomach
Insect*	242	81.5	34.6
Amphipod	52	17.5	7.4
Other	3	1.0	0.4
Total	297	100	42.4

* Ephemeroptera 63.2%;
Diptera 25.2%;
Trichoptera 11.6%

Cobble Flat (n = 5)

Prey Item	No.	%	0 No. per Stomach
Insect*	177	83.9	35.4
Amphipod	31	14.7	6.2
Other	3	1.4	0.6
Total	211	100	42.2

* Ephemeroptera 60.0%;
Diptera 34.5%

Bed Rock (n = 3)

Prey Item	No.	%	0 No. per Stomach
Insect*	90	90.1	30.0
Fish	6	6.1	2.0
Other	3	3.0	1.0
Total	99	100	33.0

* Diptera 86.7%;
Ephemeroptera 10.1%

Rip Rap (n = 2)

Prey Item	No.	%	0 No. per Stomach
Amphipod	36	64.3	18.0
Insect*	12	21.4	6.0
Other	8	14.3	4.0
Total	56	100	28.0

* Diptera 66.7%

TABLE 8. Comparison of diets between habitat types for juvenile chinook salmon in the upper Klamath estuary from October 1991 to January 1992.

Sand Flat (n = 10)

Prey Item	No.	%	0 No. per Stomach
Insect*	109	41.3	10.9
Isopod	104	39.4	10.4
Amphipod	29	11.0	2.9
Mysidacea	18	6.8	1.8
Other	4	1.5	0.4
Total	264	100	26.4

* Hemiptera 33.0;
Trichoptera 22.0%;
Lepidoptera 12.8%;
Diptera 11.9%

Gravel Flat (n = 8)

Prey Item	No.	%	0 No. per Stomach
Insect*	151	64.5	18.9
Amphipod	66	28.2	8.3
Other	17	7.3	2. 1
Total	234	100	29.3

*Diptera 66.9%; Trichoptera 20.5%

Open Water (n = 6)

Prey Item	No.	%	0 No. per Stomach
Amphipod	38	51.4	6.3
Insect*	23	31.1	3.8
Isopod	13	17.6	2.2
Total	74	100	12.3

* Trichoptera 43.5%;
Diptera 43.5%

Bed Rock (n = 4)

Prey Item	No.	%	0 No. per Stomach
Insect*	202	56.3	50.5
Amphipod	103	28.7	25.8
Mysidacea	53	14.8	13.3
Other	1	0.3	0.3
Total	359	100	89.8

*Diptera 99.5%

Cut Bank (n = 8)

Prey Item	No.	%	0 No. per Stomach
Insect*	331	62.8	41.4
Amphipod	157	29.8	19.6
Mysidacea	22	4.2	2.8
Other	17	3.2	2.1
Total	527	100	65.9

* Diptera 76.7%;
Trichoptera 14.2%

Rip Rap (n = 6)

Prey Item	No.	%	0 No. per Stomach
Mysidacea	188	65.3	31.3
Isopod	64	22.2	10.7
Amphipod	22	7.6	3.7
Other	14	4.9	2.3
Total	288	100	48.0

Cobble Flat (n = 9)

Prey Item	No.	%	0 No. per Stomach
Amphipod	348	43.7	38.7
Insect*	319	40.1	35.4
Mysidacea	67	8.4	7.4
Isopod	56	7.0	6.2
Other	6	0.8	0.7
Total	796	100	88.4

* Diptera 68.0%;
Trichoptera 22.6%

TABLE 9. Comparison of diets between habitat types for juvenile chinook salmon in the lower Klamath estuary, from July through September, 1991.

Sand Flat (n = 12)

Prey Item	No.	%	0 No. per Stomach
Insect *	522	82.9	43.5
Amphipod	98	15.6	8.2
Other	10	1.6	0.8
Total	630	100	52.5

* Ephemeroptera 79.3%;
Homoptera 18.2%

Gravel Flat (n = 17)

Prey Item	No.	%	0 No. per Stomach
Insect *	276	60.3	16.2
Amphipod	138	30. 1	8.1
Mysidacea	15	3.3	0.9
Other	29	6.3	1.7
Total	456	100	26.9

* Homoptera 46.0%;
Ephemeroptera 31.1%;
Diptera 14.1%

Beach (n = 11)

Prey Item	No.	%	0 No. per Stomach
Insect *	63	42.3	5.7
Amphipod	53	35.6	4.8
Fish	14	9.4	1.3
Other	19	12.8	1.7
Total	149	100	13.5

* Homoptera 76.2%;
Diptera 15.9%

Diet Preferences - Overall, juvenile chinook captured in the lower estuary habitats preferred insects, especially homopterans, ephemeropterans and hymenopterans (ants and bees,) and mysidaceans over other potential prey (Table 10). They also strongly avoided isopods and gastropods. The most apparent difference in chinook diet preferences between habitats was their avoidance of mysidaceans in sand flat habitat (Table 10). This was caused primarily by the mysidacean's higher rank in abundance in sand flat habitat, because their rank in the diet of chinook did not change appreciably between habitats. We also calculated diet preferences substituting epibenthic tows for pelagic tows in lower estuary gravel flat habitat. In general this caused most insect groups, especially hymenopterans, to become even more preferred. It also caused mysidaceans to drop from the second to the ninth most preferred food item and arachnids to drop from the fifth to the tenth most preferred food item due to their relatively higher abundance in the epibenthic tows compared to the pelagic tows.

In the upper estuary habitats insects, especially ephemeropterans, trichopterans, and lepidopterans (butterflies), mysidaceans, and amphipods were the most preferred prey items of chinook salmon (Table 10) . Arachnids, coleopterans (beetles), and especially oligochaete and gastropods were avoided. There was variation in the rankings of individual prey groups between habitats, but no apparent pattern. In all but a few instances prey items were either preferred or avoided in all habitats.

We also calculated diet preferences substituting epibenthic tows for pelagic tows in gravel flat and sand flat habitats. In gravel flats this caused ephemeropterans to move up from the fourth to the first most preferred food item and arachnids to move up from the tenth to the fourth most preferred food item. These changes were primarily due to their relative scarcity in the epibenthic samples as compared to the pelagic samples. Mysidaceans fell from the third to the eleventh most preferred food item due to their higher rank of abundance in the epibenthic tows.

We ran a series of Kruskal-Wallis tests to compare abundances of preferred prey items between habitat types. We used the juvenile chinook diet preference data from 1991 to determine which food items to include in the preferred category. There were no significant differences in the abundance of preferred items between habitat types for lower estuary pelagic and epibenthic tows (Table 4). There was also no significant differences in upper estuary pelagic tows from March 1991 to March 1992. But when upper estuary pelagic tows were compared from March

TABLE 10. Diet preference values of chinook salmon for prey items collected by pelagic tows in Klamath River estuary habitats.

Upper Estuary

	Habitat						
Group	Gravel Flat	Sand Flat	Rip Rap	Open Water	Bed Rock	Cut Bank	Mean Preference
Ephemeroptera	+ 5.0	+ 8.5	+ 8.5	+ 0.5	+ 5.0	+11.5	+ 6.50
Trichoptera	+ 8.0	+ 4.0	+ 3.0	+ 8.5	+ 8.0	+ 7.5	+ 6.50
Mysidacea	+ 6.0	+ 3.5	- 0.5	—	+ 9.0	+ 5.5	+ 4.70
Lepidoptera	—	+ 5.0	—	—	+ 4.0	+ 3.5	+ 4.17
Amphipods	+ 4.0	+ 4.0	+ 4.0	0	+ 5.5	+ 5.0	+ 3.75
Homoptera	—	+ 6.0	+ 4.5	+ 5.5	—	- 3.0	+ 3.25
Plecoptera	+ 12.0	+ 3.0	- 5.0	+ 3.0	—	+ 3.0	+ 3.20
Hymenoptera	+ 1.0	+ 8.0	- 1.5	—	- 2.0	+ 3.0	+ 1.70
Diptera	0	0	- 1.0	0	+ 2.0	0	+ 0.17
Hemiptera	- 2.0	0	+ 6.0	- 0.5	- 5.0	- 3.0	- 0.75
Fish	+ 4.0	- 6.0	—	—	+ 1.5	- 4.0	- 1.13
Isopod	- 4.0	0	- 1.0	0	- 10.0	- 3.0	- 3.00
Arachnid	- 3.0	- 3.0	- 9.0	- 8.0	- 3.0	- 9.0	- 5.83
Coleoptera	- 3.0	- 13.0	- 3.5	- 5.0	- 6.0	- 5.0	- 5.92
Oligochaet	- 10.5	- 8.0	—	- 4.0	—	—	- 7.50
Gastropod	- 13.5	- 9.0	- 8.0	—	- 9.0	-10. 0	- 8.30

Lower Estuary

	Habitat			
Group	Beach	Sand Flat	Gravel Flat	Mean Preference
Homoptera	+ 6.5	+ 5.0	+ 9.0	+ 6.83
Ephemeroptera	+ 3.5	+ 8.5	+ 6.5	+ 6.17
Hymenoptera	+ 5.5	+ 6.5	+ 5.0	+ 5.67
Mysidacea	+ 8.5	- 4.5	+ 8.0	+ 4.00
Diptera	+ 4.0	+ 4.0	+ 2.0	+ 3.33
Amphipod	+ 1.0	+ 3.0	+ 1.0	+ 1.67
Arachnids	- 5.5	- 3.5	+ 3.5	- 1.83
Coleoptera	- 4.0	+ 3.0	- 7.0	- 2.67
Hemiptera	- 7.0	- 2.5	+ 1.0	- 2.83
Fish	+ 1.5	- 5.5	- 6.0	- 3.33
Gastropod	- 9.0	- 7.5	- 9.0	- 8.50
Isopod	- 11.5	- 9.5	- 7.5	- 9.50

through July 1991 (when juvenile chinook abundances were most abundant in the upper estuary) there was a significant difference ($r = 11.225$, $p = 0.0471$) between habitats with gravel flat habitat having by far the highest average rank of preferred prey.

We did not capture enough coho, steelhead or cutthroat to calculate their food preferences by habitat.

<u>Prey Item Abundance 1992-1993</u> - Amphipods, isopods, insects, and mysidaceans were the most numerous organisms captured in 1992-1993. Their numeric rank however varied by sampling method (Table 11). In pelagic tows insects, primarily dipterans, coleopterans and ephemeropterans were the most common organisms captured, followed by arachnids, and amphipods. In epibenthic tows, isopods, insects (almost exclusively dipterans), amphipods, and mysidaceans were the most numerous individuals in our samples. The benthic samples contained primarily amphipods (Table 11). Again as in the 1991-1992 samples there was at least an order of magnitude increase in the density of organisms captured progressing from pelagic to epibenthic to benthic sampling (Table 11).

We plotted the monthly CPUE of preferred juvenile chinook prey items captured by pelagic, epibenthic and benthic sampling to describe their relative abundance in the estuary and to discern if their abundance was lower during periods of high juvenile chinook abundance. We used the juvenile chinook diet preference data from 1991 to determine which food items to include in the preferred category. The number of organisms captured varied greatly between the biweekly samples. No replicate samples were collected so no estimate of within sample variation can be made, though no doubt it was high.

Pelagic tows showed a relatively high monthly CPUE in June of 0.82 preferred items/m^3, and a low abundance in September of 0.01 preferred items/m^3. In the remaining months the CPUE of preferred prey items remained relatively constant between 0.08 to 0.20 preferred prey items/m^3 (Figure 3). Our project's epibenthic and benthic sampling suggests that the abundance of preferred prey items was lower in the summer and early fall than in the spring or late fall and winter (Figure 3). The May 1992 epibenthic samples showed a relatively high abundance of 572 preferred items/m^3, while low abundances of 19 and 11 preferred items/m^3 occurred in July and September respectively (Figure 3). Monthly CPUE of preferred items in the benthic samples were generally higher September through January than May through August, the time of peak chinook abundance. Monthly CPUE of benthic samples in May, June and August ranged

TABLE 11. Most numerous organisms captured by pelagic tows, epibenthic tows, and Ekman dredges from the Klamath River estuary 1992-93.

Pelagic Tows (Effort =l,899.75m^3)

Group	No.	% Catch	CPUE (#/m^3)
Insects*	405	37.9	0.21
Arachnids	351	32.8	0.18
Amphipoda	97	9.1	0.05
Isopoda	56	5.2	0.03
Gastropoda	53	5.0	0.03
Other	107	10.0	0.06
Total	1,069	100	0.56
* Diptera	139	34.3	0.07
Coleoptera	126	31.1	0.07
Ephemeroptera	54	13.3	0.03
Hymenoptera	23	5.7	0.01
Other	63	15.6	0.03

Epibenthic Tows (Effort = 55.86m^3)

Group	No.	% Catch	CPUE (#/m^3)
Isopoda	7,514	52.4	134.51
Insects*	3,149	21.9	56.37
Amphipoda	2,255	15.7	40.37
Mysidacea	1,297	9.0	23.22
Other	135	0.9	2.42
Total	14,350	100	256.89
* Diptera	3,136	99.6	56.14

Ekman Samples (Effort = 1.30m^2)

Group	No.	% Catch	CPUE (#/m^3)
Amphipoda	8,814	85.8	6,784.17
Isopoda	668	6.5	514.16
Bivalvia	291	2.8	223.98
Insects*	220	2.1	169.33
Other	276	2.7	212.44
Total	10,269	100	7,904.09
* Diptera	191	86.8	147.01
Other	29	13.2	22.32

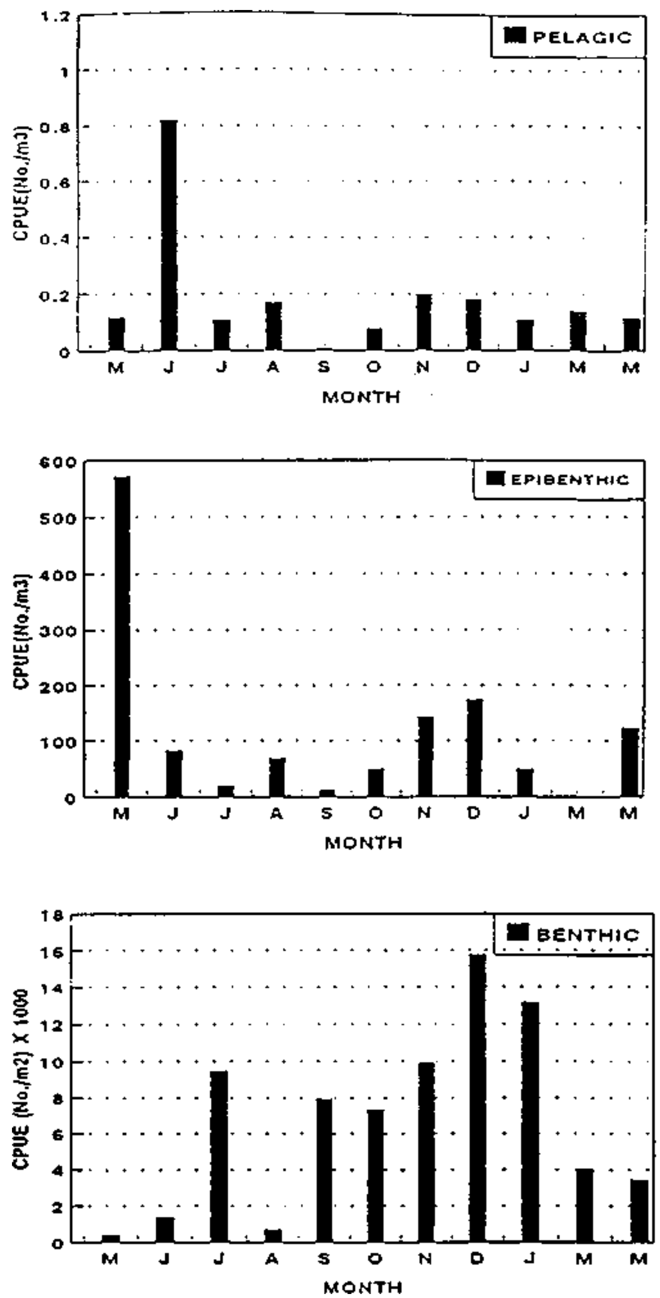

FIGURE 3. Pelagic, epibenthic, and benthic CPUE of juvenile chinook salmon preferred prey items from the Klamath River estuary, 1991 - 1993.

from about 400 to 1350 preferred items/m^2 compared to about 7400 to 15,800 preferred items/m^2 in September to January (Figure 3).

It is important to keep in mind the limitations of this study. It was designed to provide direction for future comprehensive feeding or estuarine production studies, if results warranted, rather than to provide definitive answers about these subjects. The rationale behind this study was to provide a "snapshot" of the composition and the relative abundance of major taxonomic prey groups available to juvenile salmonids within selected habitats and describe what juvenile salmonids ate within those selected habitats. Due to the general nature of this study's goals and because of the concurrent field studies being conducted by our project, we undertook measures to reduce the amount of time needed to collect and process samples.

First, we did not collect replicate samples within habitats, so no estimate of within sample variation can be calculated. Second, fish stomach contents were collected from only esophagus to pyloric caeca. This was done to minimize the bias of finding a greater portion of digestive resistant hard bodied prey vs. soft bodied prey, and more importantly, to hopefully limit the amount of prey fish may have consumed in other habitats as they moved about the estuary. Third, in most cases identification of both prey and potential prey items were done only to Order. This level of identification did meet our goal of describing major prey groups and a more detailed identification would have been time consuming.

Finally, we counted prey items rather than calculated their weight or volume. Counting prey items tends to over state the importance of small prey items collected in large numbers (Hyslop 1980). However, Hynes (1950) and Mann and Orr (1969) as reported by Hyslop (1980), stated that important items in the diet will be obvious irrespective of the method of stomach analysis employed. Also, MacDonald and Green (1983) found in their study that number, weight, and volume were highly correlated and any one will adequately describe prey species importance. However, all the above "short cuts" should be avoided in future comprehensive feeding studies or studies designed to determine if the Klamath estuary is limiting salmonid production in the basin.

<u>Salmonid Diets vs. Prey Abundance</u> - In general juvenile chinook appear to be opportunistic feeders in estuaries (Healey 1991) and depend heavily on food chains that are based on detrital production (MacDonald et al. 1990). In the Klamath estuary the most abundant organisms in our invertebrate samples were

isopods (Gnorimosphaeroma lutea) ,amphipods (primarily Corophium spinicorne) and dipteran larvae (probably mostly chironomids) which for the most part are benthic or epibenthic organisms. Most of these organisms are scavengers, herbivores, or detritus feeders. Also samples from this study showed at least an order of magnitude increase in the density of organisms in benthic and epibenthic samples compared to pelagic surface tows. Busby (1991) also found a much higher density of invertebrates in benthic samples than in planktonic samples from the Mattole River lagoon. Based on the high number of epibenthic prey in salmonid stomachs such as dipteran larvae and amphipods we feel that chinook from the Klamath estuary are also highly dependent on a detrital based food chain and are primarily epibenthic foragers. Their foraging strategy is probably due to the high availability of epibenthic prey compared to pelagic prey.

Juvenile chinook from the Klamath estuary consistently contained mostly dipterans and amphipods which were often the most common prey item available to them even though other prey groups such as ephemeropterans and trichopterans were more preferred. The most notable exception to their eating the most abundant organism available was their consistent avoidance of isopods, especially in the lower estuary where isopods were the most numerous organism collected. Many other salmonid feeding studies concluded that juvenile salmonids tend to feed upon the most numerous component available (Simenstad and Salo 1982; Johnson and Johnson 1981; MacDonald et al. 1990). Rondorf et al. (1990) found in their study on the Columbia River that only rank in availability of food items in the environment (not rank in preference) was consistently correlated with rank of those items in sub yearling chinook diets.

Dipteran larvae or amphipods have been shown to be important prey items of chinook in other estuaries (McCabe et al 1983; Sasaki 1966; Levy and Levings 1978; Reimers 1971; Levy et al 1979; MacDonald et al 1990; Healey 1980a). Dipteran larvae contain freshwater, brackish and marine representatives (Ward 1992), and the amphipod Corophium spinicorne, is able to tolerate a wide range of water salinities (Simenstad 1983). The Klamath estuary has highly varying salinity levels due to changing river flows and tidal cycles, which would make it ideally suited for dipterans and C. spinicorne to reside in with little competition from other obligate freshwater or marine organisms.

Krakker (1991) reported that from February to September 1986 juvenile chinook ate mostly ephemeropterans and dipterans in

the upper Klamath estuary and amphipods and larval fish (probably clupeids and osmerids) in the lower estuary. In May to August 1991, chinook collected from the upper estuary ate mostly dipterans, while chinook collected in the lower estuary ate primarily ephemeropterans, amphipods and homopterans. However, about 86% of the ephemeropterans consumed in the lower estuary were eaten by only two fish. The frequency of occurrence of ephemeropterans and homopterans was only 11% and 18% respectively while the frequency of occurrence of amphipods and dipterans in their diet was 77% and 36% respectively. This type of clumping or non normal distribution of the number of prey items in fish stomachs was why we chose to analyze prey preference by ranks as described by Johnson (1980).

One reason for the differences between this and Krakker's findings may simply be that he collected stomach samples over a larger portion of the year. According to Healey (1991) seasonal changes in diet are typical. Our diet data showed that chinook shifted from primarily dipterans in the spring to amphipods in summer, and suggested that they switched to ephemeropterans in the fall. Since Krakker included fish from the spring and fall, or if he included non summer collected fish in higher proportions he easily could have found a higher reliance on insects than we did because of these seasonal differences.

Another reason may be dietary differences of chinook between habitats. Krakker did not state from what habitat types these fish were collected. Healey (1991), cited numerous studies which stated that chinook fed primarily on insects, and amphipods in nearshore estuarine habitat (Reimers et al 1978; Bottom 1984; Levy and Northcote 1981) but switched to primarily fish in offshore estuarine habitat (Levy and Northcote 1981; Healey 1980a) . MacDonald et al. (1987) found that salmonid diets differed depending upon the habitats occupied by fish. We also found that there was some differences in the diets of chinook between selected habitat types. In most upper estuary habitats dipterans were the most numerous prey item consumed. However, in sand flat habitat chinook contained mostly amphipods, which were more abundant in this habitat than in other upper estuary habitats. Also, in some habitats such as cut banks and open water, dipterans made up 80 to 90% of chinook insect prey, while in others such as gravel and cobble flats, they comprised only about 50 to 60%.

Interspecific Competition - Diet overlap in the Klamath estuary from April through June 1991 was significant (0.91) between chinook and coho salmon, but not between chinook and steelhead (0.47) or chinook and cutthroat (0.26). However diet overlap was significant between chinook and steelhead (0.72) and between chinook and cutthroat (0.68) from June through August 1991. McCabe et al. (1983) found that during the spring in pelagic areas of the Columbia River estuary, all salmonids except steelhead had significant diet overlap. Healey (1980b) also felt that juvenile chinook and coho had similar food habits in the Straits of Georgia. However, Zaret and Rand (1971) as cited by Emmett et al. (1986) stated that high diet overlap may indicate abundant food supply (of only a few prey groups) and not competition. MacDonald et al. (1987) felt that interspecific competition may play a lesser role in segregating salmonid species within estuaries than in rivers. McCabe et al. (1983) felt that the diet overlap in spring was due primarily to the importance of C. salmonis and C. spinicorne as prey items. We believe this to also be the case for the significant diet overlap between salmonids during the summer of 1991 as all three species fed primarily on amphipods.

Healey (1980b) felt that juvenile chinook and coho segregated themselves spatially within the Straits of Georgia to minimize competition. Interspecific competition in the Klamath estuary is probably reduced by the different peak emigration timings exhibited by juvenile salmonids. Wallace (1995) reported that the peak emigration times through the Klamath estuary were late June to early July for chinook, April and May for coho and steelhead, and April to June for cutthroat. Therefore the present CDFG hatchery practice of releasing yearling coho in March and April and chinook in June should continue because it probably helps reduce competition for food between juvenile chinook and coho in the estuary.

Prey item samples from this study indicate that chinook preferred prey abundance was lowest in the summer, and that the abundance of preferred prey was markedly lower in the summer of 1991 compared to the summer of 1992. We combined 1991 pelagic tows conducted in the same habitats as 1992, and compared them to 1992 pelagic tows. We also compared epibenthic tows from the same site in 1991 and 1992. This revealed a pattern of lower abundance of preferred prey for pelagic and epibenthic samples during the summer of 1991 (Figure 4). Also, as stated earlier, epibenthic and benthic samples from 1992-1993 suggested that the abundance of preferred prey was lower during the summer and early fall than in the spring or late fall and winter (Figure 3). Juvenile chinook abundance peaks in the Klamath estuary during the early summer which suggests that high chinook abundance could be taxing the food supply in the estuary. Also the average number of prey items consumed by chinook in the lower estuary was lowest in August, and the months with the highest rate of empty chinook stomachs was August (26%) and July (17%) in the upper and lower estuary respectively. In October, 28% of the sampled chinook in the upper estuary had empty stomachs, but these were probably mostly comprised of recently released hatchery fish,

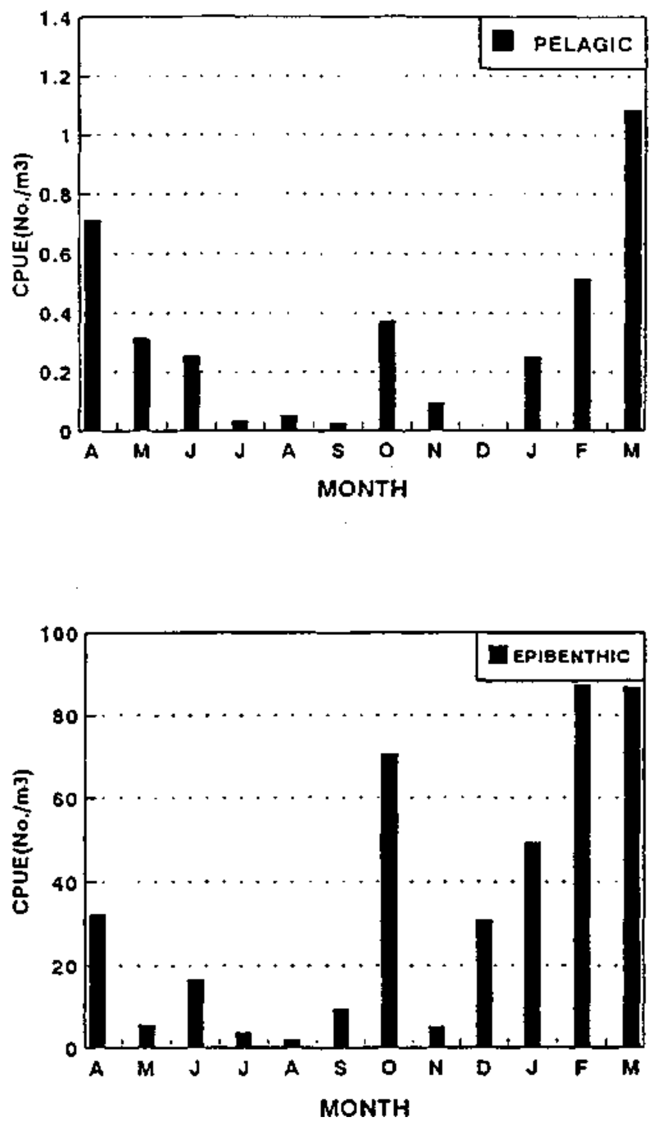

FIGURE 4. Pelagic and epibenthic CPUE of juvenile chinook salmon preferred prey items from the Klamath River estuary, 1931-1992.

which based on the relatively high numbers of isopods and gastropods in their stomachs, had not fully adapted their feeding habits from hatchery to wild conditions.

Other studies have noted low prey abundance during high fish abundance and therefore concluded that salmonid production in estuaries may be limited by low prey abundance. Nelson (1979) found that the percent of free living amphipods (compared to tube dwelling amphipods) was lowest in a North Carolina estuary during the peak of fish abundance. Salmonid production being limited by lack of prey has been suggested for the Sixes River (Reimers 1971), Hood Canal (Simenstad and Salo 1982), and Nanaimo estuaries (Healey 1980a) among others.

However, other factors may be just as important in influencing the amount of prey available to juvenile salmonids in the Klamath estuary. Simenstad and Wissmar (1984) stated that there is wide annual variation in both abiotic and biotic conditions in Pacific Northwest estuaries. They cited a number of studies using the density of Corophium amphipods as an example to show the wide annual and spatial variation which occurs in these estuaries. These studies concluded that physical factors such as river discharge, salt water intrusion, sediment scour or deposition, and sill formation at the river mouths all effected Corophium density patterns within estuaries. Simenstad and Wissmar (1984) felt that the reported annual variation in Corophium densities was due to ephemeral occurrences of fine mud sediments. Variation in salt water intrusion and substrate composition at our epibenthic sampling station was apparent in each year of our survey (CDFG 1992, 1993, 1994a, 1994b). The change in the location of the Klamath River mouth between the summers of 1991 and 1992 caused water circulation patterns to change and a layer of fine sediment was deposited over the gravel where we collected our epibenthic samples. This change in substrate composition could have increased the abundance of preferred prey in 1992.

Hatchery vs. Natural Interactions - Simenstad and Salo (1982) stated that for securing the success of chum salmon enhancement programs in Washington, it was important to gather some basic knowledge about relationships between prey resources and migration characteristics of the salmon. They suggested it would be worthwhile to adjust the densities, sizes, and temporal distributions of outmigrating chums to minimize the possibility that they encounter inadequate prey resources. (In other words, they suggested to release the fish when there is something for them to eat!). Murphy et al. (1988) felt that in systems with hatchery inputs, stocking levels would be higher and salmon size and timing of migrations different than in natural systems which could increase competition and predation. Simenstad et al. (1982) stated that hatchery releases often differ from the outmigration of naturally produced fish in terms of density, fish size, and timing which can result in altered estuarine utilization patterns of juvenile salmon. Wallace (1995) documented that hatchery and natural chinook were present concurrently in the Klamath estuary during every year of his study.

The Klamath basin has two major mitigation hatcheries operated by the CDFG (as well as numerous smaller rearing programs) which normally release between 5 and 10 million fingerling chinook annually. The hatcheries are stuck in the quandary of releasing chinook during times of high food abundance to insure an adequate survival rate for their fish, but at the same time try not to overwhelm natural salmonid stocks and depress their survival through competition. The abundance of pelagic and especially epibenthic preferred prey was markedly lower in the summer of 1991 compared to the summer of 1992. CDFG hatcheries released about 9.8 million fingerling chinook in 1991 and about 4.4 million in 1992. We have no estimate of the number of natural juvenile chinook produced in the basin for those years, but adult returns of natural fall chinook salmon to the Klamath basin was about 35% higher in 1990 than 1991 (CDFG 1994c) and therefore we assumed that more natural juvenile chinook were produced in 1991 than 1992. Since we did not collect any diet data from 1992 we do not know if the lower abundance of preferred prey effected the amount or type of prey consumed by juvenile salmonids in 1992. It is tempting however to assume that the higher abundance of juvenile chinook produced in the basin (both natural and hatchery origin) in 1991 led to a more marked decrease in the abundance of preferred prey in the Klamath estuary than in 1992. This suggests that the carrying capacity of the estuary had been reached or surpassed and that large hatchery releases of salmonids could exacerbate the problem.

It is probably simplistic to conclude that the lower abundance of preferred prey in the Klamath estuary in 1991 was in response to only a single factor (the higher abundance of chinook) in light of the high variation of physical and biological conditions in West Coast estuaries reported above. However, Simenstad and Wissmar (1984) stated that the role of density dependent estuarine mortality is generally unknown and may negate the influence of variability in salmon prey resource production or availability. Also, most of the juvenile chinook that enter the Klamath estuary have already attained the reported minimum size (70mm) to adapt to saltwater. So if they encounter poor estuarine conditions they should be able emigrate almost immediately to the ocean, albeit at a smaller size than the optimum size of 120-160mm reported by Nicholas and Hankin (1989). The combination of natural salmonid production, the tremendous number of salmonids annually released by basin hatcheries and rearing programs, the estuary's small size, and the lowered abundance of preferred prey in the summer during peak chinook abundance, are reasons to suspect that density dependent mortality or increased emigration of chinook at a relative small size may be occurring within the Klamath estuary.

However, based on the combination of the estuary's small size, the relatively large size of chinook (75-85mm) entering the estuary, and long average travel times to the estuary by marked natural and hatchery chinook (Wallace 1995), it seems likely that significant chinook rearing (and therefore feeding) occurs above the estuary in the mainstem river. We know of no studies describing salmonid diets and prey availability in the mainstem river, and therefore have no information about whether food resources are taxed in the mainstem river. Until we are able to separate the effects of predator (chinook) densities from that of temporal variation of physical and biological factors in both the estuary and mainstem river we will not be able to determine what levels of fish production the basin can support or determine if, (or at what level) hatchery production is likely to cause a shortage of prey in the estuary.

VI. Recommendations: Fieldwork, data analysis, and a first draft of this study have been completed. A final report should be completed shortly and submitted to the Federal Aid in Sport Fish program.

VII. Estimated FY 94-95 Job Cost: $22,309

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