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National Oceanic and Atmospheric Administration
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F/NWC1

Memorandum

Date: March 6, 2011

To: Bob Turner, Asst. Regional Administrator, Salmon Management Division, NMFS

From: Tom Cooney (Northwest Fisheries Science Center)

Subject: Report on Task B from the 2010 Lower Columbia Harvest Biological Opinion

The attached report describes updated analyses of current and blocked juvenile chinook rearing habitats downstream of natal spawning reaches for Lower Columbia tule chinook populations. Prior analyses of current habitat capacity developed for use in life cycle modeling were expanded to incorporate blocked extant marsh (and degraded intertidal tributary mainstem) habitats in accordance with Task B from the 2010 Lower Columbia Harvest Biological Opinion:

> *Task B: NMFS will produce or receive a report identify the amount and distribution of extant marsh type habitats currently inaccessible for juvenile rearing. The report will focus specifically on lower tributary and mainstem Columbia juvenile rearing habitats used by Lower Columbia River tule Chinook populations. The report should also identify ongoing efforts to gather additional data on current and potential juvenile rearing habitat distribution in the Lower Columbia River.*

cc: D. Holzer, M. Ford, P. McElhany (NWFSC); P. Dygert, P. Dornbusch (NOAA Fisheries NWR)

Lower Columbia Tule Chinook Populations:

Estimating Intertidal Rearing Capacities and Survival Rates

Technical Review Draft

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Northwest Fisheries Science Center

March 4, 2011 UPDATED DRAFT

Note: This draft replaces an earlier version (Feb. 9, 2010). Major changes include: partitioning gis based estimates of the amount (hectares) of extant wetland into accessible and blocked categories using spatially explicit dike distribution data set obtained from Catherine Corbett (LCREP) and revising calculations to include estimates of edge rearing habitats in lower tributary mainstem sections.

Introduction

Lower Columbia 'tule' fall Chinook salmon are classified as 'ocean' type, migrating to the ocean during their first year of life (e.g., Myers et al., 1998). Tule chinook populations are associated with relatively short tributary rivers entering the Columbia River mainstem. Studies of ocean type chinook in similar geographic settings in British Columbia, Puget Sound and the Oregon coast indicate that a substantial portion of fry production may migrate downstream from natal spawning reaches shortly after emergence (e.g., Healy,1980, Reimers, 1973, Carl & Healy, 1984, Lister and Genoe, 1970, Levings et al., 1986, Bottom et al., 2005). In general, each of these studies highlights the importance of lower tributary and mainstem intertidal habitats as rearing areas for emigrating chinook juveniles. A number of different patterns of use and mechanisms to 'explain' the relative proportions of fry production moving downstream into these areas from spawning reaches are suggested in these studies. We developed a relatively simple model of fry rearing capacity as a function of marsh type habitats and applied it to each of the Lower Columbia River primary populations. We also developed a crude estimate of historical intertidal fry rearing capacity to provide a context for evaluating potential contributions to achieving recovery plan objectives for each population.

We framed our analysis around the following questions:

> What patterns of fry and subyearling smolt emigration occur in Lower Columbia tule populations?
>
> What basic assumptions regarding emigration timing, rearing capacities and rearing stage survival are available for use in modeling Lower Columbia tule populations?

For each of the lower Columbia River tributaries associated with primary tule fall chinook populations;

> How much habitat is available to support fry to pre-smolt rearing in the intertidal lower tributary and the adjacent downstream mainstem Columbia River?
>
> How much rearing habitat was historically available to each population?

We generated estimates of current and blocked rearing habitats using 1) assumptions regarding the potential rearing densities associated with different types of channel habitats from the literature and 2) map based estimates of the amount and distribution of channel habitats derived from currently available spatial data sets. A major study of is underway in the lower Columbia River to further elucidate the estuary's contribution to spatial structure and life history diversity of Columbia River salmon stocks[1]. Results from that effort will include updated maps of juvenile rearing potential and additional information on relative densities. In addition, the study has the potential to generate more detailed information on the temporal and spatial distribution of juvenile chinook originating from Lower Columbia River populations.

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[1] Research proposal to COE. Dan Bottom (NWFSC) project leader. *The contribution of tidal fluvial habitats in the Columbia River estuary to the recovery of diverse salmon ESUs.* Proposed duration: 2010-2018.

Tule Chinook Juvenile Life History Patterns

Mechanisms driving the emigration of fry from natal spawning areas downstream to intertidal rearing habitats are not well understood. At least three different mechanisms have been suggested for northwest chinook populations exhibiting ocean type life histories. Healy (1980) and Carl and Healy (1984) suggested that emigration rates for fry in the Nanaimo River (British Columbia) were influenced by distance from the intertidal or estuarine rearing areas, based on emigrant trapping at three different locations ranging upstream from the estuary. The Nanaimo River is a relatively short drainage emptying into an extensive estuarine area along the inner coast of Vancouver Island. Almost all the fry produced from the lower sections emigrated relatively soon after emergence down into rearing areas in the transition zone to seawater for extended rearing. Roughly half of the production from middle sections of the river migrated to the upper estuary, the rest reared in freshwater and emigrated in the summer. A substantial proportion of the fry produced in the upper most sections of the system remained in upper tributary habitats for extended rearing. Some studies have suggested a genetic linkage to propensity to migrate downstream soon after emergence. Others have suggested that a tendency towards early migration to the estuary might be linked to specific spawning habitats within a drainage.

McCabe et al lengths consistent with hypothesis that fish rearing in intertidal areas in upper estuary are presmolts (fry that have grown approx 30 mm, one month, since leaving dtribs.

Juvenile Outmigration Patterns

The Washington Department of Fish and Wildlife (WFDW) has monitored the outmigration of fall chinook juveniles from three lower Columbia tributaries in recent years (e.g., Sharpe et al., 2009). Traps Screw traps are located in tributary mainstems below most spawning areas in Coweeman River, Grays River, Germany Creek, Mill Creek and Abernathy Creek. The juvenile outmigration from the Coweeman River occurs primarily in two peaks – a major pulse of 40-50 mm fry leave the system in March and early April. A second mode in the outmigration occurs centered on early July and is comprised of pre-smolts 70-90mm in length. Virtually all of the juvenile outmigrants from Germany, Mill and Abernathy Creeks pass the smolt traps prior to the middle of April. The spawning reaches in these three systems are a relatively short distance upstream from intertidal compared to the Coweeman River.

We used the results from the WDFW trapping studies to reconstruct the relative proportions of fry that migrate downstream into intertidal reaches relatively soon after emergence (Rawding, Cooney and Sharpe, 2010). Based on the WDFW outmigrant trapping results and information from studies on ocean type chinook populations in other northwest regions, we as**s**ume that the outmigration patterns for individual Lower Columbia tule populations are variations on two basic themes (figures 1 & 2). Virtually all of the naturally produced juveniles in the three relatively short systems that comprise the Germany/Mill/Abernathy population migrate to intertidal reaches as fry in March and April. In the longer systems, a portion migrates downstream as fry in the early spring, the bulk of the remaining juveniles rear through early summer and emigrate downstream in late June/early July. In the

Coweeman River, approximately 15% of the estimated number of fry available to migrate in early April emigrate to intertidal reaches, the remaining 85% remain in freshwater through early summer. Quantitative estimates of the relative proportions migrating as fry versus as presmolts are only available for the WDFW study streams.

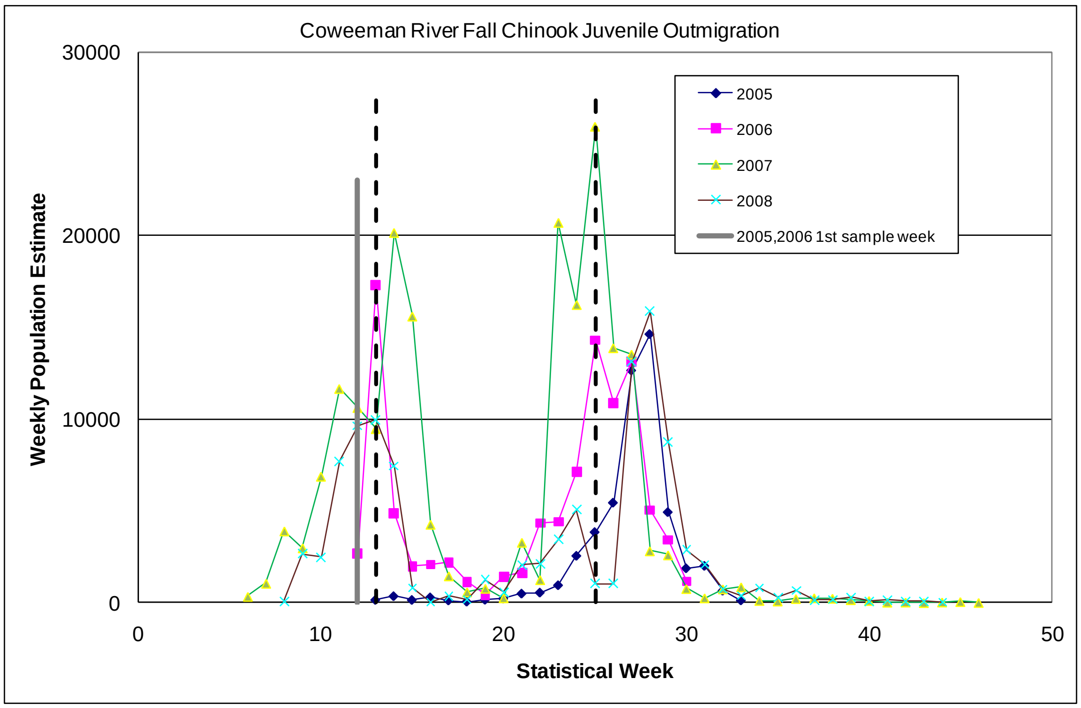


Figure 0-1. Juvenile outmigrants counted at lower river trap. Dashed lines indicate first weeks in April, July .

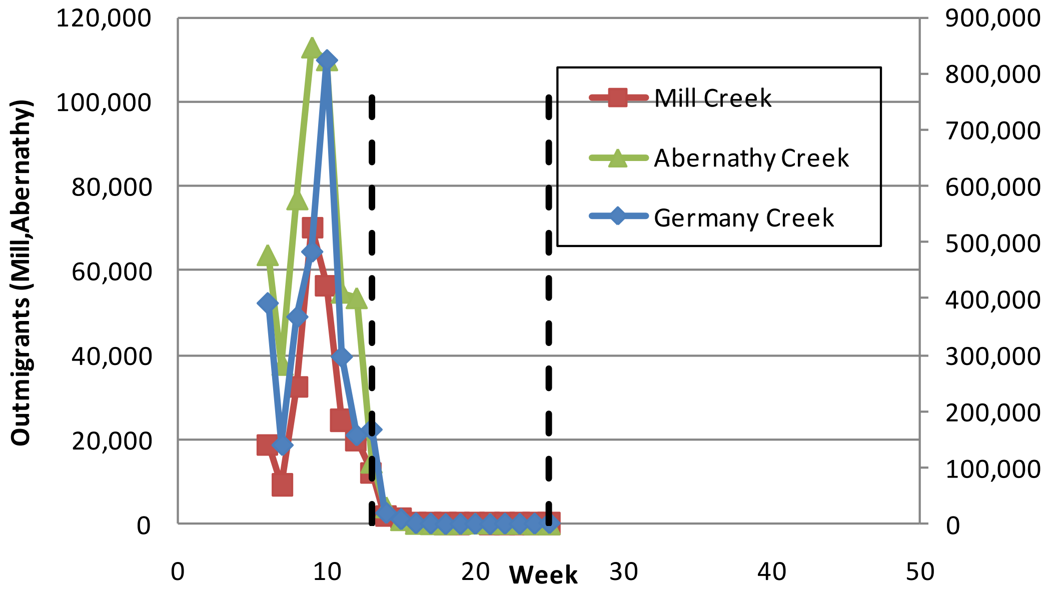
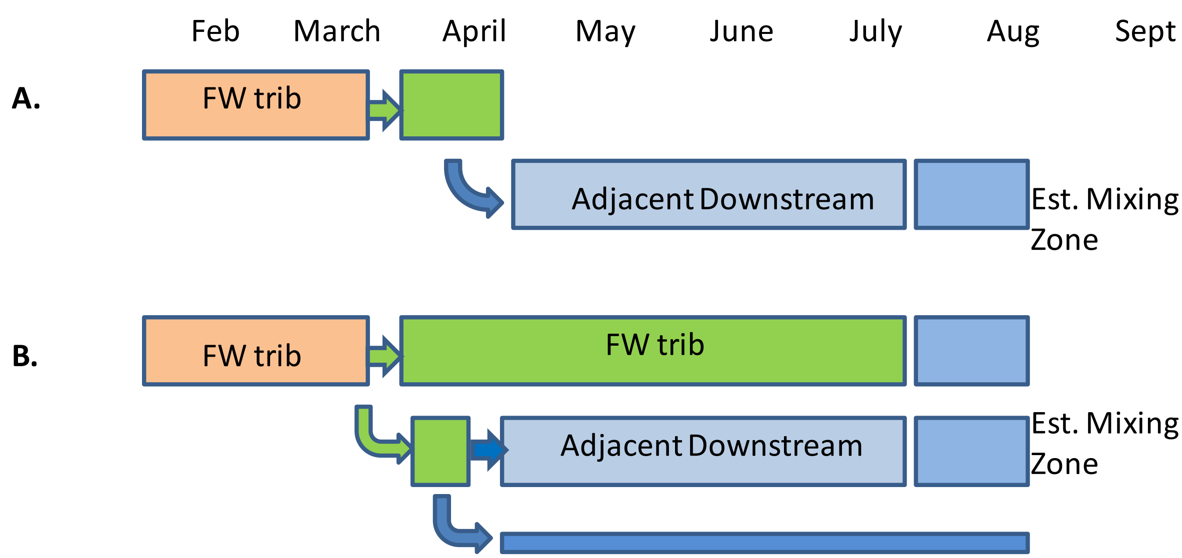


Figure 0-2 Juvenile outmigrants counted at lower river trap. Dashed lines indicate first weeks in April, July

The migration patterns observed in the Lower Columbia studies could be explained by any of the three general hypotheses (proportion of fry migrating to intertidal a function of distance from spawning reaches, genetic mechanism, or link to spawning in particular reaches. Given the potential implications for restoration planning, life cycle modeling should incorporate sensitivity analyses to these alternative mechanisms.



<u>Juvenile Survival Estimates</u>

The derivation of egg to fry stage survival estimates developed for use in modeling lower Columbia River tule chinook populations are described in Rawding et al. 2010 and Fullerton et al. 2010.

Fry to Presmolt Survival Rates

No direct estimates of juvenile rearing life stage survivals are available for Lower Columbia River tule populations. Greene and Beechie (2004) compiled a set of habitat specific life stage survival rate estimates based on a review of published estimates for ocean type chinook stocks. We estimated average residence times for fry juvenile outmigrants and subyearling outmigrants in natal tributary and intertidal habitats and applied the synthesized tributary weekly mortality rate. (Greene and Beechie 2004: Table 2). Greene and Beechie (2004) concluded that mortality rates likely differed among rearing habitats in freshwater tributaries, delta channels and nearshore shoreline habitats. They speculated that mortality rates on rearing juveniles were the lowest in delta habitats, higher in nearshore shoreline areas and intermediate in natal freshwater habitats. Given the lack of specific data on fry to presmolt survival rates for lower Columbia River tule type chinook stocks, we assumed that the weekly rate was the same in natal tributary rearing habitats and intertidal rearing habitats. The weekly mortality (.138) is expressed as a mortality coefficient In an exponential equation. We assumed that fry following each of the two basic migration/rearing patterns (fry remaining in freshwater natal tributary reaches vs. fry emigrating downstream and rearing in intertidal reaches) reared for an average of 10 weeks before migrating relatively quickly to the lower Columbia mixing zone (salt water influenced). The estimated survival rate in the absence of density dependent effects for the subyearling JOM pathway was S = exp (-.138 X 10) = 0.25. The survival to the mixing zone for the fry JOM was also 0.25, assuming 2 weeks in the natal tributary habitat followed by 8 weeks rearing in intertidal reaches (0.76 X 0.33).

Presmolt to Ocean Survival Rates:

No direct estimates of residence time in the estuarine mixing zone are available for lower Columbia tule chinook juveniles. We developed the following assumption set based on inferences from studies in other systems, genetic analysis of juvenile samples from lower Columbia reaches and PIT tag studies of subyearling migrants originating from hatcheries in the Upper Columbia River detected passing Bonneville Dam.

Studies in other Northwest river systems indicate that juvenile ocean type chinook shift from nearshore estuarine/marsh channel type habitats to schooling in deeper waters after reaching a length of 80-90 mm. Downstream movement towards the ocean accelerates when this size threshold is reached. Detections of tagged subyearling juvenile chinook migrating downstream after passing through Bonneville Dam indicate a relatively rapid transit to the brackish water mixing zone in the lower Columbia River. We assumed that presmolts transitioning from either natal tributary or intertidal rearing habitats moved relatively quickly down the mainstem Columbia River to the estuarine mixing zone and were subjected to the same weekly mortality rate as applied to fry to presmolt rearing (transition survival = exp{-.138*1 week} = 0.76.

Based on acoustic tagging, juvenile subyearling chinook begin entering the nearshore ocean/Columbia River plume after two weeks to a month residence in the mixing zone. Temporal patterns in the relative contribution of West Cascades stock to the aggregate juvenile chinook population occupying the mixing zone also supports a relatively rapid movement into nearshore ocean waters in mid to late summer. Based on the loss rates from acoustic tagging studies for similar sized subyearling migrants originating above Bonnneville Dam, we assumed that survival from the mixing zone to the plume is 0.70 (reference?? Slides from D. Teal).

Estimating intertidal rearing habitat capacities

We developed simple spatial models of intertidal fry rearing capacity as a function of available habitat based largely on work done on the Skagit River and Snohomish River drainages in Puget Sound (Beamer et al, 2005, Bartz et al., 2006). We considered two general types of habitat: marginal edge habitats along the lower mainstems of each population tributary (from the lower end of spawning to the confluence with the Columbia River mainstem) and subtidal marsh habitats. Two general assumptions framed the analysis:

> Fry rearing capacity is a function of available tributary margin and wetlands marsh type habitat.
>
> The relative value of available rearing habitat to a particular population decreases with distance downstream from natal spawning areas.

The analysis was organized into a series of steps:

1. Estimate the amount of accessible bank margin and wetlands habitat in 1 km increments downstream from the terminus of freshwater spawning/rearing habitat for each system by intersecting estimates of tidal range on NWI spatially explicit data sets depicting wetlands habitat categories. For each 1 km increment, calculate estimates of amount of extant and blocked intertidal rearing rearing habitats using the NWI wetlands .
2. Marginal edge habitat:
    a. Estimated total stream length (m) in the lower mainstem of a population, distance from lower end of spawning (obtained from ODFW and WDFW) to the confluence of the tributary with the mainstem Columbia River .
    b. Calculated the proportion of that habitat that intersects with currently accessible marsh habitat by intersecting stream with marsh habitat from NWI spatial data set.
    c. Calculated potential rearing capacity of accessible marginal edge habitat by applying assumptions used in Bartz et al 2006. Assumed usable rearing habitat extends out 10 m from each bank and a natural bank edge rearing capacity of 0.875 juveniles per m2.
    d. Calculated capacities associated with modified habitats using the same procedure, substituting the proportion of the reach intersecting blocked marsh habitat and the mean density corresponding to modified habitats (0. 360) from Bartz et al. (2006)

3. Subtidal marsh capacities:
   a. Alternative based on Skagit River studies (Greene & Beechie, 2004, Beamer et al., 2005):
      i. Apply estimates of deep (2 m depth or greater) tidal channel area per unit of wetlands habitat estimated from Skagit field studies.
      ii. Calculate an estimate of rearing capacity for each 1 km increment by multiplying the amount of deep channel habitat by the average maximum rearing density from Skagit study.
   b. Alternative based on Snohomish River analyses (Batz et al. 2006)
      i. Estimate usable channel habitat as 6% of wetlands area.
      ii. Apply average densities per m2 of channel habitat based on data in Table 4, Bartz et al.,2006.

   c. Accumulate an estimate of total available fry rearing habitat for each population after incorporating a measure of connectivity (weighting by distance downstream) based on Skagit field studies.

The estimates of degraded and blocked habitats generated by this analysis represent only a portion of losses from historical conditions (e.g., Thomas, 1983). Available assessments of historical habitat conditions are generally limited to the reach below the bay associated with the Elochoman River. More detailed assessments of current vs. historical extending up river to Bonneville Dam are underway (C. Simenstad, personal communication).

We were not able to develop a submodel of potential rearing capacities for application to pre-smolts entering the lower Columbia mixing zone for this analysis. Modeling capacity interactions in this zone requires information and/assumptions about additional considerations including the relationship of larger, schooling presmolts and habitat capacity over a relatively short period of time (residence time in days or weeks), interactions among presmolts produced from all lower Columbia tule populations, and interactions with hatchery releases from a broad range of programs.

Tidal model

Juvenile fall chinook use intertidal marsh areas in the lower reaches of tributaries and along the mainstem Lower Columbia River for rearing for extensive periods during the spring and summer. In order to estimate rearing capacity in intertidal reaches,, it was first necessary to delineate the tidal zone within lower Columbia River fall Chinook tributaries. In general, tidal cycles influence the surface elevation of the Columbia River mainstem from the mouth upstream to Bonneville Dam. In fact, the effects can be quite dramatic and frequently initiate flow reversals during the highest tides at least as far upstream as river kilometer 83. For our purposes, we were most interested in the areas of mean tidal maxima during the times rearing juvenile fall Chinook were present (spring through at least mid-summer).

River level fluctuations are measured by tidal stations managed by NOAA's Center for Operational Oceanographic Products and Services (CO-OPS). We collected all available data for Columbia River sites between Bonneville Dam and Astoria, Oregon. In total, six locations were summarized by month and the elevation of the Columbia River for the average of the higher high water height of each tidal day (MHHW). We used the June value as an approximation of the maximum extent of tidal inundation because it coincides with the presence of juvenile fall Chinook originating from Lower Columbia River populations and the highest spring tides.

From this data, it was necessary to estimate a series of continuous values along the length of the river. There is a strong relationship between the station's distance from the mouth of the Columbia River and the elevation of the MHHW (fig. 1). By applying a regression model we were able to calculate a MHHW height for each river kilometer from the mouth upstream to Bonneville Dam. The MHHW values attributed to each 1km river segment were then converted to a Euclidean allocation grid which was then subtracted from a mosaic generated using USGS digital elevation model (DEM) results. All negative values from this raster calculation correspond to the inundated area as represented by the DEM and mean June MHHW heights. Prior to analysis, we adjusted all input datasets to a common vertical datum (NAVD 1988).

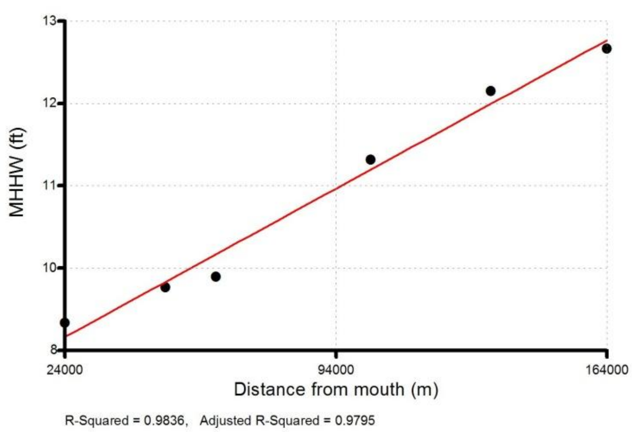


Figure 3. Comparison of modeled vs. observed mean tidal height as a function of distance upstream from Columbia River mouth.

GIS application

The area of tidal inundation (Figure 4) became the foundation for the tributary and associated downstream fall Chinook rearing zones. We assigned each population with a series of reaches starting with the main tributary estuary (Figure 5). The first zone included all areas upstream from the mainstem confluence. Progressing downstream from this point, we split the tidally inundated areas into one kilometer sectors that were further subdivided by the centerline of mainstem flow. Each discrete zone was then attributed with its appropriate river kilometer and bank side.

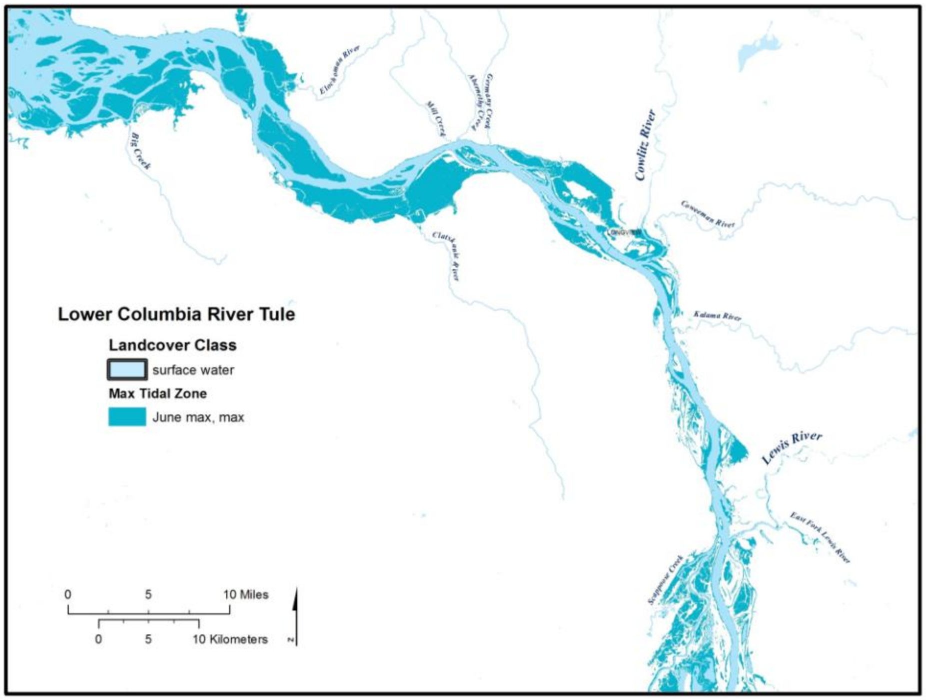


Figure 4. Estimated extent of tidal influence.

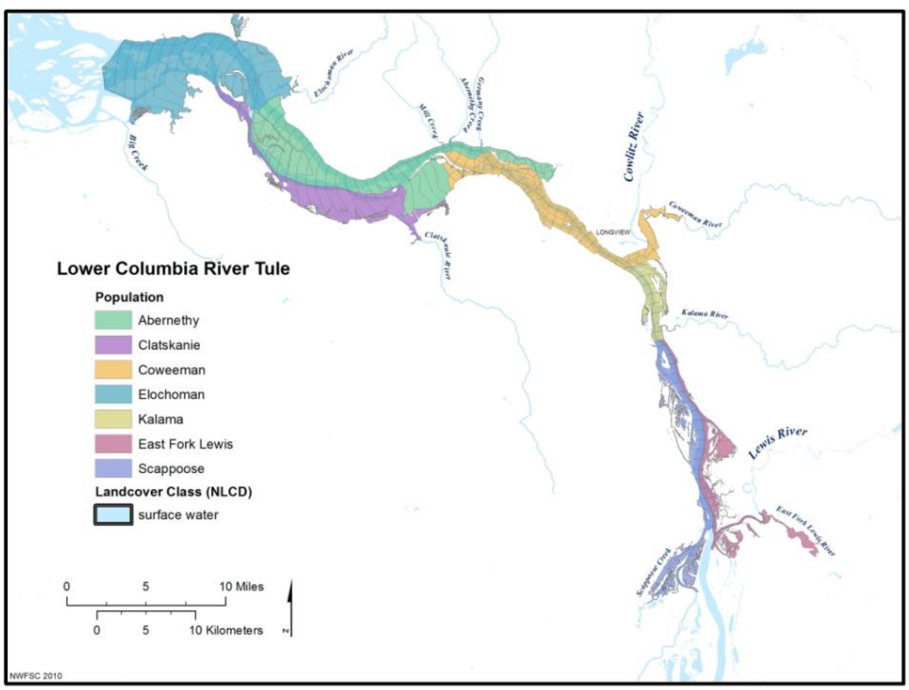


Figure 5. River reach habitats downstream of specific Lower Columbia tule chinook populations.

NWI maps

We utilized the National Wetland Inventory (NWI) from the United States Fish and Wildlife Service (USFWS) as the basis for quantifying wetland habitats within the intertidal zone (Figure 6). The NWI spatial layers for Washington and Oregon were obtained and clipped to the subbasins within the Lower Columbia River subbasins. We then used the NWI classification scheme to identify and quantify wetland habitats that would likely support rearing fall Chinook juveniles.

Estuary/marine, freshwater emergent, and freshwater forested wetlands were considered the most preferred habitat types within saltwater tidal, freshwater tidal, and nontidal water regimes. Additionally, we selected for temporarily, seasonally, semi-permanently, intermittently, and regularly flooded wetland types (Figure 3). Once the dataset was queried for these attributes, the selection set was converted to a new spatial theme and clipped to the tidally inundated zonal theme. From the resulting dataset we were able to summarize the quantity of wetlands by type within one kilometer segments extending downstream from the lower extent of spawning for each population.

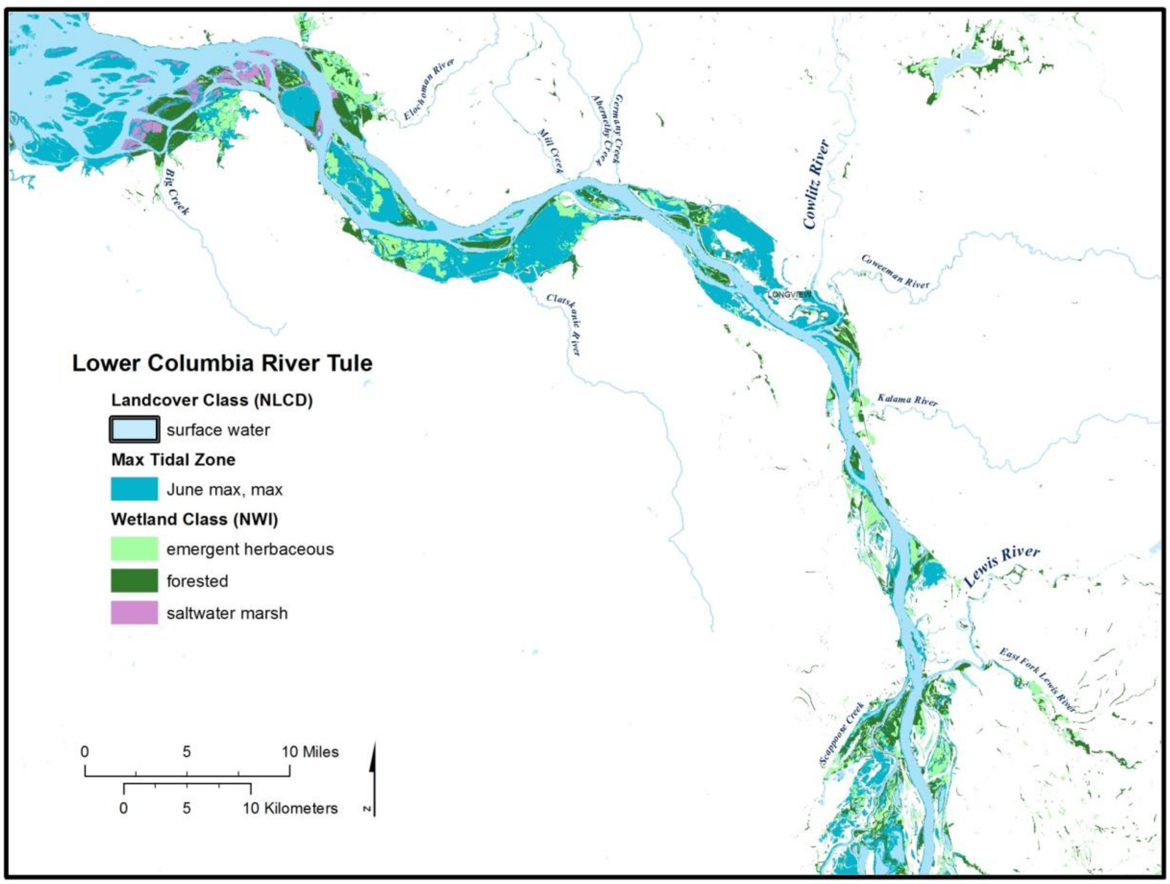


Figure 6. Distribution of NWI wetland class designations across Lower Columbia River subtidal habitats.

Blocked marsh habitats

In order to assess disconnected extant wetlands within our populations, we calculated the amount of NWI defined habitat intersected by currently diked areas. It was assumed that intact wetlands within levied areas could provide similar rearing opportunities to those in currently accessible areas. GIS diking data for the mainstem Columbia River was developed by the Lower Columbia River Estuary Partnership (LCREP), from which we added levied portions of the East Fork Lewis River near LaCenter, Washington. Additional areas within the East Fork Lewis River were identified from the East Fork Lewis River Basin Assessment (Johnston et al. 2005). Diked areas and their associated NWI classes are shown in Figure 7. We then intersected all diked features to the wetlands contained within Tule Chinook populations, and summarized blocked habitat by wetland class and subbasin proximity zone.

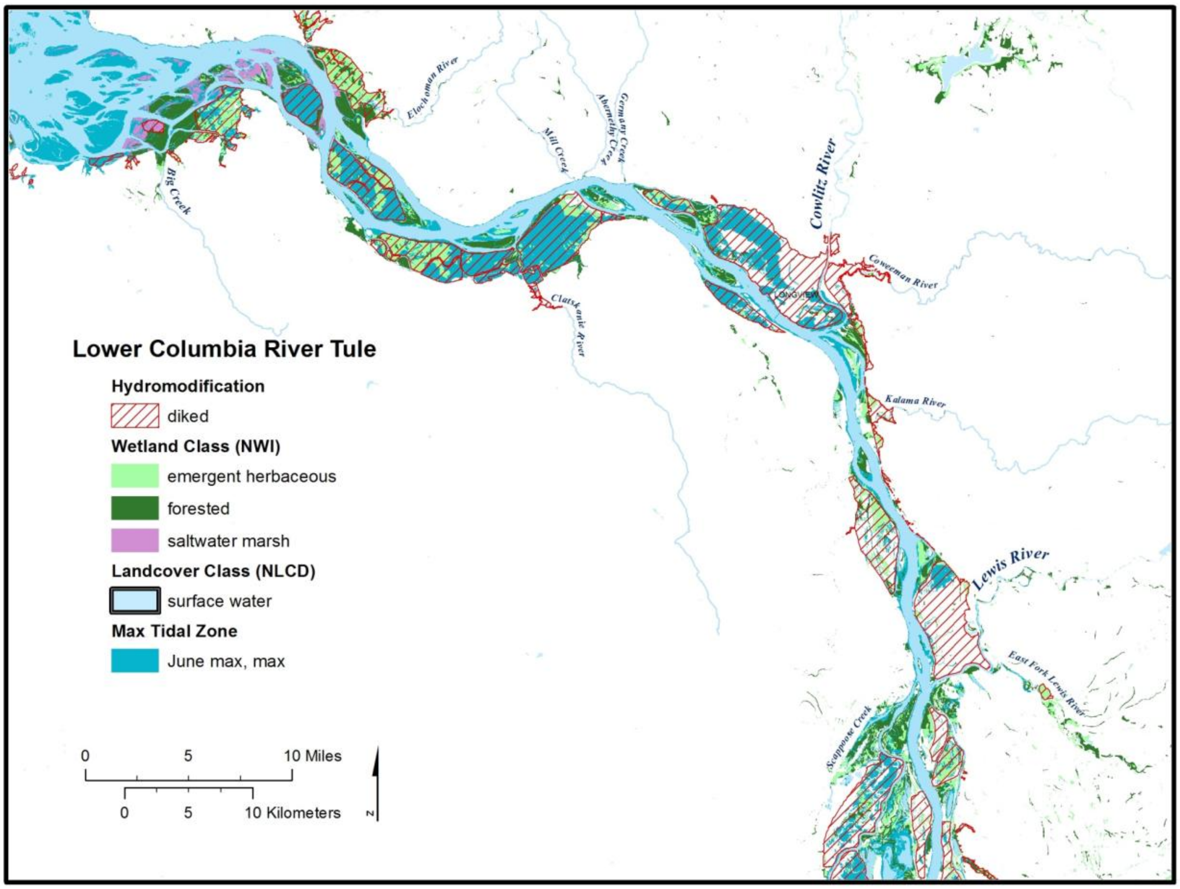


Figure 7. Overlay of diked habitats (LCREP spatial data) on NWI wetland distribution for Lower Columbia River subtidal habitats.

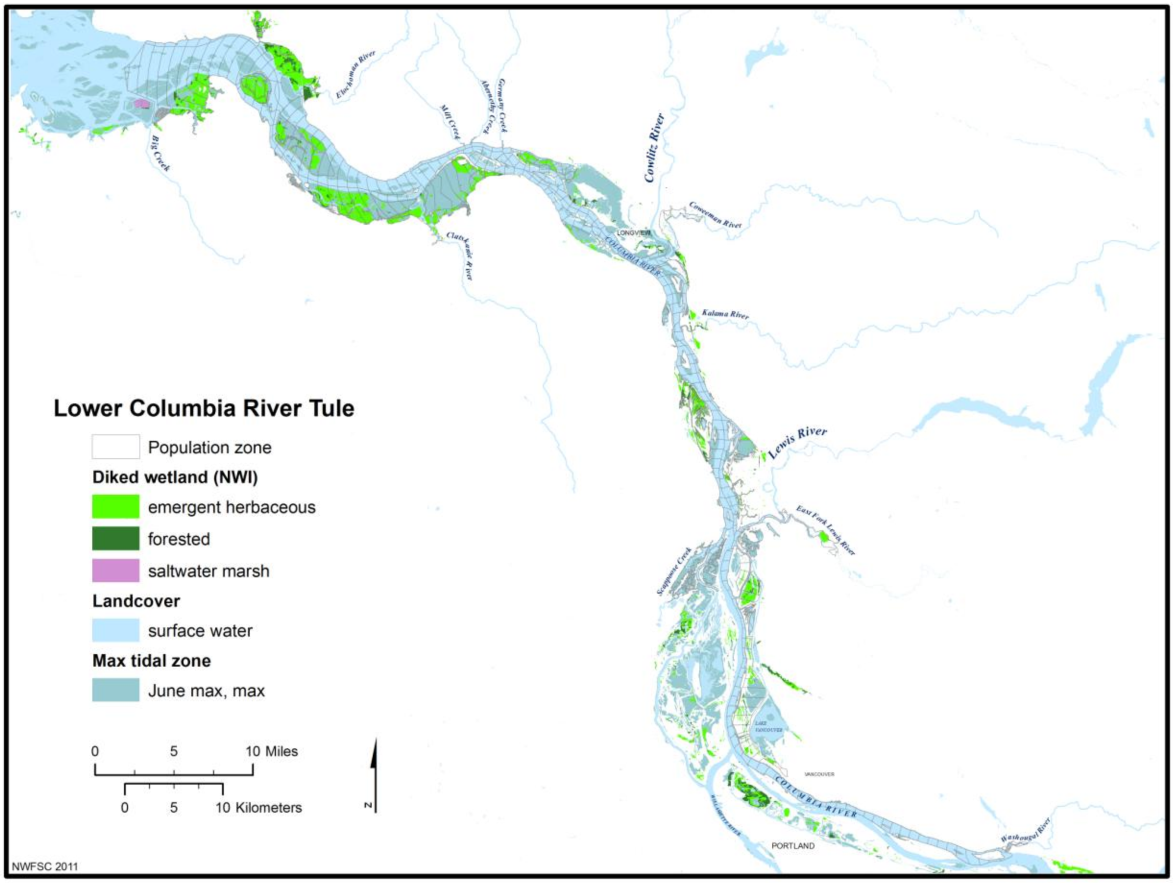


Figure 8 . Distribution of blocked extant wetland habitats derived from overlaying LCREP dike data base on NWI marsh habitats.

Tributary mainstem edge rearing habitat

Studies in several systems supporting ocean type chinook production have indicated that marginal edge habitats in lower mainstem tributary reaches support juvenile rearing (e.g., Hayman et al. 1996, Bartz et al. 2006). We estimated the amount of lower tributary mainstem edge habitat for each population from GIS stream layer maps and information in population specific assessments (Johnson et al. 2005, anon,2000). For each system we apportioned the marginal habitat into two categories, natural edge and hydro-modified edge by intersecting the GIS stream layer with the NWI habitat maps. The length of margin intersecting with currently accessible marsh habitat was accumulated as natural edge habitat. For each population, we estimated potential rearing capacity for edge habitats by expanding total length to area and multiplying the resulting totals by average density estimates for each habitat category (from Hayman et al., 1996: average width of marginal edge rearing habitats = 2.6m, juvenile chinook densities of 0.97 and 0.35 for natural edge and hydro-modified edge habitats, respectively).

Rearing habitat per unit wetlands

Relatively small (40-50 mm) subyearling chinook juveniles emigrating into intertidal wetlands habitats use deeper channel habitats for refuge during non-feeding hours. Population models developed for Puget Sound chinook have assumed that rearing capacity for juvenile chinook in intertidal wetlands is a function of the amount of channel habitat.

We applied the results of field studies in the Skagit basin to generate population specific estimates of available wetlands channel habitat associated with each of lower Columbia tule chinook populations designated as Primary in the current recovery planning drafts. We then applied two estimates of capacity per unit channel habitat reported in Puget Sound studies (Greene and Beechie, 2004; Bartz et al., 2006) to generate a range of capacity estimates for 1 km segments of mainstem habitats extending downstream from each of the primary populations.

Beamer et al. (2005) analyzed infrared orthophotos of a subsample of marsh habitats in the Skagit delta to determine potential relationships between channel surface area and marsh surface area. Regressions of channel area on marsh area differed when samples from the North and South Fork Skagit delta were analyzed separately (see appendix DIII in Beamer et al 2005). Estimates for marsh areas outside of either the North or South Fork delta sections clustered more closely with the South Fork. We applied the fitted relationship developed from the South Fork Skagit River to estimate the amount of intertidal channel habitat associated with Lower Columbia tule populations.

Emergent wetlands: Channel area = .006 X (hectares of wetlands)^1.48

The Skagit River juvenile studies confirmed that some proportion of fry emigrating downstream from up-river spawning areas transit through the Skagit delta and enter pocket estuaries – defined as wetlands that result from small tributaries or general runoff into margins away from main tributary (e.g., along Puget sound shoreline but not directly associated with major tributaries. Beamer et al. 2005 developed a separate regression relating the amount of channel area to total marsh area for pocket estuaries. We incorporated this relationship into our assessment of marsh type habitats currently accessible along the mainstem Columbia River.

Pocket marsh habitats: Channel area = .0614 X (wetlands hectares)

Analyses of the field sampling data from the Skagit delta indicated that chinook densities during the spring and early summer rearing phase were influenced by channel depth and average water velocity (Beamer et al., 2005 appendix DII). Beamer et al. 2005 concluded that fry densities were low in habitats shallower than 0.2 m or where average water velocities exceeded 0.2 m per sec. The Skagit delta habitat surveys indicated that for channels up to 100 m in width, approximately 20% of the channel habitat would exceed 0.2 m depth while having an average water velocity below 0.2 m per second. We applied the 20% estimate in our analysis of potential intertidal rearing habitat for Lower Columbia tule chinook populations.

Densities

Beamer et al. (2005) estimated that the average Skagit delta juvenile rearing density at capacity was 1.31 fish/m3 of rearing habitat (appendix DVII of Beamer et al. 2005). We assumed that this estimate applied per unit channel rearing habitat to the Lower Columbia tule populations . We also assumed it represents the maximum expected output of 80-90 mm early summer pre smolt migrants per unit of habitat. We also calculated the total capacity by applying averages of the estuarine marsh rearing densities reported in Table 4 of Bartz et al.(2006). For one set of scenarios, we applied a density of 0.14 per m2 of channel area, corresponding to the values for forested riverine tidal and estuarine emergent marsh. As alternatives, we also applied the 0.28 (average of forested riverine tidal, estuarine scrub-shrub, and estuarine emergent marsh) and 0.21 (average over the same categories plus connecting side channel).

Connectivity

Beamer et al. 2005 concluded that the effective capacity of a unit of habitat dropped off as a function of distance and channel complexity (number of alternative pathways from natal areas) in the Skagit delta. A model that included a capacity index (1/distance) provided the best fit to relative density data collected from different sections of the delta. The Skagit sampling results indicated that chinook densities leveled off at connectivity values exceeding 0.40, corresponding to a distance of approximately 24 km in a simple linear channel (Beamer et al., figure 4.5). We adapted the connectivity relationship from Beamer et al. 2005 and used the results to generate weighted estimates of the amount of downstream rearing habitat potentially available to each of the primary lower Columbia tule populations. We assigned relative weights to the estimated amounts of rearing habitat in 1 km segments downstream from each population (Figure 7). Segments less than 25 km downstream of the lower end of a natal spawning reach were assigned a weight of 1. Based on the Skagit data, we assumed that reaches more than 60 km downstream were unlikely to support fry rearing . Weights for segments in the intervening distances were assigned as a function of connectivity (1/distance).

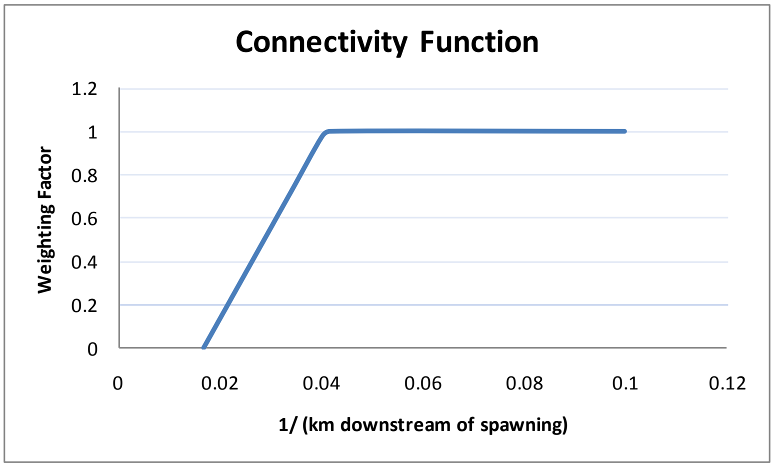


Figure 9. Relative weighting applied in accumulating estimated mainstem Columbia River rearing habitat for each Lower Columbia tule chinook population. Based on sampling results from the Skagit River delta (Beamer et al., 2005)

We generated a range of estimates of total potential channel habitat for Lower Columbia tule chinook populations using a systematic approach. We analyzed the populations targeted for restoration to high or very high viability in recovery planning – the primary populations (note: we did not attempt to model downstream rearing habitats associated with the Toutle River and Hood River populations for this report). We generated a range of estimates by applying alternative inputs for two factors: the channel to wetlands area conversion and the relative discount for distance downstream from the lower end of tributaries. We report the point estimate for one set of assumptions (Skagit delta channel to wetlands area ratio applied down tributary confluence with Columbia mainstem, pocket estuary relationship in mainstem Columbia; connectivity factor of 1/ distance downstream of natal tributary confluence) along with the range of capacity estimates across the remaining combinations of marsh channel habitat ratios and connectivity assumptions). Option 2: applied emergent wetlands channel estimate across all of the habitats associated with each population.

East Fork Lewis River Example

The East Fork Lewis River supports a tule chinook population designated for primary status by recovery planners (targeted for restoration to high viability). Chinook spawning in the East Fork extends upstream from the confluence of a side tributary (Mason Creek) just upstream of the town of La Center. WDFW spawning survey records indicate that virtually all spawning occurs in mainstem East Fork habitats. The starting point for our estimates of potential intertidal rearing habitats in the Lewis River was the confluence with Mason Creek. We generated estimates of the amount of currently available rearing habitat associated with the marginal edge of the mainstem downstream of the Mason Creek confluence and an estimate of the off-channel marsh habitat using the methods described above. We estimated the total amount of marsh habitat currently available under spring flow conditions for the same reach. We continued the analysis downstream from that confluence, summing the estimated current marsh habitat associated with each 1 km increment of distance down the mainstem Lewis River to the confluence with the Columbia River. We continued accumulating estimates of current marsh habitat in 1 km increments downstream for 50 km. We calculated alternative estimates of the potential rearing capacity for each increment using different combinations of channel usage and maximum rearing densities as described in the Methods section. We applied the connectivity function derived from the Skagit River field studies (Beamer et al., 2005) and summed the results for downstream habitats in two categories: less than 25 km downstream (connectivity =1.0) and greater than 25 km downstream (decreasing connectivity as a function of distance). We repeated the analysis to generate estimates of the potential capacities associated with extant marsh habitats that are blocked off from access to emigrating chinook (Figure 10).

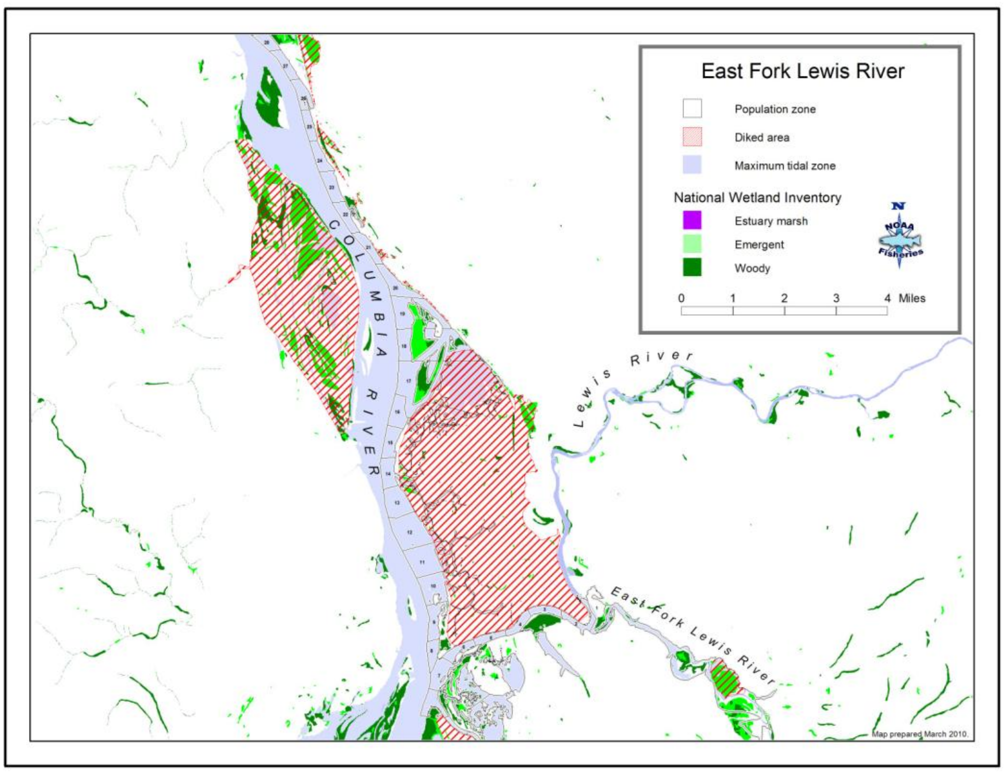


Figure 10. East Fork Lewis River. Distribution of wetlands vs diked areas. Includes delineation of 1 km increments downstream from lower end of confluence of the East Fork with the mainstem Lewis River.

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Population Estimates

Estimates of the current intertidal rearing capacities for each primary Lower Columbia tule chinook population are summarized in Table 1. More detailed breakouts of the estimated current rearing capacities by habitat zone (lower tributary, first 25 km downstream, 25 to 50 km downstream) are illustrated in Figure 11 for assumption sets representing the lowest and highest capacity estimates across populations (results are also provided in tabular form in attachment 1). The range in estimated capacity as a function of specific combinations of assumed channel usage and density multipliers was the least for the Washougal River population and the highest for Elochoman River. The results for the Washougal largely reflect the lack of extant or blocked marsh type habitats in the 50 km downstream from spawning in that system (Figure 7, attachment 1). The results for the Elochoman River population are driven by the presence of extensive tidal wetlands just downstream of its confluence with the mainstem Columbia River. The presence of relatively large, contiguous marsh areas results in relatively high estimates of channel usage when the south Fork Skagit relationship is applied.

Table . Summary of Lower Columbia River juvenile chinook capacity estimates generated by applying combinations of alternative estimates of channel use and maximum densities.

Population	Channel: / Density:	6% of Marsh / .141 per m2	SF Skagit / .28 per m2	6% of Marsh / .131 per m3	SF Skagit / .131 per m2	Median
Abernathy/Mill/Germany		98,300	190,900	353,400	483,200	***272,200***
Claskanine River		158,900	250,900	412,500	488,900	***331,700***
Coweeman River		107,400	145,500	212,500	354,900	***179,000***
Elochoman River		185,400	305,100	515,200	507,900	***406,500***
Lewis River (EF)		107,700	132,500	176,000	265,600	***154,300***
Scappoose River		150,100	212,600	322,300	387,500	***267,500***
Washougal River		44,300	45,300	46,900	56,900	***46,100***

Blocked marsh habitat capacities

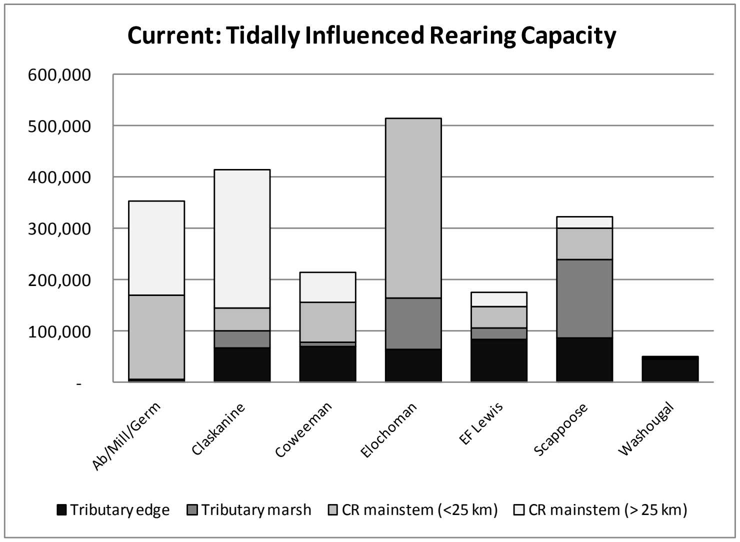
The relative proportions of blocked habitat across populations were relatively consistent across the different combinations of assumed channel usage and maximum densities (Figure 11, attachment 1). The amount of extant but blocked rearing capacities relative to current levels ranged from approximately 29% (Scappoose River) to 262% (Washougal River). The distribution across habitat zones differs among populations. Degraded main channel edge and associated marsh habitats in the lower reaches of population tributaries contribute substantially to the totals for the Scappoose River, East Fork Lewis River, Washougal River and Coweeman River populations. Relative losses associated with mainstem marsh habitats are relatively high for the Claskanine River, Elochoman River and Abernathy/Germany/Mill Creek populations.

The estimates of current and blocked habitat capacities generated in this analysis are intended to aid recovery planners in targeting more detailed assessments of potential restoration actions for particular populations. Ongoing efforts to map rearing opportunities as a function of reach specific depth, velocity and temperatures under a range of flow conditions should lead to improved estimates in the future. The estimates derived in this report were based on a number of simplifying assumptions, including using long term average June high tide levels as the basis for estimating the relative area of usable marsh habitats. More detailed studies of habitat availability for the lower most sections of the mainstem Columbia River indicate that the amount of usable rearing habitat may be substantially influenced by year/month specific flow conditions (Burla et al.,). Further development of flow/depth/temperature based habitat opportunity models should generate improved reach specific capacity estimates.

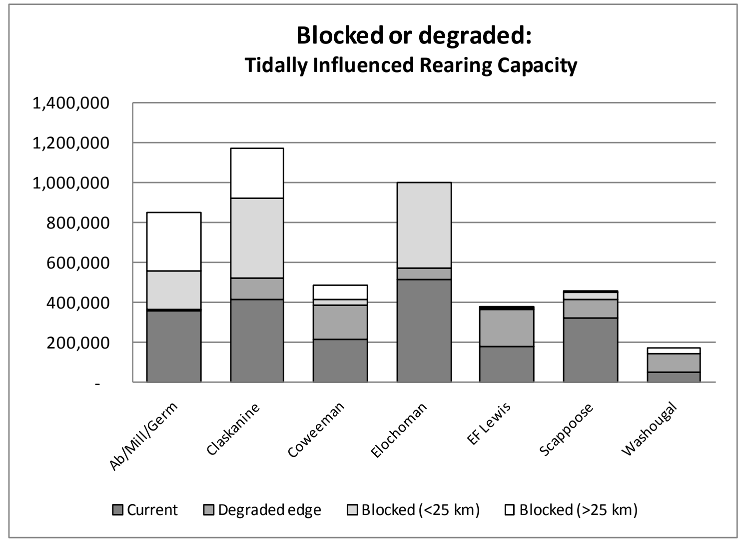
Ongoing or planned field sampling studies in the Lower Columbia River may generate more specific information on channel usage and maximum densities as well. In the interim, the ranges of capacity estimates provided in this report allow for updated model based sensitivity analyses of potential conservation and recovery strategies.

Figure 11 . Distribution of estimated juvenile chinook rearing capacities among intertidal habitats based on alternative combinations of average channel habitat per hectare of marsh, maximum juvenile capacity per unit of channel habitat. Skagit So. Fork channel/density (A.1,B.1),Bartz et al 2006 general (A2,B2). Current (A.1.,A.2.) and extant blocked marshes (B.1, B2).

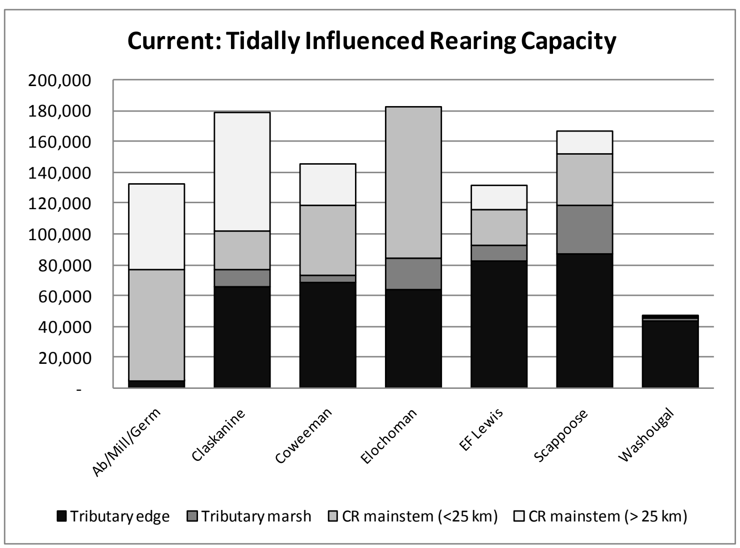
A.1.



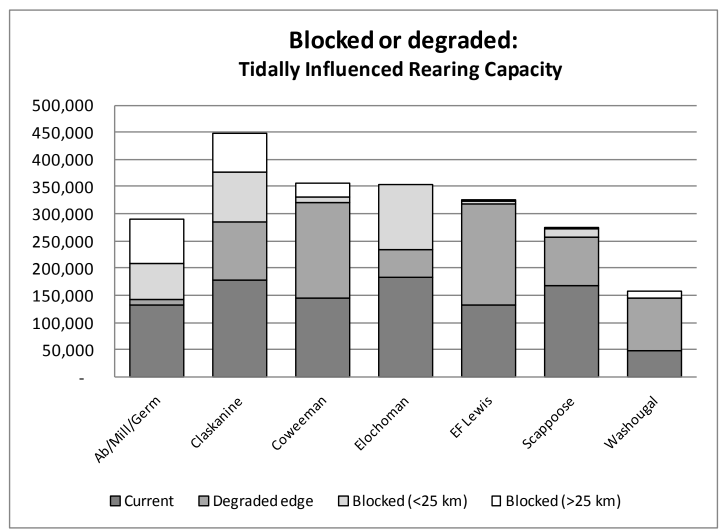
B.1.



A.2.



B.2



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Attachment 1A. Estimated juvenile chinook rearing capacities for selected Lower Columbia tule chinook populations. Estimates derived assuming 6% of channel habitat, 0.14 chinook per m2

	Lower Tributary marginal edge rearing habitats					Juvenile Rearing Capacity			
Population	km below spawning	Total Edge habitat (m)	Wetlands Edge (m)	Wetlands Edge (m2)	Modified Edge (m2)	Natural	Modified	Total	Potential Addition
Abernathy/Mill/Germany	0.0	1,734	320	832	3,677	807	3,567	4,374	10,192
Claskanine River	7.3	25,960	11,196	29,111	38,384	28,238	37,233	65,470	106,379
Coweeman River	9.0	27,243	3,063	7,965	62,866	7,726	60,980	68,706	174,229
Elochoman River	3.5	25,393	18,160	47,215	18,807	45,799	18,243	64,041	52,122
Lewis River (EF)	9.5	32,718	6,788	17,648	67,418	17,119	65,395	82,514	186,843
Scappoose River		34,377	21,965	57,109	32,271	55,396	31,303	86,699	89,437
Washougal River	5.8	17,206	3,813	9,913	34,824	9,616	33,779	43,395	96,512

	Lower Tributary Marsh Habitat		Juvenile Rearing Capacity		
Population	Current Hectares	Blocked Hectares	Current	Blocked	Total
Abernathy/Mill/Germany	4	-	280	-	280
Claskanine River	136	50	11,340	4,200	15,540
Coweeman River	54	19	4,480	1,540	6,020
Elochoman River	238	367	20,020	30,940	50,960
Lewis River (EF)	119	66	9,940	5,600	15,540
Scappoose River	376	0	31,640	-	31,640
Washougal River	1	-	1,960	-	1,960

	Mainstem Columbia River juvenile chinook rearing habitat	Within population zone				More than 25 km downstream		Mainstem totals	
Population	Current Hectares	Blocked Hectares	Current	Blocked	Subtotal	Dist. Wted Current	Dist. Wted Blocked	Total Current	Total Blocked
Abernathy/Mill/Germany	52	48	72,100	66,640	138,740	55,554	80,342	127,654	146,982
Claskanine River	18	66	24,640	92,820	117,460	77,160	70,300	101,800	163,120
Coweeman River	38	41	45,154	11,811	56,965	26,843	26,236	71,997	38,047
Elochoman River	31	31	98,560	117,880	216,440	-	-	98,560	117,880
Lewis River (EF)	17	21	23,100	4,760	27,860	15,873	3,157	38,973	7,917
Scappoose River	22	22	33,880	16,800	50,680	14,838	750	48,718	17,550
Washougal River	23	24	560	-	560	1,087	13,882	1,647	13,882

			Juvenile Rearing Capacity							
Population	Current Hectares	Blocked Hectares	Current	Blocked	Total	Dist. Wted Current	Dist. Wted Blocked	Total	Prop Blocked	Blocked/ Current ratio
Abernathy/Mill/Germany	56	48	76,754	76,832	153,586	132,308	157,174	289,482	0.54	1.19
Claskanine River	153	116	101,450	203,399	304,849	178,611	273,699	452,310	0.61	1.53
Coweeman River	92	60	118,340	187,580	305,921	145,183	213,816	358,999	0.60	1.47
Elochoman River	269	398	182,621	200,942	383,563	182,621	200,942	383,563	0.52	1.10
Lewis River (EF)	136	87	115,554	197,203	312,757	131,427	200,360	331,787	0.60	1.52
Scappoose River	398	22	152,219	106,237	258,455	167,056	106,986	274,043	0.39	0.64
Washougal River	24	24	45,915	96,512	142,426	47,002	110,393	157,395	0.70	2.35

Attachment 1B Estimated juvenile chinook rearing capacities for selected Lower Columbia tule chinook populations. South Fork Skagit channel habitat function (0.2 X (.006hectares^1.48)), 1.31 chinook per m3.

	Lower Tributary marginal edge rearing habitats					Juvenile Rearing Capacity			
Population	km below spawning	Total Edge habitat (m)	Wetlands Edge (m)	Wetlands Edge (m2)	Modified Edge (m2)	Natural	Modified	Total	Potential Addition
Abernathy/Mill/Germany	0.0	1,734	320	832	3,677	807	3,567	4,374	10,192
Claskanine River	7.3	25,960	11,196	29,111	38,384	28,238	37,233	65,470	106,379
Coweeman River	9.0	27,243	3,063	7,965	62,866	7,726	60,980	68,706	174,229
Elochoman River	3.5	25,393	18,160	47,215	18,807	45,799	18,243	64,041	52,122
Lewis River (EF)	9.5	32,718	6,788	17,648	67,418	17,119	65,395	82,514	186,843
Scappoose River		34,377	21,965	57,109	32,271	55,396	31,303	86,699	89,437
Washougal River	5.8	17,206	3,813	9,913	34,824	9,616	33,779	43,395	96,512

	Lower Tributary Marsh Habitat		Juvenile Rearing Capacity		
Population	Current Hectares	Blocked Hectares	Current	Blocked	Total
Abernathy/Mill/Germany	4	-	-	-	-
Claskanine River	136	50	35,108	8,384	43,492
Coweeman River	54	19	7,336	1,572	8,908
Elochoman River	238	367	99,036	149,340	248,376
Lewis River (EF)	119	66	23,056	14,672	37,728
Scappoose River	376	0	150,912	-	150,912
Washougal River	1	-	2,620	-	2,620

	Mainstem Columbia River juvenile chinook rearing habitat	Within population zone				More than 25 km downstream		Mainstem totals	
Population	Current Hectares	Blocked Hectares	Current	Blocked	Subtotal	Dist. Wted Current	Dist. Wted Blocked	Total Current	Total Blocked
Abernathy/Mill/Germany	31	37	164,012	192,832	356,844	185,057	292,774	349,069	485,606
Claskanine River	9	77	44,540	402,432	446,972	267,417	246,853	311,957	649,285
Coweeman River	38	41	78,482	27,132	105,614	57,933	73,475	136,415	100,607
Elochoman River	31	31	352,128	433,872	786,000	-	-	352,128	433,872
Lewis River (EF)	17	21	41,920	5,240	47,160	28,498	6,753	70,418	11,993
Scappoose River	22	22	61,308	36,156	97,464	23,351	651	84,659	36,807
Washougal River	23	24	-	-	-	895	26,179	895	26,179

			Juvenile Rearing Capacity							
Population	Current Hectares	Blocked Hectares	Current	Blocked	Total	Dist. Wted Current	Dist. Wted Blocked	Total	Prop Blocked	Blocked/ Current ratio
Abernathy/Mill/Germany	35	37	168,386	203,024	371,410	353,444	495,798	849,242	0.58	1.40
Claskanine River	144	127	145,118	517,195	662,313	412,535	764,048	1,176,583	0.65	1.85
Coweeman River	92	60	154,524	202,933	357,457	212,457	276,408	488,866	0.57	1.30
Elochoman River	269	398	515,205	635,334	1,150,539	515,205	635,334	1,150,539	0.55	1.23
Lewis River (EF)	136	87	147,490	206,755	354,245	175,988	213,508	389,496	0.55	1.21
Scappoose River	398	22	298,919	125,593	424,511	322,270	126,243	448,513	0.28	0.39
Washougal River	24	24	46,015	96,512	142,526	46,910	122,690	169,601	0.72	2.62