Group:

I offer some observations regarding salinity preferences of juvenile salmon upon movement from riverine habitats into estuaries and beyond.

Buell

Baggerman, B. 1960. Salinity preference, thyroid activity and seaward migration of four species of Pacific salmon (Oncorhynchus). J. Fish. Res. Bd. Can. 17(3): 295-322.

Baggerman repeated and extended the initial work of Houston (1957) in this area, using four species of pacific salmon: pink, chum, sockeye and coho. She found that pink and chum salmon were obligate for anadromy and all fry died if held for extended periods in fresh water, whereas sockeye and coho juveniles passed through cycles of strong sea water preference and a reversion to fresh water preference if not allowed to go to sea. All test fish were placed in gradient tanks where they could choose to be in fresh or salt water. Onset of strong salt water preference corresponded directly with increases thyroid activity (now replaced by the familiar and easier to conduct ATP-ase diagnostic), which is associated with smolting. Pink fry started strong and consistent salt water preference about one month after complete resorption of the yolk sac (beginning of May). Chum salmon showed a weak preference for salt water in April after yolk sac resorption but exhibited a strong and persistent halophilic response by May. Sockeye juveniles showed a more complex response to exposure to sea water, exhibiting a preference for sea water from April through the end of August of their first year, reverting to a preference for fresh water by September. Yearling sockeye showed a strong and persistent preference for sea water from April through June, but this preference reversed by August if fish were held in fresh water. Coho juveniles exhibited very weak preference for sea water by a small proportion of test individuals during their first spring (end of May), but otherwise a consistent preference for fresh water for their first year. Coho yearlings began showing a strong and persistent preference for salt water by the end of March. When held in fresh water, this preference reversed by the end of May. Baggerman concluded that sea water preference could be used as an accurate diagnostic for "migration-disposition". She was able to alter the timing of the halophilic response (and the associated thyroid activity) through manipulation of photoperiod, having previously done the same with sticklback, which has since become a well-known phenomenon. Finally, Baggerman was able to reverse the preference for sea water by treatment with thyroid inhibitors, clearly implicating the hormone in the preference response.

Williams, I.V. 1969. Implication of water quality and salinity in the survival of Fraser River sockeye smolts. Prog. Rep. No. 22, Int. Pac. Salmon Fish. Comm. New Westminster.

Williams compiled recruitment data along with river discharge and water quality information and noted a strong influence of "some survival factor" prior to entry into salt water. Among other things, he conducted salinity preference tests on wild smolts captured at lake outlets in salt water gradients (about 2 to about 29 ppt. in 4-6 layers) for fish held previously in various salinities. Williams noted a difference in salinity "tolerance" among stocks from different lakes in the Fraser system, but he had difficulty interpreting his results. The stock closest to the mouth of the

Fraser generally tolerated full strength sea water with no acclimation; stocks from lakes further upstream required some acclimation and recovery from capture before tolerating sea water well. I suggest that the stock closer to the mouth (very close) is genetically predisposed to enter salt water soon after leaving their lake. In salt water preference tests, smolts from the lake nearest the mouth (Cultus Lake) "preferred" full strength sea water, when placed in a gradient where they could choose, within only a few (2-9) hours of being introduced into the gradient; control fish showed no spacial distribution corresponding to the salinity gradient tank or showed an opposite distribution, confirming salinity preference in the experimental group. Smolts from lakes further upstream "preferred" full strength seawater only after having been held in fresh water for a few days after capture, presumably indicating that some time needed to elapse before these fish were "ready" to make the transition. Interestingly, fish "forced" immediately after capture into sea water for holding, and then introduced into the gradient showed less preference for sea water than their counterparts held for a short time in fresh water prior to introduction into the gradient. [This may have implications for release sites for either hatchery fish or salvaged fish in the Central Valley system.] Williams interpreted his data to indicate, among other things, that it is important for survival of the various stocks of sockeye in the Fraser system to reach the estuary very near the time when acceptance of, or "preference" for, sea water occurred, and that this is genetically mediated. Both river velocity and turbidity (the lack of which retards migration of sockeye during the day) are thought to be influential factors. Once sea water "acceptance" has occurred within the fish "very little if any acclimation is necessary for survival." Premature or delayed entry can impair survival, however.

Hurley, D.A. and W.L. Woodall. 1968. Responses of young pink salmon to vertical temperature and salinity gradients. Prog. Rep. No. 19, Int. Pac. Salmon Fish. Comm. New Westminster.

Hurley and Woodall tested newly emergent pink salmon fry from a variety of stocks for both temperature and salinity "preference". They found that if pink fry were held for 2-3 months in fresh water after emergence, they died. Preference for both colder temperatures and increasing salinities occurred in an "orderly sequence" during the sea water transition period. The completion of this transition was less than one month for all stocks (a strong preference usually developed within 5-10 days) and was more rapid for later emerging fry. Salinity preference was observed to be independent of the salinity of the previous holding environment.

Tyler, R.W. 1963. Migration of juvenile salmon in Everett Bay. Report, Fish. Res. Inst., U. of Wash. Seattle.

Tyler noted that juvenile salmon emigrating from the Snohomish River into Everett Bay tended to enter saline environments quickly and migrate primarily along the north side of the estuary. This is the side away from the freshwater plume of the River, which bends south and passes primarily between "Jetty Island" and harbor facilities on the mainland. There was no correlation between the distribution of chum, coho or chinook juveniles and concentrations of spent sulfite liquor. This is consistent with observations made by others and cited by Tyler.

Conley, R.L. 1977. Distribution, relative abundance, and feeding habits of marine and juvenile anadromous fishes of Everett Bay, Washington. M.S. Thesis, U. of Wash. Seattle.

Conley observed that juvenile coho, chinook and chum salmon were most abundant in his sampling stations from May through July, during the peak of downstream migration. Chinook tended to have a more protracted migration period, but all three species moved rapidly into saline environments. Abundances were lowest for the two sites dominated by the fresh water plume (sites 3 and 4). Two large sulfite paper mills are located in the Port Gardner area, contributing effluent to the estuary, but the spent liquor concentrations are very localized and the plume tends to stay in the fresher water lens (Tyler, 1963; pers. obs.). [The Portland Harbor Study (ODFW) showed that juvenile salmon do not avoid shoreline developments, including a variety of commercial port developments and revetments, and in some cases tend to congregate in such areas; predation was found to not be a problem. Therefore, presence of port facilities is probably not a factor explaining smolt spacial distribution.] Conley's thesis did not address salinity directly, since he was primarily interested in structural habitat features, spent sulfite liquor and feeding, but the data speak for themselves.

Levings, C.D. 1982. Short term use of a low tide refuge in a sandflat by juvenile chinook Oncorhynchus tshawytscha, Fraser River estuary. Can. Tech. Rep. No. 1111, Fish. Aquat. Sci. Vancouver.

Levings documented use of depressions in the substrate of Sturgeon Bank (Fraser River estuary) as low tide refuges by chinook salmon pre-smolts (fry). Fork length ranged from 38 to over 60 mm, with modes of 42 and 54 mm for fish caught in beach seines and purse seines, respectively. Salinities ranged from 5 to 25 ppt, with higher values associated with the "refuge" except during very large ebb events when the Fraser River mixed the halocline.

Ryall, R. and C.D. Levings. 1987. Juvenile salmon utilization of rejuvenated tidal channels in the Squamish Estuary, British Columbia. Can. Manuscript Rep. N. 1904, Fish. and Aquat. Sci. West Vancouver.

Ryall and Levings documented the use of brackish (2-16 ppt) tidal channels in the Squamish Estuary by pre-smolt coho and chum salmon. Fork length of the coho ranged from 33 to 57 mm over the time period of residency (early July through mid-August). Upon smolting, the juvenile salmon left the area.

Other references, archived and difficult to obtain... I'm still trying:

Houston, A.H. 1957. Responses of juvenile chum, pink and coho salmon to sharp seawater gradients. Can. J. Zool. 35:371-383.

McInerney, J.E. 1964. Salinity preference: an orientation mechanism in salmon migration. J. Fish. Res. Bd. Can. 21(5):995-1018.

Still more references bearing on this subject, for those who are interested:

Birt, T.P., J.M. Green and W.S. Davidson. 1990. Smolting status of downstream migrating Atlantic salmon (Salmo salar) parr. Can. J. Fish. Aquat. Sci. 47(6):1136-1139.

Chernitskiy, A.G., G.V. Zabruskov, D.S. Shkurko and S.P. Gambaryan. 1995. On the nature of seaward migration of Atlantic salmon (Salmo salar) smolts through an estuary. J. Ichthyol. 35(7):52-61.

Healey, M.C. 1979. Utilization of the Nanaimo River estuary by juvenile chinook salmon, Oncorhynchus tshawytscha. Fish. Bull. 77(3):653-668.

Iwata, M. 1995. Downstream migratory behavior of salmonids and its relationship with cortisol and thyroid hormones; a reveiw. Aquacult. (Netherlands) 135:131-139.

Iwata, M., H. Ogura, S. Komatsu and K. Suzuki. 1986. Loss of seawater preference in chum salmon retained in fresh water after migration season. J. Exp. Zool. 240(3):369-376.

Iwata, M., H. Ogura, S. Komatsu, K. Suzuki, RS. Nishioka and H.A. Bern. 1985. Changes in salinity preference of chum and coho salmon during development. Aquacult. 45:380-381.

Macdonald, J.S., I.K. Birtwell and G.M. Kurzynski. 1987. Food and habitat utilization by juvenile salmonids in the Campbell River estuary. Can. J. Fish. Aquat. Sci. 44(6):1233-1246.

Mahnken, C., E. Prentice, W. Waknitz, G. Monan, C. Sims and J. Williams. 1982. The application of recent smoltification research to public hatchery releases: an assessment of size/time requirements for Columbia River hatchery coho salmon (Oncorhynchus Kisutch). Aquacult. (Netherlands) 28:251-268.

Virtanen, E., L. Soederholm-Tana, A. Soivio, L. Forsman and M. Munoa. 1991. Effect of physiological condition and smoltification status at smolt release on subsequent catches of adult salmon. Aquacult. (Netherlands) 97(2):231-257.

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