WHEN POPULATION AND PHYSIOLOGICAL ECOLOGY MEET:

CHINOOK SALMON SPAWNING

AND THE FATE OF THEIR PROGENY

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EXTENDED ABSTRACT ONLY - DO NOT CITE

We explore the developmental dynamics of pre-emergent chinook salmon in their natural environment (Methow River, Washington, USA). Using models of developmental processes and daily temperature changes, the emergent properties of two allopatric chinook salmon stocks are explored using data on the timing and location of spawning, characteristics of spawned smolts, life-history patterns; and annual cycles of water temperature and flooding.

Development is modeled with coupled differential equations (Beer and Anderson 1997) with temperature dependent terms for anabolism, catabolism and water absorption. Embryo growth and yolk absorption depend on the daily temperature pattern which ultimately defines the development rate and mass of the fish at emergence. Emergence is defined at a physiological point, either maximum alevin mass or button up, both of which are easily identified (Fig 1). The model can be run on the internet at www.cbr.washington.edu/egg_growth

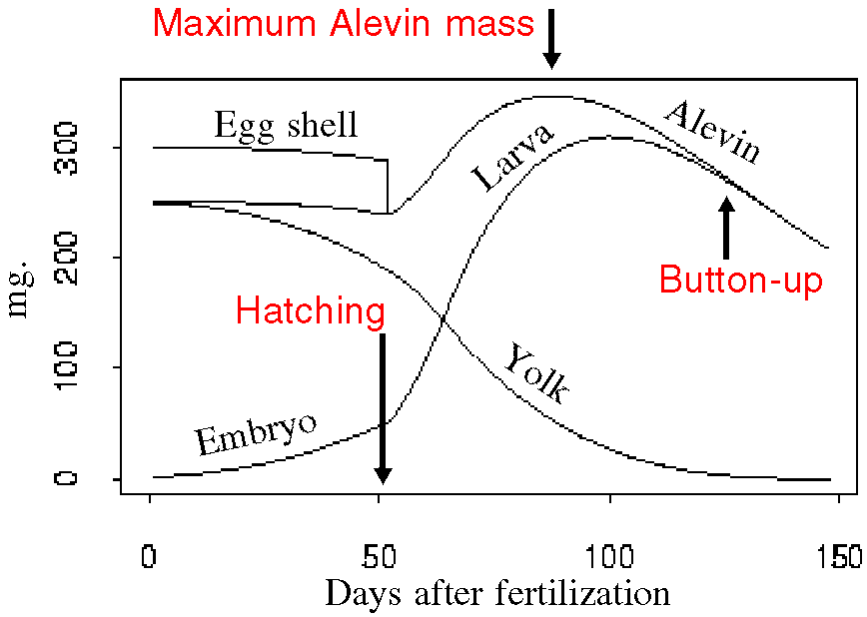


Fig.1 Example growth trajectories tracked through time by the model

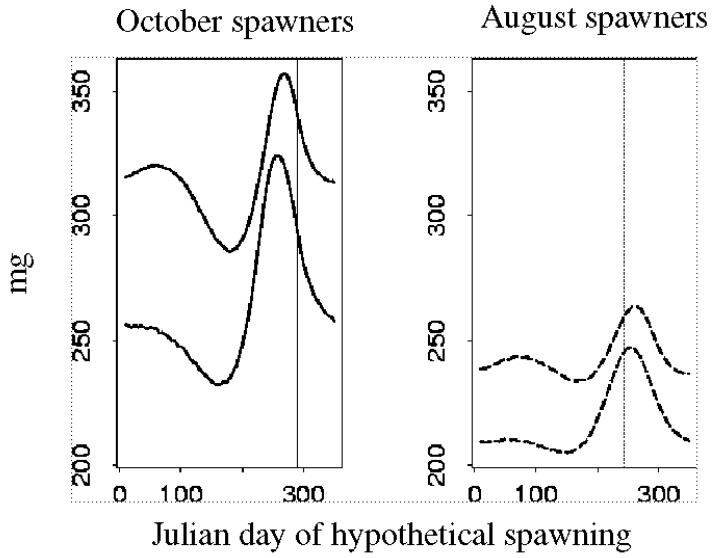
We established a base case for each of the two stocks that spawn in the Methow River. August spawners deposit 218 mg. eggs over a narrow range of elevations near 560 m in a two week range spanning August 31. October spawners deposit 284 mg. eggs over a broad range centered at elevation 444 m in a two week range in mid-October. The mean time and range of times to emergence, and mass at emergence (alevin maximum or button-up) were modeled. Subsequent runs examined the consequences of deviations from the base case on emergence properties:

- spawning over the entire year (example in Fig. 2),
- spawning over the entire river,
- variation in egg size.

Considering environmental conditions during the year we conclude that progeny of August spawners are likely to emerge closer to button-up with a wide range in emergence times. Progeny of October spawners are *forced* to emerge when the alevins reach maximum size but have a narrow emergence timing range (for
predator response saturation). A thermal barrier limits first spawning time while the scour risk limits the end of incubation. In general, the further downstream that spawning occurs, the narrower the window of opportunity for successful incubation.

Despite the presence of high quality flow and gravel between their preferred spawning grounds, neither stock can fully exploit this environment although the broad spatial range used by October spawners is predicted from the insensitivity of emergence to elevation given their spawning time.

Fig. 2 Emergence mass at alevin maximum(upper line) or button-up (lower). Vertical lines show actual spawning



Developmental times of embryonic salmon are an important link between the behavior of spawners and fate of their progeny. Other studies measuring intra-

specific divergence in developmental rates have had mixed results. We assumed they were identical for both August and October spawners but demonstrate the importance of egg size, spawning day and spawning location in influencing developmental times.

We conclude that the important differences between emergence qualities of the progeny of August and October spawners are a result of 1) adaptive behaviors on the part of the spawners to optimize the survival of their progeny in different ways, and 2) egg mass which has the effect of altering the observed developmental rate. Efforts to protect and restore salmon runs must consider the spatial distribution of development as a result of temperatures because some habitat may not be usable for reasons related to physiology.

Reference

Beer, W. N. and J. J. Anderson. 1997. Modelling the growth of salmonid embryos. Journal of Theoretical Biology. 189:297-306.