FISH DIVISION
Oregon Department of Fish and Wildlife

Seasonal Meromixis in the Winchuck Estuary:
Implications to Production of Wild Chinook Salmon
in Certain Oregon Estuaries
Seasonal Meromixis in the Winchuck Estuary: Implications to Production of Wild Chinook Salmon in Certain Oregon Estuaries

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INTRODUCTION

While reviewing the contents of field notebooks that contained information about chinook salmon in small southern Oregon streams, we discovered a notation of an unusual occurrence: water near the bottom of the Winchuck River estuary was warmer than water at the surface of the estuary. This situation is remarkable because (in the summer months) estuaries in Oregon are generally thought to be characterized by warmer freshwater overlaying cooler saltwater. The field notes we reviewed did not contain an explanation of this unusual event. We now believe that impoundment of stratified fresh- and saltwater in the estuary permitted solar heating of the denser saltwater layer. This process is called meromixis, and the stratified state of the water body is referred to as meromictic.

Density stratification has been described in some inland lakes and in some estuarine impoundments that are flooded by high tides at infrequent intervals (Wetzel 1973). In these water bodies, a well-mixed surface layer (miozolimnion) refracts sunlight into an underlying, denser layer (monolimnion), heating and insulating it from diurnal and seasonal cooling. Meromictic water bodies are efficient heat traps. Hudee and Sonnerfeld (1974) estimated that 90% of available solar energy can be trapped in stratified tropical lagoons. This process has been used in Israel in excavated ponds along the Dead Sea for commercial electrical generation (personal observation during 1983 of coauthor Thomas J. Lichatowich).
The purpose of this report is to document the basis of our conclusion that the Winchuck River estuary periodically becomes meromictic, and to discuss the implications of meromixis to wild chinook salmon populations in several small streams in southern Oregon.

MATERIALS AND METHODS

We reviewed information obtained from the files of William G. Mullarkey, Oregon Department Fish and Wildlife district biologist, Coos-Coquille District. In 1973, 1974, and 1975, a maximum-minimum recording thermometer was placed near the bottom of the Winchuck River estuary, about a mile from the river mouth. The maximum and minimum temperatures recorded on the thermometer were determined and noted about once each week from May through September. In 1974 and 1975, juvenile chinook were sampled in the estuary with a beach seine (125 feet x 8 feet; 1/2-inch stretch mesh) at irregular intervals.

RESULTS AND DISCUSSION

The water temperature and seining data we reviewed are summarized in APPENDICES A and B. Maximum temperatures exceeded 80°F during several weeks in 1974 and 1975. Field notes indicated that the highest water temperatures recorded in each of the three years occurred after a sand and gravel sill, which developed at the estuary mouth, prevented tidal exchange. On 13 August 1975 the water temperature was 61°F at the surface and 76°F about 2 1/2 feet below the surface. Field notes also indicated that relatively few juvenile chinook were observed or seined during the period when the estuary was completely impounded.
We hypothesize that the relatively dense layer of saltwater in the Winchuck River estuary receives increasingly less tidal exchange as the sill at the estuary mouth develops. As tidal exchange diminishes, the estuary becomes meromictic and the saline layer warms gradually. This process sets the stage for further heating of the saline layer if the sill eliminates entry of cool ocean water at high tide. This situation is illustrated in Figure 1.

We assume that the highest temperatures documented in 1973, 1974, and 1975 occurred as a consequence of meromixis when a sill impounded stratified fresh- and saltwater in the estuary. We assume that the maximum temperature recorded during these periods occurred in the saltwater layer, and that the minimum temperature recorded during these periods was the temperature of the freshwater layer at the time the thermometer was lowered into or raised out of the estuary each week.

We also believe that several other Oregon estuaries become meromictic for periods during the summer months. The estuaries of New River, Sixes River, Elk River, Euchre Creek, Hunter Creek, and Pistol River are small embayments that frequently become isolated from tidal exchange by the formation of a sand sill at their mouths. Bottom et al. (1982) documented the occurrence in Sixes River estuary of warmer saline water overlain by cooler freshwater during a period when the inflow of ocean water at high tide was limited by a sand sill at the estuary mouth.

Juvenile chinook salmon rear for extended periods in these small estuaries (for example see Reimers 1973, 1978 and Reimers and Concannon 1977), but we can only speculate about the impacts of meromixis on the rearing populations. Little is known of how juvenile chinook are distributed in the water column of these two-layered water bodies. However, the maximum
Figure 1: Tidal profile of a small hypothetical Oregon estuary. In A, the sill at the estuary mouth is overtopped at flood tide, providing an inflow of relatively cool ocean water. In B, the sill has built up so that it blocks tidal flow and traps a layer of relatively dense saltwater that becomes warmed by solar heating. FW means freshwater; SW means saltwater.
temperatures recorded in the Winchuck River estuary frequently were higher than desirable for optimum growth rates, and occasionally exceeded lethal levels reported by Brett et al. (1982). Reimers (1978) suggested that the formation of a partial sill at the estuary mouth acts as a nutrient-trap that enhances primary production and, consequently, production of juvenile chinook. We suspect that this process may create a favorable environment for juvenile chinook only until entry of ocean water is prevented by the sill. When the estuary becomes impounded, high water temperatures could adversely affect the rearing chinook juveniles and their food resources. In the absence of more detailed studies, we do not know whether seasonal meromixis in these estuaries limits wild chinook populations, or whether these stocks of chinook have developed physiological or behavioral adaptations to the condition.

We recommend that the Oregon Department of Fish and Wildlife sample these small south coast estuaries systematically to determine the extent to which meromixis occurs. Depending on the results of this survey, additional studies could be designed to evaluate the impacts of meromixis on juvenile chinook and to investigate methods to manage sill formation and tidal circulation.
REFERENCES


Reimers, P.E. 1978. The need for research on the estuarine ecology of juvenile fall chinook salmon. Oregon Department of Fish and Wildlife, Information Reports (Fish) 78-4, Portland, OR, USA.


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APPENDIX A

Water temperature recorded by a maximum-minimum thermometer placed near the bottom of the Winchuck River estuary approximately one mile from the river mouth.

<table>
<thead>
<tr>
<th>Date</th>
<th>Temperature (°F)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Maximum</td>
</tr>
<tr>
<td>1973:</td>
<td></td>
</tr>
<tr>
<td>19 June-03 July</td>
<td>72</td>
</tr>
<tr>
<td>03-10 July</td>
<td>76</td>
</tr>
<tr>
<td>10-17 July</td>
<td>74</td>
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<tr>
<td>17-23 July</td>
<td>70</td>
</tr>
<tr>
<td>23-31 July</td>
<td>73</td>
</tr>
<tr>
<td>01-07 August</td>
<td>70</td>
</tr>
<tr>
<td>07-14 August</td>
<td>70</td>
</tr>
<tr>
<td>14 August-05 September</td>
<td>78</td>
</tr>
<tr>
<td>05-25 September</td>
<td>70</td>
</tr>
<tr>
<td>1974:</td>
<td></td>
</tr>
<tr>
<td>26 June-03 July</td>
<td>73</td>
</tr>
<tr>
<td>03-10 July</td>
<td>70</td>
</tr>
<tr>
<td>10-17 July</td>
<td>80</td>
</tr>
<tr>
<td>17-24 July</td>
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<td>98</td>
</tr>
<tr>
<td>18-25 September</td>
<td>68</td>
</tr>
<tr>
<td>1975:</td>
<td></td>
</tr>
<tr>
<td>18-25 June</td>
<td>72</td>
</tr>
<tr>
<td>25 June-02 July</td>
<td>70</td>
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<td>18-28 August</td>
<td>76</td>
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<tr>
<td>28 August-03 September</td>
<td>81</td>
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<tr>
<td>03-18 September</td>
<td>83</td>
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</tbody>
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APPENDIX B

Juvenile chinook sampled with a beach seine\textsuperscript{a} in the Winchuck River estuary in 1974 and 1975.

<table>
<thead>
<tr>
<th>Date</th>
<th>Number of seine sets</th>
<th>Number of chinook caught</th>
<th>Fish length (mm)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>1974:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 September</td>
<td>2</td>
<td>140</td>
<td>82</td>
</tr>
<tr>
<td>1975:</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>29 July</td>
<td>2</td>
<td>546</td>
<td>79</td>
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<td>1,266</td>
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<td>29 September</td>
<td>4</td>
<td>19</td>
<td>87</td>
</tr>
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</table>

\textsuperscript{a} 125 feet x 8 feet; 1/2-inch stretch mesh.