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# TECHNICAL ADVISORY COMMITTEE COLUMBIA RIVER THERMAL EFFECTS STUDY

RESISTANCE OF JUVENILE SOCKEYE SALMON (Oncorbyrichus merka)

TO ELEVATED WATER TEMPERATURES !

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#### INTRODUCTION

Thermal tolerances of juvenile sockeye salmon (Oncorhynchus nerka) as described by Brett (1952), were established by laboratory tests conducted in water of generally optimal quality. Similar tests were conducted using Columbia River water, of perhaps variable quality, to determine if differences existed between laboratory and field results.

In 1968 and 1969 tests were conducted at the BCF water temperature laboratory (Snyder, Blahm, and McConnell 1970), Prescott, Oregon, to determine the survival of juvenile sockeye subjected to increased temperatures in unmodified water of the lower Columbia River.

#### MATERIALS AND METHODS

Fish used were from the National Fish Hatchery at Leavenworth,
Washington, since natural migrants were unavailable at the test site. The
fish were transported to Prescott, Oregon, by tank truck. Prior to testing,
the fish were allowed at least 10 days adjustment to the Columbia River
water. When fish were acclimated to temperatures above ambient levels,
this was achieved by imposing increases of 1 C per day until the desired
levels were reached.

Test temperatures were regulated by mixing water from heated and cooled reservoirs and were maintained within ± 0.5 C of the desired level. Water flow was regulated to provide one complete interchange each hour in the test tanks.

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Procedures used for lethal temperature determinations were based on recommendations made by Fry (1947), used by Brett (1952) and Blahm and McConnell (1970a, 1970b).

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Twenty fish were transferred to each of the test tanks at test temperatures. The test interval was 14 days or until the fish died. The time to death of each fish was recorded. Test fish were observed continuously during the initial eight to twelve hours of the test. Thereafter, periodic checks were made during the day and between 10 and 12 pm each night.

#### RESULTS

One test series was conducted in 1968, and two during 1969.

# 1968 tests

In tests conducted in October and November 1968, the survival of fish exposed to test temperatures ranging from 10 to 32 C is shown in Table 1. No mortality occurred below 23 C. At 24.5 C, 50% of the sample died in 186 minutes and all were dead in 237 minutes.

The results of the tests conducted November 19 to December 3, 1968, with fish acclimated to 15.5 C are shown in Table 1. At a test temperature of 20 C, 50% of the fish died in 11,455 minutes; at 24.5 C, all died in 1,310 minutes. Time to death for each fish used in the 1968 tests is given in the Appendix Tables A and B.

Table 1.--Minutes to death of juvenile sockeye salmon (acclimated to 10 and 15.5 C) exposed to elevated temperatures--- tested October and November 1968. Mean fish size 105 mm-- 20 fish per test sample.

Test	Time to death	(20)	% of fish samples acclimated to-		
temperature	50%	100%	50%	100%	
	Min	nutes	Min	utes	
20.0	-	<b>-</b>	11,455.0	-	
23.0	-	-	4,706.0	-	
24.5	186.0	237.0	1,218.0	1,310.0	
26.0	12.0	18.4	49.0	103.0	
29.0	2.0	6.2	2.7	5.3	
32.0	0.8	1.0	0.7	1.0 .	

# 1969 tests

In the tests conducted from July 10 to 24, the fish were acclimated to 10 C and tested at temperatures ranging from 10 C to 29 C.

No mortality occurred at temperatures up to 22 C; however, at this temperature, 50% of the fish died in 12,986 minutes. The time to death for 50 and 100% of the fish is summarized in Table 2.

In the tests conducted July 24 to August 7, the fish were acclimated to 20 C and tested at temperatures ranging from 20 to 29 C. Again, no deaths occurred below 22 C, (Table 2).

Two groups were tested simultaneously from October 7 to 21. In one group, fish were acclimated to 12 C and tested at temperatures from 12 to 29 C. Below 24 C no fish were killed, but at 24 C, 50% mortality occurred in 5,829 minutes and 100% of the fish were killed in 8,589 minutes (Table 3).

In the final tests, October 7 to 21, 1969, fish acclimated to 17 C were subjected to test temperatures from 17 to 29 C. Again no fish were killed below 24 C, where 50% mortality was recorded in 4,251 minutes; at 25 C, 50% of the fish were killed in 102 minutes and all in 386 minutes (Table 3). Time to death of all fish used in 1969 tests is given in Appendix Tables C, D, E, and F.

Table 2.--Minutes to death of juvenile sockeye salmon (acclimated to 10 and 20 C) exposed to elevated temperatures--tested July 1969. Mean fish size 67 mm--20 fish per test sample.

Test	Time to death of		_	s acclimated to			
temperature	50%	100%_	50% 100%				
-1	Minute	S	Minu	tes			
22	12,986.0	- ,	16,988.0	17,258.0			
23	8,605.0	10,045.0	15,545.0	15,545.0			
24	5,730.0	6,030.0	6,933.0	8,343.0			
25	134.0	160.0	4,188.0	6,888.0			
26	50.8	65.5	149.0	196.0			
,29	0.9	1.2	4.8	9.6			

Table 3.--Minutes to death of juvenile sockeye salmon (acclimated to 12 and 17 C) exposed to elevated temperatures-tested October 1969. Mean fish size 100 mm--20 fish per test sample.

Test		th of 50 and 100% 2 C	of fish samples acclimated to— - 17 C			
temperature C	50%	100%	50%	100%		
	M	linutes	Mir	nutes		
24	5,829.0	8,589.0	4,251.0	-		
25	205.0	291.0	102.0	386.0		
26	63.5	85.7	62.3	112.8		
29	2.5	9.0	2.2	8.4		

## CONCLUSIONS

The ultimate upper lethal temperature for juvenile sockeye reported for laboratory tests by Brett (1952) was 24.4 C; however, when tested in Columbia River water at Prescott, the same year class of fish died at 22 C. Comparing Brett's data to the examples from our tests (Table 4), the fish tested in Columbia River water died at lower temperatures and generally, in less time.

Data from the tests indicate that in waters of the natural environment, factors other than temperature may lower the resistance of sockeye salmon to thermal increases. Differences between our test results and those reported by Brett emphasize the need for information from tests that incorporate actual condition of the environment in order to establish the criteria on which to base water temperature standards.

Table 4.--Median resistance times to death at high temperatures of juvenile sockeye salmon acclimated to 10 and 20 C.

Comparing data from Brett (1952) with results of tests conducted in lower Columbia River.

		10 C Acclimation							
Temperature C	Brett	Lower Columbia							
	Minutes								
23	<u>1</u> /	8,605							
5/1	660	5,730							
25	150	134							
26	72	51							
29	No test	1.0							
_,	<u> </u>								
		*							
		20 C Acclimation							
		Minutes							
24	<u>1</u> /	6 <b>,</b> 933							
25	7,300	4,188							
26	550	149							
29	No test	5.0							
	9								

<sup>1/ 50%</sup> mortality of the sample did not occur.

## LITERATURE CITED

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- Brett, J. R. 1952. Temperature tolerance in young Pacific salmon, genus Oncorhynchus. J. Fish. Res. Bd. Can. 9(6): 265-323.
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# APPENDIX

Tables of Basic Data from the Experiments
(Tables A, B, C, D, E, F)

Table A.--Individual time to death in minutes of juvenile yearling sockeye salmon subjected to elevated water temperatures for two weeks or until death. Time is when death was noted.

•	·								
TI: 1	10*	Tir 14	me to dea	th at te	st tempe 23	ratures 24.5	of°C 26	20	32
Fish Number	10	<u> </u>					20	29	
**************************************		,	15	MINUTES :	TO DEATH				
ı	<u> 1</u>	<i>J</i> .	÷ .	1 (	<b>2</b> 86	22.3	7.7	1.5	.4
2					· , !	24.7	7.8	1.7	.6
3						132	8.5	1.9	.6
14				-		148	8.8	2.0	•7
5			w.			151	10.7	2.0	.7
6						165	10.8	2.1	•7
7 .						171	11.5	2.1	•7
8 .				,	į.	172	11.6	2.2	.8
9						192	11.8	2.2	.8
.50%-10				.e.		186	12	2.2	.8
. 11						196	12.2	2.5	.8
12			1	3		199	12.5	2.7	.8
13						204	12.8	3.0	.8
14						233	13.2	3.0	.8
. 15						234	13.8	3.7	.8
16						234	14	4.0	•9
17						240	15.8	4.8	1.0
18						241	17	<b>5.</b> 8	1.0
19						270	18	<b>5.</b> 9	1.0
20						273	18.4	6.2	1.0

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<sup>1/</sup> Solid line indicates no mortality
 Tested October 1968
 20 fish per test

<sup>\*</sup> Control

Table B.—Individual time to death in minutes of juvenile yearling sockeye salmon subjected to elevated water temperatures for two weeks or until death. Time is when death was noted.

	Fish umbe:	- 11	15.5*	17	Time to 20	death at 23	test t 24.5	emperatures 26	of 70 29	C 32
_						MINUTES	TO DEA	TH		
	1	:	11/	14250	4255	3240	76	33	1.3	0.6
1	2			14250	4255	4255	83	34	1.5	0.6
	3	i		· _;	4255	4255	115	36	1.6	0.6
	14				4255	4255	218	37	2.1	0.6
	5	i			4255	4255	1218	39	2.1	0.6
	6				4255	4255	1218	39	2.2	0.7
	7	·*.	4		5755	4576	1218	40	2.2	0.7
•	8				8575	4580	1218	42	2.3	0.7
	9				10015	4597	1218	145	2.6	0.7
50%	-10				11455	4706	1218	49	2.7	0.7
	11	_			11455	4707	1218	50	2.8	0.8
	12	*			15955	7705	1218	56	3	0.8
	13				1	7705	1218	61	3.1	0.8
	14	,				7705	1218	70	3.2	0.8
;	15					7705	1218	70	3.2	0.8
	16	3			-	10145	1218	74	3.8	0.8
	17	٠.		1		10145	1218	79	3.9	0.9
	18					11515	1218	84	4.6	0.9
	19	1				13015	1218	86	5	0.9
* *	20					F1 .	1310	103	5.3	1.0

<sup>1/</sup> Solid line indicates no mortality
 Tested November 1968
 20 fish per test

<sup>\*</sup> Control

Table C.--Individual time to death in minutes of juvenile under-yearling sockeye salmon subjected to elevated water temperatures for two weeks or until death. Time is when death was noted.

			Time	to dea	th at test	temperat	ures of-	- °C		
Fish Number	10*	17	20	2		23	24	25	26	29
				M	INUTES TO 1	DEATH				
1 .	1/	~ <sub>1</sub>	; 	ĺ	8606	5725	4290	114.8	11.7	•7
. 2					8909	7165	4290	115.9	16.9	.8
3		Ì		2	12986	7465	4290	117.3	20.0	.8
4		Ì			12986	7465	4290	118.3	27.2	.8
5					12986	7465	1414O	121.3	47.5	•5
6					12986	7615	4530	121.3	47.9	•9
7				İ	12986	8605	4770	121.7	49.4	•9
8					12986	8605	4770	123.6	49.9	•9
9			Na -		12986	8605	4770	132.5	49.9	•9
50%-10				e.	12986	8605	5730	134.0	50.8	•9
11					12986	8605	5730	134.4	51.0	•9
. 12				š	14486	8605	5730	137.7	51.2	1.0
13				٠.,	15866	8605	5730	141.8	52.0	1.0
14					17246	8735	5730	148.5	52.6	1.0
. 15					17246	10045	5730	150.8	53.1	1.0
16			2		18686	10045	5730	151	53.7	1.0
17				a a	20126	10045	5730	152.8	54.3	1.0
18					20126	10045	5810	153.1	55.9	1.0
<b>1</b> 9					, 1	10045	.5910	158.6	57.6	1.0
20				Ì		10045	6030	160.3	64.5	1.2

<sup>1/</sup> Solid line indicates no mortality
 Tested July 1969
 20 fish per test

<sup>\*</sup> Control

Table D.--Individual time to death in minutes of juvenile under-yearling sockeye salmon subjected to elevated water temperatures for two weeks or until death. Time is when death was noted.

	ī	Tin	no to do	46 04 4-	-1. 1		- 00		
Fish Number	20 *	21	22	23	st tempe: 24	25	or <b>-</b> - °C 26	29	
	MINUTES TO DEATH								
1	1_/	1	8828	14525	4203	1298	109	2.4	
2			14108	15545	6933	1533	110	2.5	
3			15548	15545	6933	1546	126	2.5	
14			15548	15545	6933	2928	129	3.9	
5			15908	15545	6933	30148	137	3.9	
6			15998	15545	6933	3048	141	4.3	
7			15998	15545	6933	4188	143	4.6	
8			<b>1</b> 5998	15545	6933	41.88	144	4.7	
9			16988	15545	6933	4188	146	4.8	
50%-10			16988	155 <sup>1</sup> +5	6933	51,48	149	4.8	
11			16988	15545	6933	5448	152	5.0	
12			16988	15545	6933	5448	156	5.4	
13			16988	15545	6933	5448	160	6.2	
14			16988	15545	6933	5448	168	6.5	
, 15			16988	15545	6933	5448	169	6.6	
16			16988	155 <sup>1</sup> <sub>4</sub> 5	6933	5628	180	7.6	
17			16988	15545	7173	5748	183	7.9	
18			16988	15545	7173	5928	188	9.1	
19			16988	15545	8343	6888	194	9.5	
20			17258	15545	8343	6888	196	9.6	

<sup>1/</sup> Solid line indicates no mortality
 Tested July and August 1969
 20 fish per test

Table E.--Individual time to death in minutes of juvenile yearling sockeye salmon subjected to elevated water temperatures for two weeks or until death. Time is when death was noted.

										-
Fish number	12*	17	Tim 20	e to death 21	at test 22	tempera 23	tures of- 24	°C 25	26	29
				MIN	TES TO	DEATH				
1	1	<u> </u>	[	17237	1		260	136	34.9	1.6
. 2				7			265	153	36.2	1.8
3							366	157	53.5	1.9
Ĭţ							<b>2</b> 829	168	55.2	1.9
5							2829	171	55.9	2.0
6							2829	181	56.7	2.4
7							4269	189	60.4	2.4
. 8							4269	198	60.5	2.4
9							4553	200	60.6	2.5
50%10						- 0	5829	205	63.5	2.5
11	-						5829	209	64.3	2.5
12							5829	210	66.1	2.8
13							5829	219	69.5	3.1
14							5829	221	74.7	3.4
15				÷			7239	232	76.4	3.4
16	12		181	,			7239	240	77.6	3.9
17							7239	245	82.9	4.1
18							7239	257	83.4	4.2
19				10			8589	285	84.3	5.4
20							8589	291	85.7	9.0

<sup>1/</sup> Solid line indicates no mortality
 Tested October 1969
 20 fish per test

<sup>\*</sup> Control

Table F.--Individual time to death in minutes of juvenile yearling sockeye salmon subjected to elevated water temperatures for two weeks or until death. Time is when death was noted.

		Time	to des	ath at te	est tempe	ratures	0f°C				
Fish Number	17*	20	21	22	23	24	25	26	29		
namber.	- MINUTES TO DEATH										
1	- <u> </u> <u>1</u> /	2820	7	85	8603	126	33	26	•9		
. 5		2820		4265	8723	353	38	27	•9		
3		1			12323	1371	40	36.3	1.0		
4					13430	2811	48	<b>3</b> 8	1.2		
5			ľ		13445	2811	53	39	1.3		
6					· ;	2811	72	41.5	1.6		
7						2811	73	41.5	1.8		
8		-				2811	75	49.3	2.0		
9					!	2811	98	59.5	2.2		
50%-10						4251.	102	62.3	2.2		
11 -						4251	123	67	2.3		
12						5811	126	68:	2.5		
13			Į.			5811	140	82.5	2.5		
$\mathfrak{I}^{l_{\mathfrak{t}}}$						7221	145	85.8	2.7		
15						7221	149	92.9	3.5		
16						7221	175	95.9	3.5		
17				n		7221	1.86	101.6	4.3		
18 ,						8721	196	106.8	5.0		
19						8571	212	107.3	8.2		
20						, L	386	112.8	8.4		

<sup>1/</sup> Solid line indicates no mortality
 Tested October 1969
 20 fish per test

<sup>\*</sup> Control