Aquaculture, 32 (1983) 183—188
Elsevier Scientific Publishing Company, Amsterdam — Printed in The Netherlands

INCREASED SEAWATER SURVIVAL AND CONTRIBUTION TO THE FISHERY OF CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*) BY SUPPLEMENTAL DIETARY SALT

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(Accepted 13 May 1982)

ABSTRACT

Zaugg, W.S., Roley, D.D., Prentice, E.F., Gores, K.X. and Waknitz, F.W., 1983. Increased seawater survival and contribution to the fishery of chinook salmon (*Oncorhynchus tshawytscha*) by supplemental dietary salt. *Aquaculture*, 32: 183—188.

Addition of sodium chloride (NaCl) to the diet of juvenile fall chinook salmon for 6 weeks prior to release resulted in 65% greater adult recovery in the fishery and return to the hatchery than obtained with controls fed an unsupplemented diet. In a separate study, juvenile fall chinook salmon fed supplemental sodium chloride had significantly higher gill sodium and potassium (Na^+-K^+) ATPase activities and greater survival than controls when transferred directly to seawater net-pens.

INTRODUCTION

Laboratory tests have shown that seawater survival of coho salmon (*Oncorhynchus kisutch*) can be increased by feeding diets supplemented with inorganic salts, especially sodium chloride (NaCl) (Zaugg and McLain, 1969). The beneficial effect of salt feeding toward survival was particularly apparent in fish which had not yet developed seawater tolerance associated with smoltification.

Studies reported here have incorporated salt into hatchery production diets to determine the potential of this practice to increase survival and contribution to the fishery of chinook salmon (*Oncorhynchus tshawytscha*).

METHODS AND MATERIALS

Fall chinook salmon at the Spring Creek National Fish Hatchery (NFH) (Washington) were fed Abernathy dry pellet formulation (Fowler, 1971) from initial feeding (18 December 1975) to 28 February 1976, when two

0044-8486/83/$03.00

coded-wire tagged experimental groups were started on salt supplemented diets. One diet contained added NaCl at 7% (dry wt), and the other a mixture of sodium and potassium chlorides (NaCl at 5% and KCl at 2%, dry wt). Controls were maintained on regular Abernathy dry diet (1.4% NaCl, 0.23% KCl) and coded-wire tagged.

At approximately 2-week intervals (28 February to release on 13 April 1976 into the Columbia River, river km 269) 40 to 70 fish from each control and the two salt diets were examined for survival in artificial seawater. Seawater challenges were performed with 34‰ Instant Ocean salts (Aquarium Systems, Inc., Wycliffe, Ohio[1]) at 11.5°C in 130-liter fiberglass tanks with recirculating pumps and filters. Salt water was changed every 1 or 2 days as needed. Fish were obtained from their respective hatchery ponds and held for 24 h without food before being given identifying fin clips and introduced directly into artificial seawater for 161 h (12, 24 March) or 140 h (1, 13 April). Very few mortalities occurred after 140 h.

In a second study, fall chinook salmon at the Garrison Springs Hatchery (Washington Department of Fisheries) were fed an Oregon Moist Pellet (OMP-2) diet from initial feeding (1 February 1980) until 22 August 1980 when fish in two ponds were started on OMP-2 supplemented with 7.9% (dry wt) NaCl. Two groups of controls in separate ponds were maintained on OMP-2. At 2-week intervals, from 14 August to seawater transfer, 30 fish were taken from each of the four ponds, weighed, measured, and visually assessed for status of smoltification. Gill filaments from each fish were used for determination of gill Na^+-K^+ ATPase activities using a partially purified enzyme preparation (Zaugg, 1982). All four groups were transferred to seawater net-pens at Fox Island (Washington) on 30 September or 1 October 1980.

RESULTS

Results of seawater tolerance tests indicated greater survival of Spring Creek NFH fall chinook salmon fed salt-supplemented diets (Table I) with one unexplained exception (1 April, NaCl-KCl, Table I). Smaller individuals of each group tested, regardless of diet, were less able to survive. As adults, salt-fed groups contributed more to the ocean fishery and to the hatchery return than did controls (Table II).

Fall chinook salmon at Garrison Springs Hatchery fed OMP-2 containing an added 7.9% (dry wt) NaCl showed distinct increases in gill Na^+-K^+ ATPase activity after 4 weeks on the diet (Table III). High enzyme activity in controls suggested that smoltification was occurring at this time. Visual assessment of the relative numbers of parr, transitional, and smolted animals

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[1] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

TABLE I

Seawater tolerance of juvenile fall chinook salmon from Spring Creek National Fish Hatchery

Date (1976) & diet[1]	Days on diet	No. of fish tested	Mean fork length and, in parentheses, + S.D. (mm)			
			Total population	Mortalities	Survivors	Percent survival[2]
12 March						
Control	—	70	66 (8)	65 (7)	78 (5)	6
NaCl-KCl	12	70	68 (8)	66 (6)	80 (4)	11
NaCl	12	40	70 (10)	67 (9)	77 (9)	27
24 March						
Control	—	63	79 (8)	76 (6)	86 (5)	28
NaCl-KCl	24	68	69 (9)	66 (9)	74 (6)	40
NaCl	24	68	70 (9)	67 (8)	76 (6)	35
1 April						
Control	—	64	77 (8)	74 (7)	84 (6)	28
NaCl—KCl	32	59	68 (9)	66 (9)	75 (4)	22
NaCl	32	67	75 (8)	70 (7)	81 (5)	45
13 April						
Control	—	52	78 (8)	76 (7)	88 (5)	15
NaCl—KCl	43	51	74 (10)	68 (8)	81 (7)	45
NaCl	43	52	82 (10)	77 (7)	88 (8)	46

[1] Control diet was Abernathy dry; NaCl diet contained added 7% (dry wt) NaCl; NaCl-KCl diet contained added 5% NaCl-2% KCl (dry wt).
[2] Salt water (Instant Ocean salts) at 34 ppt, 11.5°C for 161 h (12, 24 March) or 140 h (1, 13 April).

TABLE II

Catch and escapement of fall chinook salmon from Spring Creek National Fish Hatchery

Diet[1]	Number of tags released	Size at release (no./lb)	Number of tags recovered in fishery[2]	Return to hatchery	Total catch and escapement	Total increase (%)
Control	102 503	80	170	123	293	—
NaCl- KCl	101 080	87	241	195	436	49
NaCl	94 137	79	269	211	480	64

[1] See Table I.
[2] Actual numbers of tags recovered from salt-fed fish have been adjusted to a release of 102 503 fish for comparison to controls to allow for differences in numbers of fish released. Catch information for 1977, 1978, and 1979 from California, Oregon, and Washington and for 1977 and 1978 from Canada has not been expanded to estimate total contribution.

TABLE III

Effect of supplemental salt on gill Na^+-K^+ ATPase activities of fall chinook salmon from Garrison Springs Hatchery

Date (1980)	Controls[1]		Salt fed[2]	
	Na^+-K^+ ATPase and, in parentheses, S.E.[3]	Mean fork length (mm) and, in parentheses, S.D.[4]	Na^+-K^+ ATPase and, in parentheses, S.E.[3]	Mean fork length (mm) and, in parentheses, S.D.[4]
14 August	31.0 (1.5)	107 (9)	—	—
4 September	28.3 (0.9)	119 (9)	33.2 (1.2)	120 (10)
18 September	35.9 (1.3)	124 (9)	56.6 (1.4)	127 (8)
29 September	35.6 (1.9)	129 (7)	63.7 (1.9)	131 (7)

[1] Diet: Oregon Moist Pellet (OMP-2).
[2] Diet: NaCl added to OMP (7.9% dry wt), started feeding 22 August.
[3] Activity given as μmoles ATP hydrolyzed · mg protein^{-1} · h^{-1} ± standard error; each number represents activities from 60 fish (30 from each pond) combined to make 20 groups of 3 fish each.
[4] Mean fork length of 60 fish ± standard deviation.

TABLE IV

Stage of smoltification, size, and seawater survival of fall chinook salmon from Garrison Springs Hatchery

Experimental group and smoltification stage[1]	Percentage of the population and, in parentheses, length data, by date[2]				Seawater mortality (%)[3]
	14 Aug.	4 Sep.	18 Sep.	29 Sep.	
Controls					16
Parr	6(86 ± 4)	12(106 ± 4)	2(98)	0	
Transitional	56(105 ± 6)	55(117 ± 5)	40(117 ± 7)	23(121 ± 5)	
Smolt	38(115 ± 4)	33(127 ± 7)	58(129 ± 6)	77(131 ± 5)	
Salt-fed[4]					2
Parr	—	10(101 ± 7)	2(110)	0	
Transitional	—	48(118 ± 5)	38(121 ± 7)	20(124 ± 4)	
Smolt	—	42(126 ± 7)	60(131 ± 5)	80(133 ± 6)	

[1] Parr = parr marks distinct; Transitional = parr marks evident but fading; Smolt = parr marks absent.
[2] Sixty fish taken each date; mean fork length (mm) ± standard deviation in parentheses.
[3] Transferred directly to seawater net-pens on 30 September and 1 October 1980. Control population = 28 600; salt-fed population = 25 950. Percent mortality did not change from day 10 to day 30.
[4] Salt diet contained 7.9% (dry wt) added NaCl. Feeding began on 22 August.

(Table IV) supported the Na^+-K^+ ATPase data relative to the onset of smoltification and clearly showed that larger fish underwent smoltification earlier.

DISCUSSION

Activation of physiological processes involved in extrarenal salt excretion resulting from feeding supplemental NaCl to juvenile fall chinook salmon appears to be a practical method of increasing seawater survival for either direct transfers to seawater or for releases to freshwater streams where migration to the ocean follows. Catch and return data from the experiment conducted at Spring Creek NFH and data from the Garrison Springs Hatchery direct transfer study clearly show the benefits of this practice.

There may be instances, however, when salt feeding would have no beneficial effects. Juvenile chinook salmon migrating long distances after release or remaining in fresh water for an extended time may lose the beneficial effect of salt feeding. It is known that gill Na^+-K^+ ATPase activities in seawater-adapted coho and chinook salmon return to normal freshwater levels after about 1 month in fresh water (Zaugg and McLain, 1969). Also, two salt feeding experiments using yearling coho salmon failed to show better returns for salt-fed fish (J. Lagasse, personal communication, 1976). A trial exposing coho salmon to $39^0/_{00}$ salt water showed no difference in survival between salt-fed fish and controls (unpublished observation), suggesting that all of the fish may have developed maximal salt regulatory ability in the absence of added dietary salt, and increasing the level of dietary salt did not induce greater seawater tolerance.

Small decreases in weight gain and diet utilization efficiency in coho and chinook salmon have been observed with salt supplemented diets (Zaugg and McLain, 1969; Westgate et al., 1976). However, Shaw et al. (1975) reported no effect in Atlantic salmon (*Salmo salar*). In the experiments at the Spring Creek and Garrison Springs Hatcheries, differences in weight gains were insignificant between controls and test groups fed diets containing extra salt.

CONCLUSION

On the basis of these studies, the inclusion of additional NaCl at 7 to 8% (dry wt) to diets of fall chinook salmon for 4 to 6 weeks prior to release or transfer to seawater appears to increase survival.

ACKNOWLEDGEMENTS

Funds for the 1976 Spring Creek NFH study were furnished by the Environmental and Technical Services Division, National Marine Fisheries Service, Portland, OR. S. Leek, biologist, U.S. Fish and Wildlife Service, furnished tag recovery information. L. Fowler, U.S. Fish and Wildlife Service, Abernathy Salmon Development Station, assisted in obtaining salt diets for the Spring Creek NFH study. Technical assistance of L. McLain and cooperation of hatchery personnel at Spring Creek NFH and Garrison Springs Hatchery are gratefully acknowledged.

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