SWIMMING ABILITY AND SURVIVAL OF SEAWATER PARR REVERTANT COHO SALMON (*ONCORHYNCHUS KISUTCH*)

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Flagg, T.A., E.F. Prentice, and L. S. Smith. Swimming ability and survival of seawater parr revertant coho salmon, *Oncorhynchus kisutch*.

Abstract

Swimming stamina, stride length, and post-test survival were assessed in seawater for both smolt and parr revertant coho salmon, *Oncorhynchus kisutch*. Parr revertants had lower swimming stamina (-20%), lower stride efficiency (-20%), and greatly reduced 96-h post-test survival (-89%) compared to smolts with the same residence time in seawater.

Introduction

The phenomenon of apparently smolted coho salmon, Oncorhynchus kisutch, regaining external parr-like characteristics after a period of seawater residence is well documented in marine salmonid culture (Mahnken, 1973; Clarke and Nagahama, 1977; Woo et al., 1978; Prentice et al., 1980, 1981; Folmar et al., 1982; Mahnken et al., 1982). Normally the smoltification process in coho salmon culminates with a fully smolted fish that enters seawater and continues development to the adult phase. However, if smolting juvenile coho salmon enter seawater in other than fully smolted condition, normal growth and development is altered, with the fish often reverting to a parr-like state.

Researchers have associated seawater parr reversion with a hypofunctional endocrine-mediated osmoregulatory system and abnormalities in both metabolic and somatic development (Clarke and Nagahama, 1977; Woo et al., 1978; Folmar et al., 1982). Observations at marine culture sites indicate that most parr revertants eventually die from complications related to osmoregulatory failure (Mahnken, 1973; Prentice et al., 1980; Folmar et al., 1982; Mahnken et al., 1982).

Although seawater parr revertants have yet to be noted in natural populations in seawater, both Folmar et al. (1982) and Mahnken et al. (1982) indicated that this phenomenon might occur in the natural environment. Mahnken et al. (1982) further suggested that seawater parr reversion is an unrecognized source of ocean mortality. The preponderance of evidence suggests that these fish are physiologically compromised and would have difficulty surviving in the natural environment. The present study further documents the extent of these physiological compromises and their relationship to survival.

Methods and Materials

Coho salmon used in this study were reared at the National Marine Fisheries Service (NMFS), Northwest and Alaska Fisheries Center, Seattle, Washington, at 15°C and fed intensively to produce underyearling (0^+) smolts. On 12 July 1978, the population was transferred directly to seawater ($\sim$ 29 ppt) net-pens in Puget Sound at the NMFS Marine Experimental Station near Manchester, Washington. After 3 weeks in seawater, approximately 150 smolts (determined using the morphological criteria of Prentice et al., 1980) were segregated from the population. Parr revertants became apparent in this segregated group after 7 weeks of seawater culture. The revertants were removed and tested to compare them with smolts.

Swimming ability for 24 smolts (mean length, 130.5 mm) and 20 parr revertants (mean length, 83.8 mm) was evaluated in a Blaska type respirometer-stamina tunnel similar to but smaller than that described by Smith and Newcomb (1970). This 27.4 l tunnel was modified with a cross-sectional compartment to allow testing of four fish at a time. After an individual fish was anesthetized with MS-222 and fork length determined to the nearest mm, it was placed into a test compartment. After a 1-h recovery period, the initial swimming velocity was set at 1.5 body lengths per second (ℓ/s). The velocity was increased 0.5 ℓ/s every 15 min until fish fatigued and impinged on an electrified screen within the test compartment. Tests were terminated when $\sim$ 50% of the fish in the chamber were fatigued, since the blocking by these impinged fish disrupted the water flow and made further monitoring of fatigue levels unreliable.

Swimming ability was judged on several bases. Swimming stamina, the velocity at which the fish could no longer maintain position and became impinged, was determined for 9 seawater smolts and 10 seawater parr revertants using the methods and U-critical formula described in Beamish (1978). Swimming proficiency was determined for all 24 smolts and 20 parr revertants by visually observing the number of tail beats (tb) per minute over a limited range of swimming speeds, after the methods described by Bainbridge (1958). Tail beat measurements also enabled stride efficiency ($tb/\ell/s$) to be calculated as tail beats required to maintain a unit swimming speed of one body length per second.

After testing, seawater smolts (n = 16; because of space limitations, eight smolts were not observed) and seawater parr revertants (n = 20) were held (unfed) in seawater troughs. Mortality resulting from swimming the fish to fatigue was documented daily to 96-h post-test.

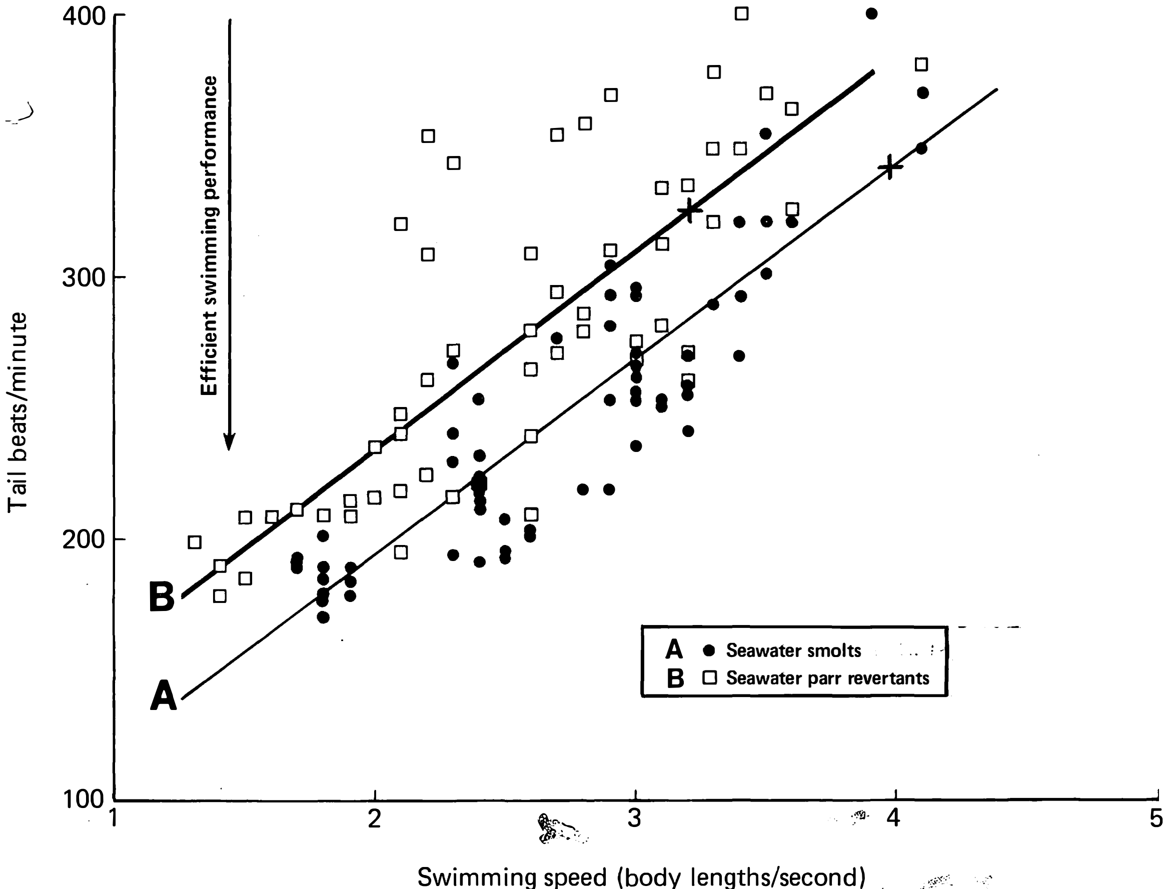
Both the swimming stamina data and stride efficiency data were compared between smolts and parr revertants using the non-parametric Mann-Whitney test. Swimming proficiency profiles of smolts and parr revertants were calculated using standard regression techniques. All data analyses followed the methods of Sokal and Rohlf (1969).

Results and Discussion

It is generally accepted that tail beat frequency increases linearly with swimming speed (Bainbridge, 1958; Beamish, 1978; Stevens, 1979). The present study is in general agreement with a linear model. Differences between swimming proficiency profiles for smolts and parr revertants suggest an overall reduction in swimming proficiency for parr revertants in seawater (Fig. 1). The Mann-Whitney statistical test indicated that both swimming stamina (Table I; $U = 11.0$, $P<0.02$) and stride efficiency ($U = 825.5$, $P<0.00001$) of seawater parr revertant coho salmon are significantly (at an $\alpha = 0.02$ level) reduced compared to smolts with the same residence time in seawater. The mean stride efficiency was 92.9 tb/ℓ/s (range, 75.2-116.1) for smolts and 111.1 tb/ℓ/s (range, 80.4-152.4) for parr revertants, suggesting that parr revertants have a 19.6% lower stride efficiency. The mean swimming stamina was 4.0 ℓ/s (range, 3.5-4.8) for the smolts and 3.2 ℓ/s (range 2.1-3.9) for the parr revertants, suggesting an average 20% decrease in stamina for the parr revertants. The observed reductions in swimming ability of coho salmon parr revertants are believed indicative of physiological compromises.

The physiological reversion to a parr-like state in seawater appears to greatly reduce the ability of coho salmon to survive physical stress. Ninety-four percent (15/16) of the swimming-fatigued smolts survived to 96-h post-test, while only 10% (2/20) of the parr revertants survived after swimming to fatigue, indicating an 89.4% decrease in ability to survive stress. The majority of these mortalities occurred within the first 48 h of the 96-h post-test holding.

Fig. 1. Comparison of swimming ability of seawater parr revertants and seawater smolts of the same residence time in seawater. Regression lines indicate swimming proficiency profiles. Mean swimming stamina for each group is indicated by a (+).



400
300
200
100
1
2
3
4
5
Tail beats/minute
Swimming speed (body lengths/second)
Efficient swimming performance
B
A
A ● Seawater smolts
B □ Seawater parr revertants

While the data presented are for accelerated underyearling (0+ smolting) coho salmon, it is believed that the same relationships exist for yearlings (1+ smolting) since both age classes of smolts show similar smoltification, parr reversion, and critical size patterns (Garrison, 1965; Mahnken, 1973; Clarke and Nagahama, 1977; Mighell, 1979; Mahnken et al., 1982).

Mahnken et al. (1982) presented information indicating that a critical size (growth) path must be maintained to avoid seawater parr reversion. If this growth path is not maintained over time, fish smaller than the largest parr in the population (regardless of external characteristics) will eventually revert to a seawater parr condition. These investigators also present limited data showing the absence in the ocean of coho salmon below this critical size, suggesting that this group dropped from the population. It is their assumption that these fish died either by osmoregulatory dysfunction or predation. They believe that reversion to parr may be a delayed and unrecognized source of ocean mortality for coho salmon. The present paper supports this view, indicating that seawater parr revertant coho salmon have a severely depressed physical stress resistance, and therefore might not long survive in the natural environment. Decreased swimming stamina and efficiency would also increase the probablilty of parr revertants being eaten by predators.

Table I. Swimming stamina (U-critical) and related average stride efficiency for seawater smolts and seawater parr revertants.

	Seawater parr revertants		Seawater smolts	
Observation	U-critical (body lengths/ second)	Stride efficiency (tail beats/body length/second)	U-critical (body lengths/ second)	Stride efficiency (tail beats/body length/second)
1	2.1	152.3	3.5	87.5
2	2.3	117.6	3.7	85.3
3	2.4	111.1	3.8	97.2
4	3.2	118.9	3.8	83.6
5	3.3	107.2	3.9	86.2
6	3.6	113.1	4.0	104.2
7	3.6	108.5	4.1	100.1
8	3.7	129.1	4.2	94.8
9	3.8	99.5	4.8	89.9
10	3.9	135.2	-	-
$\bar{X}$	3.2		4.0	

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