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SWIMMING PERFORMANCE OF ARCTIC CHAR FROM THE
SAQVAQJUAC RIVER, NORTHWEST TERRITORIES

by

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ABSTRACT

Welch, H. E. 1979. Swimming performance of Arctic char from the Saqvaqjuac River, Northeast Territories. Can. Fish. Mar. Serv. Tech. Rep. 854: iv + 7 p.

Swimming performance tests were made on Arctic char (*Salvelinus alpinus*) on location at the Saqvaqjuac River 50 km north of Chesterfield Inlet, NWT. Critical velocity (maximum swimming speed, cm s^{-1} , which could be maintained for 10 min) was equal to (10.19) (fork length $^{0.606}$). The data are compared with previous results for several species from the Mackenzie River, relative to a fish's ability to pass through highway culverts of certain lengths and water velocities.

Key words: highway; culverts; water velocity; fish passage.

RÉSUMÉ

Welch, H. E. 1979. Swimming performance of Arctic char from the Saqvaqjuac River, Northwest Territories. Can. Fish. Mar. Serv. Tech. Rep. 854: iv + 7 p.

Des expériences visant à évaluer la capacité de nage de l'omble chevalier (*Salvelinus alpinus*) ont été effectuées sur place, dans la Saqvaqjuac River, à 50 km au nord de l'inlet Chesterfield (T.N.-0). La vitesse critique (vitesse maximale, cm s^{-1} , pouvant être maintenue pendant 10 mn) s'élevait à (10.19) (longueur à la fourche $^{0.606}$). Nous comparons nos résultats avec ceux d'autres essais qui visaient à évaluer la capacité de diverses espèces du Mackenzie à franchir des ponceaux de grands routes compte tenu de leur longueur et de la vitesse du courant.

Mots-clés: grand route; canale tubulaire; vitesse du courant; passage des poissons.

INTRODUCTION

Highway construction in the Mackenzie Valley and elsewhere in the Canadian arctic entails placing culverts in streams used by migrating fish. Faulty design can result in water flows too rapid to allow upstream fish passage, so when culverts are being designed the swimming performance of the species involved must be considered.

Jones et al. (1973, 1974) determined the maximum velocity that could be maintained for 10 minutes (critical velocity for 10 minutes) on most of the common fish species found in the lower Mackenzie Valley, but did not obtain enough data on arctic char (*Salvelinus alpinus*) to define the relationship between critical velocity and length for that species. Reported herein are more data for char, using the same methodology as Jones et al. (1973, 1974). Their work should be consulted for detailed considerations of apparatus and theory.

Selection of the 10 minute standard for initial velocity was based upon previous work by Brett (1964) and Bainbridge (1960, 1962), who have shown that for 18-30 cm sockeye salmon and rainbow trout, the fatigue curve has three distinct components (Fig. 1), burst, steady, and sustained performances zones. Consideration of the distances traveled by fish in each of these zones shows that fish cannot swim the length of a long culvert in the burst mode even if the water velocity were zero. In the zone of steady performance, the swimming performance varies only 10-15% over a 4x range in fatigue time, for example between 5 and 20 minutes. Jones et al. (1973, 1974) considered that 10 minutes would allow ample time for fish to negotiate a 100 m long culvert at a net headway of about 16 cm/sec. It should be noted that a determination of critical velocity for a given time gives only one point on the fatigue curve (Fig. 1) and that to extrapolate to critical velocities for other times between about 0.5 and 300 minutes, an assumption would have to be made as to the slope of the fatigue curve in the zone of steady performance.

MATERIALS AND METHODS

Determinations were made *in situ* on fish from the "Saqvaqujac" River, about 50 km north of Chesterfield Inlet settlement on the NW coast of Hudson Bay, 16-28 August 1978. Pre-migratory juvenile char <18 cm were obtained by electrofishing slow-flowing rapids, held in a net holding pen in still water, and run within 24 h of capture. Migratory char >18 cm, and several 15-17 cm, were removed from an upstream trap upon their return from the sea 500 m downstream, and placed directly in the swimming chamber. Water temperature ranged between 9.0 and 10.0°C.

The experimental apparatus was essentially the same as used by Jones et al. (1974, 1973). River water was pumped by one or two floating, centrifugal irrigation pumps through 15 cm flexible hose to a 25 cm I.D. x 152 cm long plexiglas tube. A honeycomb of acrylic plastic was placed at the forward end of the tube to eliminate twisting flow, then three layers of 0.6 mesh grid to introduce microturbulence. Dye injections and current velocity measurements showed that the current velocity profile across the chamber was flat.

An electrified (12 V.D.C.) grid at the downstream end provided the stimulus to swim. Water velocity was measured with an Ott microflow meter mounted behind the grid, and calibrated against actual velocities measured ahead of the grid. Water velocity was controlled, somewhat crudely, by varying the pumping speed of one or both pumps, and by placing 3-12 0.6 cm mesh grids against the 15 cm reducing cone at the downstream end of the tube.

In all experiments the fish were introduced into the tube and held for one hour at a water velocity so low that they had to swim very little or not at all (resting on the bottom) to hold position. For fish 20 cm this was 0.14-0.20 m s⁻¹ and for large fish, 0.20-0.55 m s⁻¹. At the end of an hour, the velocity was increased every ten minutes by an amount approximately 0.5 fish length s⁻¹ for small fish, or 0.10-0.15 m s⁻¹ for larger fish, until the fish could or would no longer hold itself off the electrified grid.

Critical velocity (C.V.) was determined as described by Brett (1964):

$$C.V. = V_p + \left[(V_F - V_p) \times \frac{T_F}{T_I} \right]$$

where V_p = penultimate water velocity (cm s⁻¹)

V_F = final water velocity (cm s⁻¹)

T_F = time to fatigue at V_F (s)

T_I = time between velocity increments (s)

The data were fitted to:

$$C.V. = KL^e$$

where C.V. = critical velocity (cm s⁻¹)

K = constant

L = fork length (cm)

e = exponent

RESULTS AND DISCUSSION

Twenty-six determinations of critical velocity are summarized in Fig. 2. In Table 1, the results of Jones et al. (1974) may be compared with the results from this study. Noteworthy are the relatively high correlation coefficient (0.91) for char in the present study, indicating little variability between fish, and the relative magnitude of K and e, which shows that char have slightly higher critical velocities than the next best performers, suckers and walleye (shown graphically in Fig. 3). The differences between char (present study) and walleye and sucker as determined by Jones et al. (1974) are not significant, largely because of the high variances for the latter. The reasons for reduced variability in the Saqvaqujac determinations of critical velocity are unknown. There was very little handling of Saqvaqujac char prior to performance trials, and while one might expect residual physiological effects of electroshock, the variance for small fish is low, suggesting that capture stress had little effect upon swimming performance. In addition to a greater amount of pre-experimental handling (unavoidable), Jones et al. experienced difficulty with spiral flow through their performance chamber, an effect which was eliminated in the present study by the addition of honeycomb at the upstream end of the chamber.

Figure 4, from Jones et al. (1974), shows graphically the relationship between fork length and ability to move 100 m in 10 minutes against a given water velocity, at a net speed of 17 cm/s. Jones et al. (1973, 1974) derived their curve for char from rainbow trout data, with the upper right hand limb of the curve determined by the mean of 11 data points for Mackenzie Valley char, and it appears that the swimming ability of char was overestimated.

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Table 1. Relationship between fork length, weight, and critical velocity for 10 species of Mackenzie River fish.

Species	n	Length range (cm)	Weight range (g)	Condition factor ^a	Weight/length correlation coefficient	Length-velocity regression (V = KL ^e)		Length-velocity correlation coefficient	p-value for correlation coefficient	Remarks
						K	e			
Pike	192	12-62	7-1800	0.66±0.01	0.96	4.9	0.55	0.441	0.001	Regression on 12 C lab. data only-insufficient numbers in other groups.
Walleye	54	8-38	4-500	0.98±0.02	0.94	13.07	0.51	0.004	0.1	Regression on 18-20 C field data- insufficient numbers in other groups.
Grayling	94	7-37	1.5-800	1.03±0.02	0.97	36.23	0.19	0.221	0.02	Includes all groups except 7C lab. data.
	11	21-34	90-500	1.02±0.03	-	91.64	-0.14	-0.104	0.1	
Flathead chub	28	17-30	40-300	0.90±0.02	0.98	6.42	0.67	0.308	0.1	No lab. data-insufficient data for ANCOVA but all data pooled.
Inconnu	22	8-41	4-700	0.80±0.04	0.93	30.3	0.75	0.176	0.1	No lab. data field data pooled after ANCOVA showed no significant group differences.
Longnose sucker	169	4-53	0.5-2200	1.03±0.01	0.96	11.03	0.53	0.787	0.0001	All groups pooled after ANCOVA showed no significant group differences.
White sucker	20	17-37	50-550	1.37±0.21	0.90	10.03	0.55	0.501	0.02	No lab. data-field data pooled after ANCOVA showed no significant group differences.
Burbot	56	12-62	7-1100	0.51±0.01	0.96	30.6	0.07	0.045	0.1	No field data-lab. data pooled after ANCOVA showed no significant group differences.
Humpback whitefish	159	6-51	2-1500	1.09±0.02	0.94	18.2	0.35	0.36	0.0001	All groups pooled after ANCOVA showed no significant group differences.
Broad whitefish	33	6-33	1-500	1.09±0.06	0.97	9.7	0.45	0.50	0.003	All groups pooled after ANCOVA showed no significant group differences.
Char	26	7-41	-	-	-	10.19	0.606	0.91	≥0.01	

^aCondition factor = $\frac{100W}{L^3}$ where W = weight (g), L = length (cm).

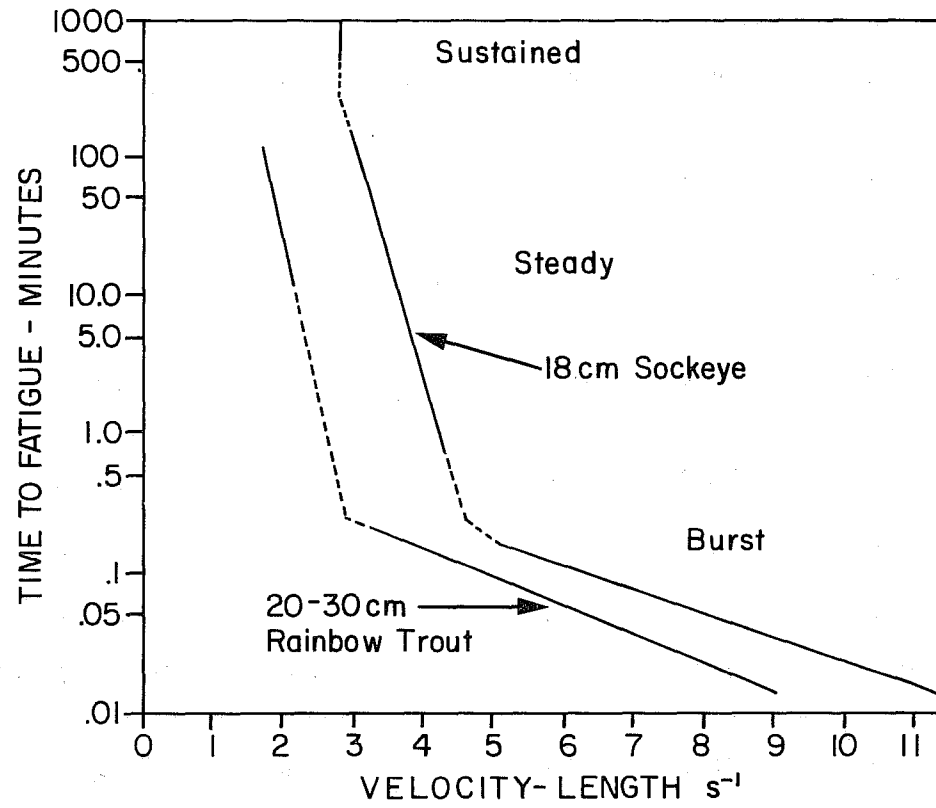


Fig. 1. Fatigue curve for sockeye salmon and rainbow trout (after Brett 1964).

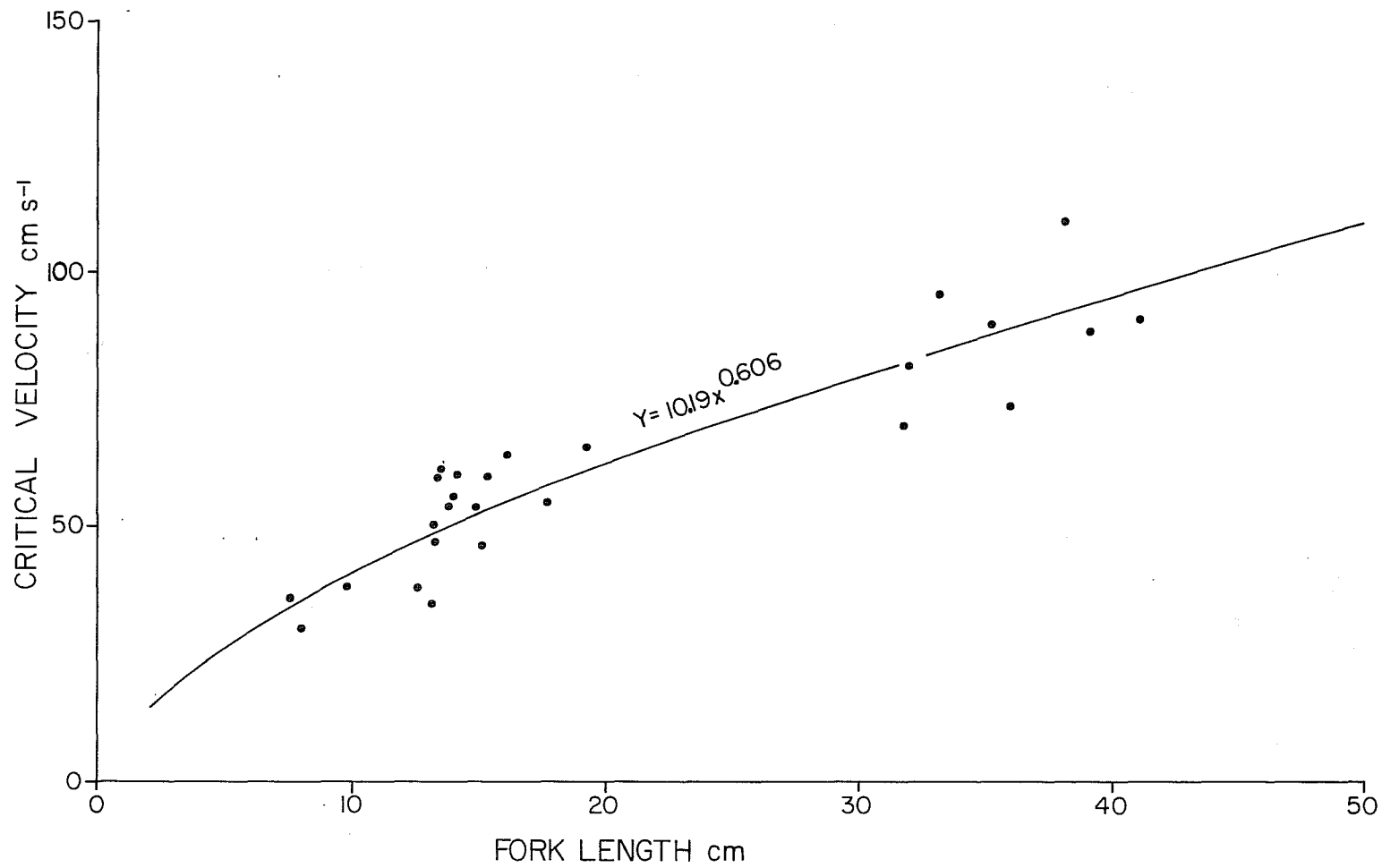


Fig. 2. Critical velocity of Saqvaquac char regressed upon fork length, $r^2 = 0.825$.

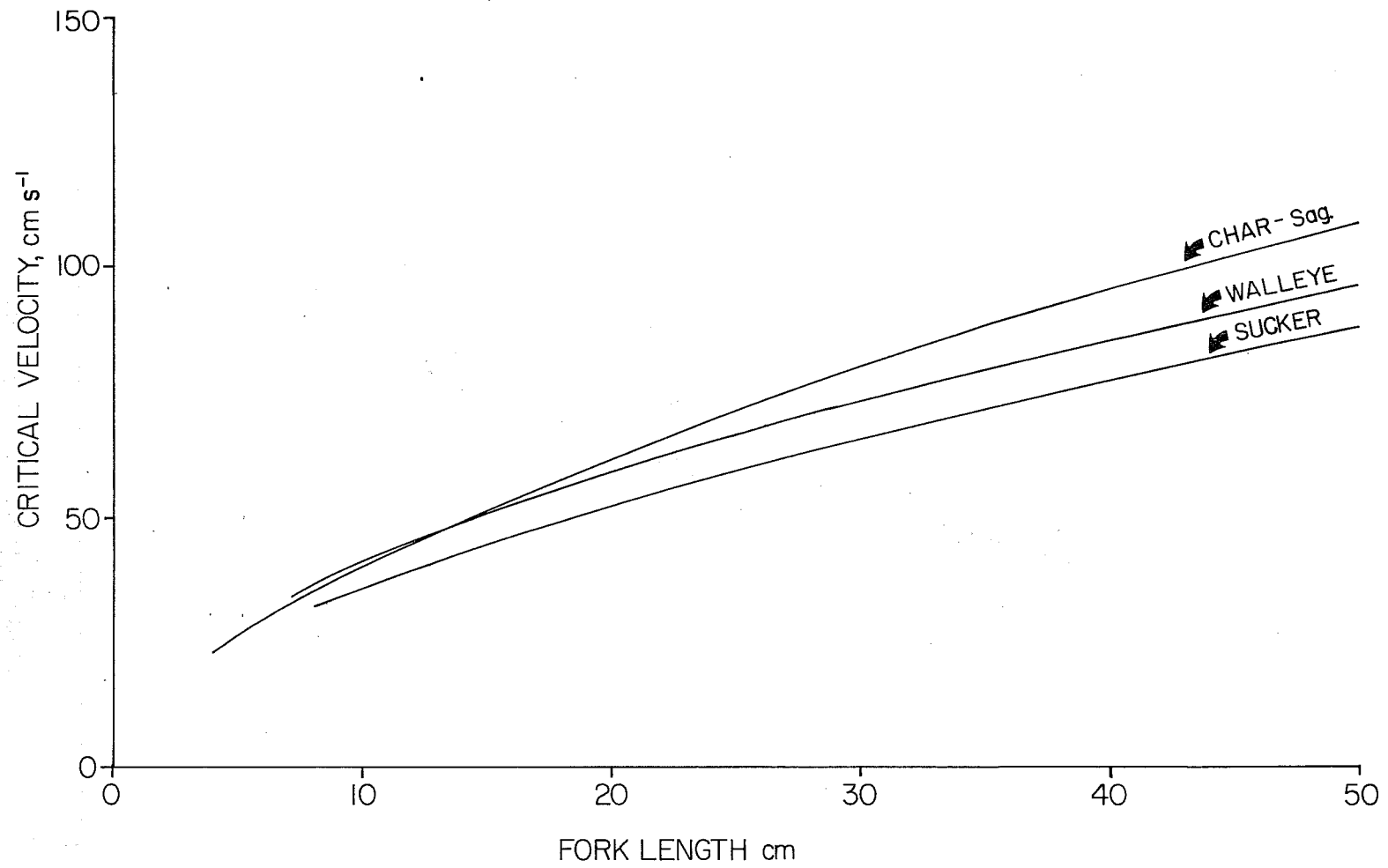


Fig. 3. Critical velocity of Saqvaqjuac char compared with the next best performers in Jones et al. (1974).

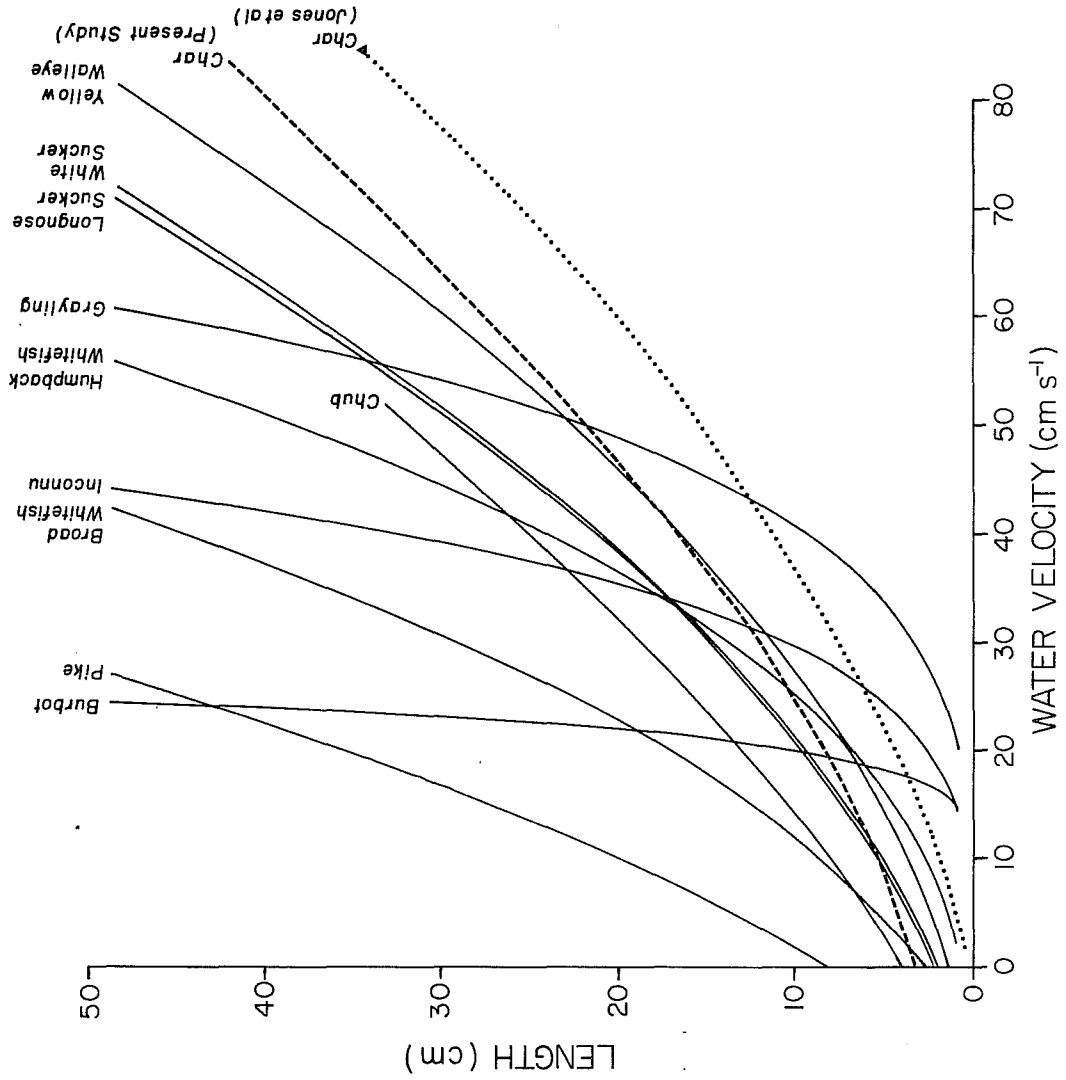


Fig. 4. Length required to pass through a 100 m culvert at a given water velocity at a net speed of 17 cm s⁻¹ (from Jones et al. 1974, with Saqvaquac char included).