FIELD-BASED MEASUREMENTS OF OXYGEN UPTAKE AND SWIMMING PERFORMANCE WITH ADULT PACIFIC SALMON (*Oncorhynchus* sp.) USING A LARGE MOBILE BRETT-TYPE RESPIROMETER SWIM TUNNEL

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Introduction

Studies examining swimming performance have continued to hold the interest of fish researchers since the pioneer work of Brett and co-workers began over 40 years ago (Brett, 1965). However, the majority of such studies have focused on immature cultured fish. The swimming performance of adult wild salmon are limited and have been conducted primarily in a laboratory setting (Brett & Glass, 1973; Jones *et al.,* 1974; Farrell *et al.,* 1998). Only three field-based swimming performance studies involving large salmon have been performed to date (Jones *et al.,* 1974; Williams *et al.,* 1986; Farrell *et al.,* 2001), none of which have measured oxygen uptake (Mo_2) during swimming. Respirometry experiments are restricted either to wild adult salmon after they have been transported long distances to laboratories (e.g., Jones *et al.,* 1974; Williams *et al.,* 1986; Randall *et al.,* 1987; Jain *et al.,* 1998; Farrell *et al.,* 1998) or to adult fish that were hatchery-reared (e.g., Kiceniuk & Jones, 1977).

The paucity of data on both swimming performance and related energetics for adult migratory salmon is clearly a handicap for fisheries managers who make annual predictions of migration success for salmon stocks returning to natal streams. In this regard, a particular problem for fisheries managers is the annual fluctuations in both river water velocity and water temperature that occur during salmon migrations and which create barriers to successful fish passage.

For this situation to be resolved, a respirometer swim tunnel that can be used in the field will be required. Here we outlined the successful development and implementation of a robust Brett-type respirometer swim tunnel that permits field-based measurements of critical swimming performance (U_{crit}) and Mo_2 with adult Pacific salmon up to 3.5 kg in mass. Because the swim tunnel is mobile, it is possible to: perform the measurements at various geographic locations without transporting fish large distances, use different species, and use natal river water at ambient temperature for the tests.

Description of Swim Tunnel

The swim tunnel was constructed to be mobile. It consists of three PVC sections, a PVC expansion chamber (Steffensen *et al.,* 1984) and a Plexiglas swim chamber. When assembled, it holds a water volume of 471.2 L. The swim chamber has a diameter of 25.4 cm (10”) and is approximately 185.5 cm (73”) long. When assembled the trailer is approximately 7 m long and 2.7 m high. Water flow is driven by a 29 cm diameter fiberglass centrifugal impellor pump that is coupled to a 7.5 hp, 208 V, 3-phase, 1200-rpm motor and controlled by a Siemens Midimaster Vector frequency drive (PLAD, Coquitlam, BC). The control unit can be operated manually by varying the frequency of the motor or can be controlled remotely via computer (RS-485 interface). When in operation for long periods of time, the controller assembly and tunnel itself was covered in tarps to minimize unnecessary weathering.

The swim tunnel assembly is housed on a single axle 1,000 kg boat trailer, reinforced with a 7 cm galvanized steel frame. The controller, pump and motor are mounted to an aluminum base plate that is attached to the trailer. During transit, the center of mass of the motor and pump assembly is relocated directly over the rear axle of the trailer by means of a track mounted on to the trailer and 9 cm ball bearing wheels on the base plate. The control unit is removed from the motor-pump assembly during transportation. By using a fiberglass impellor, PVC tubing, galvanized steel framework, and stainless steel and aluminum fittings, it is possible to routinely use seawater in the swim tunnel.

The swim tunnel can be moved in one trip using a full-size three-quarter tonne pick-up truck. Complete assembly requires two people and takes approximately four hours. The main design features the swim tunnel can be found at the following website:

www.sfu.ca/biology/faculty/farrell/swimtunnel/swimtunnel.html

Calibration

Routine calibrations are made whenever the swim tunnel is reassembled. Typically the relationship between water velocity (U) and motor frequency (Hz) is linear up to a maximum U of approximately 160 cm s^{-1}. Water flow is uniform across approximately 85% of the diameter of the swim chamber. At lower velocities variability between the extreme top and bottom of the swim chamber is largest (18% at 40 cm s^{-1}). This variability decreases as velocity increases (5% at 160 cm s^{-1}). The variability between calibrations on different occasions and locations is small (< 1%).

Swimming Performance and Mo_2

Data is shown for Early Stuart sockeye salmon (*Oncorhynchus nerka*), Somass River sockeye salmon, Chehalis River coho salmon (*Oncorhynchus kitsuch*) and transgenic coho salmon. The data illustrates that (a) U_{crit} values for Early Stuart sockeye salmon and Somass River sockeye salmon are comparable to earlier values for Stamp River sockeye salmon (Brett, 1965) (b) Maximum Mo_2 for Early Stuart sockeye salmon is higher than Stamp River sockeye salmon tested by the Brett (1965) at a comparable temperature, and (c) transgenic coho salmon swam more poorly than ocean-ranged coho salmon at a comparable temperature.

TABLE I. Mean temperature, U_{crit} and Max. Mo_2 of adult Pacific salmon species measured at various field locations with a portable swim tunnel.

	Early Stuart sockeye salmon	Somass River sockeye salmon	Stamp River sockeye salmon (Brett, 1965)	Chehalis River coho salmon	Transgenic coho salmon
Temp. (^oC)	13.0 ± 0.2	21.0 ± 0.2	15.0	7.9 ± 0.6	8.6 ± 0.1
N	6	7	9	13	5
U_{crit} (cm s^{-1})	136.8 ± 3.4	123.4 ± 5.1	107.0	96.5 ± 1.9	66.2 ± 5.2
Maximum Mo_2 (mg O_2 kg^{-1} min^{-1})	13.6 ± 0.3	n/a	12.0	8.8 ± 0.3	8.8 ± 0.2

Mean values are presented with S.E.M.

Discussion

These results and comparisons clearly show that reliable respirometry can be performed on wild exercising adult salmon in field locations using a mobile swim tunnel. Thus, by foregoing long transportation times and retaining ambient water quality and temperature when performing field-based measurements, it may be possible to reliably replicate swimming performance and energetics of wild fish *in situ*, and this may be especially valuable for fish that are too fragile for transportation.

The tools are now available to make reliable field measurements of swimming performance and Mo_2 without having to move large adult salmon long distances to laboratories. Implementation of a mobile respirometer swim tunnel should enable future studies to carefully dissect the influences of fish stocks and species, water temperature, reproductive status and sex on swimming performance and migration energetics. In doing so, it may also be possible to assess the effect migration distance may have on salmonids energetics and swimming performance.

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