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A Variable-Speed Swim Tunnel for Testing the Swimming Ability of Age-0 Fish

D. L. WARD*

Arizona Game and Fish Department, Research Branch, 2221 West Greenway Road, Phoenix, Arizona 85023, USA

O. E. MAUGHAN AND S. A. BONAR

Arizona Cooperative Fish and Wildlife Research Unit, U.S. Geological Survey, University of Arizona, Tucson, Arizona 85721, USA

Abstract.—Laboratory swim tunnels are a valuable tool for studying fish physiology and the responses of fish to controlled environmental conditions. We combined aspects of large and small swim tunnels to construct an apparatus that can confine age-0 fish to a specific area while producing a wide range of velocities. We used low-cost plumbing supplies and a centrifugal pump to create a swim tunnel capable of producing velocities from 1 to 66 cm/s. A DC electric barrier and screened knife gate valves prevented fish from leaving the test section. A flowmeter incorporated into the swim tunnel measured water velocity within the apparatus.

Testing the swimming ability of age-0 fish is difficult because body size and swimming ability increase dramatically in a short time. Swim tunnels have been used to assess the quality of fish produced in hatcheries (Thomas et al. 1964; Bams 1967), respiration rates (Beamish 1981; Bernatchez and Dodson 1985), the effects of temperature changes (Griffiths and Alderice 1972; Hocutt 1973; Berry and Pimentel 1985), the movement of fish around water diversion structures (Peake et al. 1997; Toepfer et al. 1999), and the displacement of larval fish in streams (Houde 1969; Meng 1993; Childs and Clarkson 1996). Although many different types of swim tunnels have been developed (reviewed in Beamish 1978), evaluating changes in the swimming capacity of both large and small fish within the same apparatus is difficult. Most juvenile fish are too large to test in gravity-flow swim tunnels designed for larval fish and too small to test in swim tunnels designed for adult fish. We combined aspects of large and small swim tunnels to produce a device that can confine many sizes of age-0 fish to the test section while producing a wide range of nonturbulent velocities.

We constructed the swim tunnel with common aquaculture and plumbing supplies. All plumbing connections were made with aquarium-grade silicone. Silicone forms a watertight seal while allowing easy disassembly for storage and transportation. We used a 0.13-hp (1 hp = 746 W) centrifugal pump (Sweetwater, model SHE 1.7) to circulate water between two 150-L reservoirs. A 50-cm × 7.5-cm acrylic cylinder formed the test chamber. We used commercial water storage boxes as reservoirs. Because the reservoirs are not sealed, inexpensive plastic storage containers would work equally well. We used 3.8-cm bulkhead fittings and 3.2-cm polyvinyl chloride (PVC) pipe to attach the head and tail reservoirs to the centrifugal pump (Figure 1). We regulated water velocity with a 3.8-cm adjustable gate valve on the pump outlet. A 1.3-cm PVC pipe attached to the pump outlet returned water to the tail reservoir and allowed the pump to operate continuously regardless of flow in the test section. We used tank-mount knife gate valves 7.6 cm in diameter to attach the acrylic cylinder to the water reservoirs. Two other 7.6-cm knife gate valves were modified by removing the plastic center and replacing it with a 3-mm-mesh metal screen held in place with silicone. These modified gate valves allowed water to flow through the test chamber while confining fish to the test section. A small section of plastic housing was removed from the downstream valve to allow observers to see when fish became impinged on the downstream screen during swimming tests.

A Marsh-McBirney model 201D flowmeter (Marsh-McBirney, Inc., Frederick, Maryland) fixed near the exit of the swim chamber measured water velocity to within 1 cm/s. Water velocity often increases near the exit of an enclosed pipe, so the acrylic tube extended 20 cm into the tail reservoir to prevent artificially high velocity readings. We cut a hole in the top of this extension and inserted the flowmeter to continuously measure water velocity in real time within the test

* Corresponding author: dmward@theriver.com

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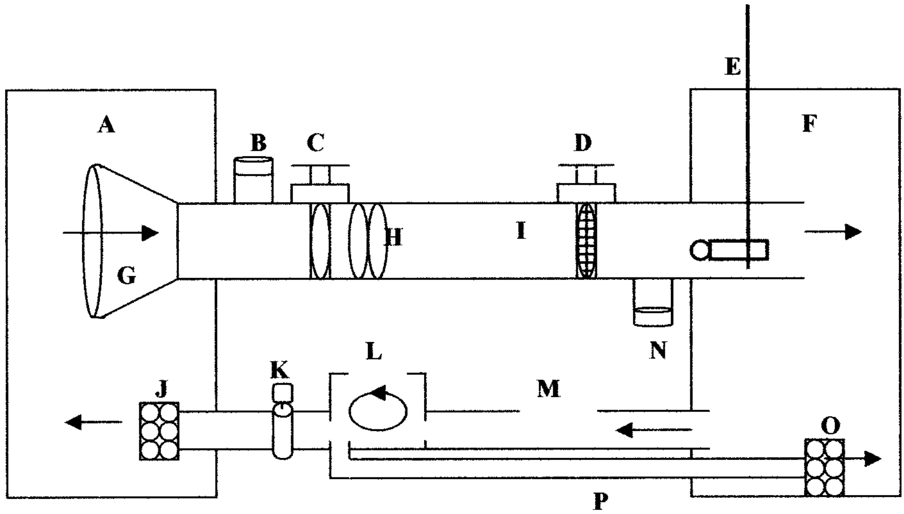

FIGURE 1.—Side view schematic diagram of the apparatus used to measure the swimming ability of age-0 fish. Abbreviations are as follows: A = 150-L head reservoir, B = 2.5-cm fish entry port sealed with an expansion plug, C and D = 7.6-cm screened knife gate valves, E = Marsh-McBirney flowmeter, F = 150-L tail reservoir, G = contraction cone made from 15-cm plastic funnel, H = 1−7-V DC electric barrier, I = 50-cm × 7.5-cm acrylic cylinder forming the test section, J and O = turbulence diffusers for garden hoses, K = 3.8-cm adjustable gate valve, L = 0.13-hp centrifugal pump, M = 1.3-cm polyvinyl chloride (PVC) water return pipe, N = 2.5-cm fish removal port sealed with an expansion plug, and P = 1.3-cm PVC pressure release pipe.

section. We timed the passage of dye through the swim chamber to verify rectilinear flow and the accuracy of flowmeter readings. Fish placed within the swim tunnel were not observed to favor one location over another, giving additional evidence that the velocity profile within the test section was uniform.

Turbulence within the test section was minimized by placing the top portion of a plastic funnel at the entrance to the swim chamber to form a contraction cone. Contraction cones minimize the formation of a turbulent boundary layer where constrictions to water flow occur (Bell and Terhune 1970). Irrigation diffusers commonly used on garden hoses were attached to the pump outlet to minimize turbulent flow within the reservoirs. The large volume of water within the system also helped to prevent cavitations within the tail reservoir and provided sufficient thermal mass to prevent fluctuations in water temperature during testing.

Fish were introduced and removed from the swim chamber through 7.6-cm × 2.5-cm plastic sewer drains positioned above and below the test section. We used expansion plugs to seal openings following the entry or removal of fish from the swim chamber. Fish were prevented from leaving the test section by an electric barrier on the upstream end of the cylinder and an electrified screen on the downstream end. During testing, the upstream screen was raised to remove all obstacles to flow and prevent turbulence within the test section. Experimentation revealed that screens left in place on the upstream end of the test section create a turbulence eddy in which small fish are able to avoid swimming. To avoid this problem and prevent fish from leaving the test section, two rings of copper wire were attached to a variable (1–30-V) DC power supply (Figure 2). The power supply transformed AC from the wall into a variable DC. Pilot tests revealed that 5–7-V DC was sufficient to keep fish from leaving the test section. Fish that attempted to swim through the electric barrier were briefly stunned and forced back into the test section by the flowing water. This same type of barrier could not be used on the downstream end of the test section because stunned fish would be swept into the tail reservoir. The downstream screen remained in place during testing because turbulence created behind this screen did not alter flow within the test section. We applied electricity to the downstream screen as needed to keep fish from resting against it as they began to fatigue. When a fish stopped swimming, we manually disconnected the power to prevent the death of the fish from continued electric shock.

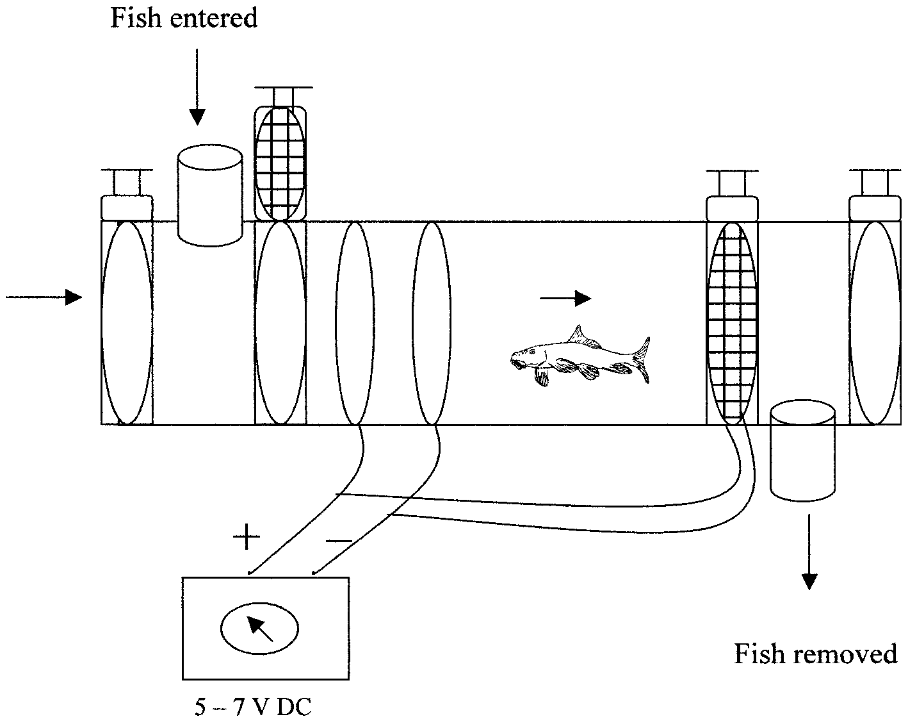

FIGURE 2.—Side view schematic diagram of the test section showing the position of fish during testing and electric barriers that keep fish from leaving the test section and prevent them from resting on the downstream screen.

Results and Discussion

Common aquaculture and plumbing supplies can be used to construct swim tunnels for specific research purposes. While the open-reservoir design of our swim tunnel does not allow respirometry measures, our swim tunnel is well suited for addressing common questions concerning hatchery fish. We have used this design to compare hatchery-reared fish with wild fish, assess the impacts of marking techniques on swimming ability, and determine the size at which small fish can be stocked into lotic environments without being displaced. Our swim tunnel can produce nonturbulent flows of 1–66 cm/s and effectively confine fish of 20–120 mm TL to the test section. The combination of DC electric barriers and screened knife gate valves was effective in confining both large and small fish to the test section while maintaining a nonturbulent flow. This type of swim tunnel allows a wide size range of age-0 fish to be tested in a single apparatus and permits evaluation of changes in swimming ability during critical early life stages.

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