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Evaluation of a New Baffle Design for Solid Waste Removal from Hatchery Raceways

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Abstract.—A modification of the Boersen–Westers baffle system for low water flows was evaluated. No differences occurred in growth or in the parameters of the health-and-condition profile of rainbow trout (*Oncorhynchus mykiss*) held in raceways with or without baffles. Distribution of dissolved oxygen in the raceways was similar in control raceways and those with baffles. Mortality was significantly higher in raceways without baffles (4.6%) than in baffled raceways (3.7%), although the strength of the association was weak. Observations during midday indicated no agonistic behavior among the fish in either the control raceways or baffled raceways.

Boersen and Westers' (1986) design for removing waste feed and feces from hatchery raceways incorporates a series of physical barriers across the width of a raceway; a space between the bottom of each barrier and the raceway floor increases the velocity of water flow along the floor. The area of the opening depends upon the flow, and it is set to force bottom currents of 0.24–0.30 m/s, the minimum velocities required to move solid waste (Burrows and Chenoweth 1955). Lower velocities do not move waste adequately, and higher velocities break up the waste, reducing its settling ability (Boersen and Westers 1986).

At low water flows, a rectangular opening between the bottom edge of the baffle small enough to maintain the desired velocity will not permit fish to move between compartments. A different design for the bottom margin of the baffle is presented in this report.

A variety of methods could be used to reduce the nuisance of handling baffles. Hinges could be used, for example. Boersen and Westers (1986) suggested creating slots in the raceway walls to hold the baffles or attaching deadbolts to the baffles that would slide into holes drilled in the raceway wall. However, retrofitting an existing raceway with drill holes in the wall below the water line or with slots presents several difficulties. When an outdoor raceway was not in use during winter, water in drill holes can freeze and break up the concrete. Slots mounted in a raceway can interfere with crowding screens and their installation is costly and time-consuming. Slots are most appropriate when they can be recessed in a raceway wall during construction. A different design for mounting baffles without drilling holes below the water line is presented in this paper.

Boersen and Westers (1986) observed no adverse effects on fish from baffles; however, they did not conduct actual tests. Kindschi et al. (1991) found that the Eagle Lake strain of rainbow trout (*Oncorhynchus mykiss*) had better dorsal fin condition in baffled raceways, which took less time to clean; however, feed conversion was better in the control raceways.

This report describes results of investigations into the effects of baffles on fish growth and other physiological parameters of the health-and-condition profile developed by Goede and Barton (1990), on oxygen concentrations in different portions of the raceways, and on fish behavior.

Methods

Experimental design.—Baffles were installed in two raceways and two other raceways served as controls. The spacing between the baffles was the same as the width of the raceway, as recommended by Boersen and Westers (1986). The four identical concrete raceways, 1.22 m wide × 11.58 m long × 0.57 m deep, were stocked on 10 January 1991 with equal weights of the Fish Lake–DeSmet strain of rainbow trout. Stocking densities were about 2,500 fish per raceway, and the average fish weight was 20 g. Fish were fed a commercial trout diet. Temperatures of 16–17°C and flows of 388–442 L/min were maintained throughout the experiment. The flow index (Piper et al. 1986) ranged from 0.025 to 0.032 kg/(L/min) per centimeter of fish length, or 53–68% of the maximum loading rate. The density index (Piper et al. 1986) ranged from 1.19 to 1.72 kg/m^3 per centimeter of fish length, or 38–54% of the maximum allowable density.

Twenty fish per treatment (10 fish from each raceway) were sampled monthly to evaluate possible physiological effects on the trout by means

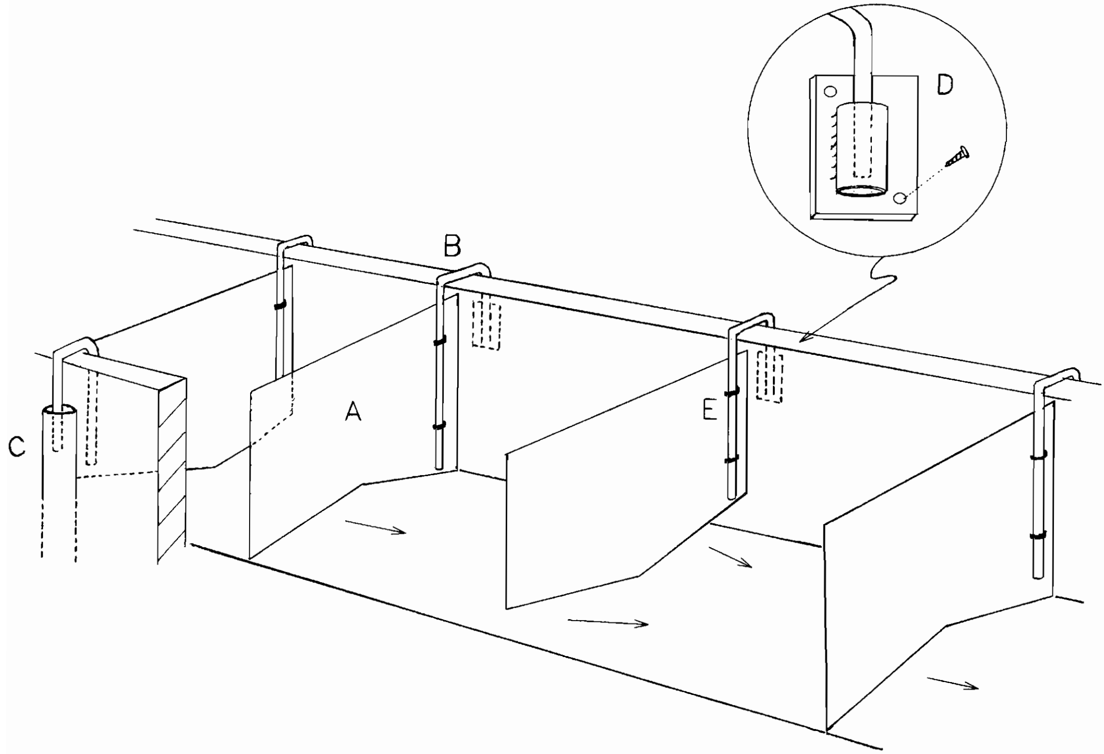

FIGURE 1.—Diagram of baffle configuration and components: (A) 2-mm aluminum baffle; (B) 13-mm reinforcement bar; (C) steel pipe driven into the ground; (D) steel pipe welded to metal plate and bolted to concrete wall; (E) U-bolt or wire. C and D show alternative ways to anchor the baffle in place. Note alternating profile of lower baffle margins and arrows indicating water flow pattern.

of the health-and-condition profile (HCP) developed by Goede and Barton (1990). In addition to the HCP sample, 70–200 fish per raceway were sampled at the same time to calculate mean weight. To capture the sample, fish were crowded to the head end of the raceway and netted out of the churning mass. Removal of baffles for sampling took about 10 min.

To avoid observer bias, I made all the observations for each necropsy and a second person recorded them. To avoid any scoring bias, I examined the fish without knowing which fish belonged to a particular treatment. A third person collected the fish for the sample and informed me of their origins only after the HCP was completed.

Mortality was recorded for each of the raceways. The experiment ended after 147 d, on 6 June 1991, when the fish reached a mean weight of 104 g.

On 25 April 1991, dissolved oxygen (DO) concentrations were measured at the head, center, and foot of each raceway. Measurements with a portable oxygen meter (YSI Inc., Yellow Springs, Ohio) were made just under the water surface and just above the raceway floor at each location.

Baffle design.—The baffles were constructed of 2-mm-thick aluminum and cut slightly wider than the raceway. When installed, each baffle was bowed slightly upstream to fit snugly in the raceway, which helped to keep it in place and to direct the flow of the water under it. The bottom margin of the baffle was cut, as shown in Figure 1, to form either a broad V or an inverted V; baffle shapes alternated down the raceway. The area of the triangular space(s) beneath each baffle was equal to the area required to concentrate the current enough to remove the waste.

To hold the aluminum sheet in place, two reinforcement bars (re-bars, 13 mm in diameter) were bent to form a squared-off J, attached with wires or U-bolts upside down to the sides of the sheet, and hooked over opposite raceway walls. One of two designs can be used to hold the baffles rigidly in place. The simplest is to drive a steel pipe into the ground next to the baffle; the re-bar fits into this pipe. The other method is to weld a

TABLE 1.—Summary of monthly mean sample weights (N = 75–200) and health-and-condition profile data (N = 20) for rainbow trout from control raceways without baffles and raceways with baffles.

Measure	Control raceways					Baffled raceways				
	30 Jan	4 Mar	29 Mar	29 Apr	4 Jun	30 Jan	4 Mar	29 Mar	29 Apr	4 Jun
Weight (g)	68	83	101	114	116	67	81	101	109	123
Condition factor[a]	1.18	1.13	1.22	1.12	1.10	1.14	1.16	1.22	1.18	1.15
Hematocrit (%)	46	44	46	42	41	46	44	42	42	46
Leucocrit (%)	1.0	1.3	0.9	1.2	1.5	1.2	1.1	1.1	1.1	1.8
Plasma protein (g/dL)	3.1	1.9	2.9	2.2	2.1	2.9	2.7	3.0	2.6	2.0
Eye (% normal)	100	85	85	60	60	100	100	85	85	75
Gill (% normal)	100	100	100	90	95	100	100	100	100	100
Pseudobranch (% normal)	95	95	100	90	100	100	95	95	95	95
Spleen (% normal)	100	100	100	90	85	100	100	90	90	85
Liver (% normal)	100	100	100	100	85	100	100	95	90	95
Thymus (% normal)	80	75	75	80	95	85	70	75	65	95
Hindgut (% normal)	100	100	100	85	100	95	100	100	95	100
Bile index[b]	0.2	0.5	0.5	1.5	1.6	0.3	0.5	0.6	1.6	0.8
Fat index[c]	3.0	3.1	3.1	3.3	3.5	2.9	2.9	3.0	3.0	2.8
Fin condition index[d]	0.9	1.9	1.9	1.8	1.9	1.0	1.7	1.7	2.0	2.0

[a] $K = 10^5 \times \text{weight/length}^3$.
[b] The bile index ranges for 0 (recent feeding) to 3 (starvation).
[c] The fat index ranges from 0 (no mesenteric fat) to 4 (abundant fat).
[d] The fin index ranges from 0 (intact) to 2 (badly damaged).

short section of steel pipe to a metal plate, which is bolted to the outside of the raceway. The diameter of this short section of pipe must be large enough to accept the re-bar easily.

Observations of agonistic behavior.—A video camera was used to film fish in all the raceways. Behavior was sampled by Altmann's (1974) focal-animal technique to determine whether baffles in raceways influence agonistic behavior. The specific behaviors I looked for were nipping, charging, chasing, frontal display, lateral display, and fleeing, as described by previous researchers (Stringer and Hoar 1955; Kalleberg 1958; Keenleyside and Yamamoto 1962; Noakes 1980).

The length of time each fish could be observed was limited by the field of view of the camera, so observation time was recorded for each fish. Observation time varied from 30 to 279 s/fish. Altogether 60 min of observations were made: 30 min for control raceways and 30 min for baffled raceways.

Statistical analysis.—Chi-square analysis (likelihood-ratio statistic; SAS Institute 1988) was used to test for homogeneity of proportions of mortality, fin condition, fat levels, and liver and eye abnormalities between baffled and control raceways. The strength of association between mortality and baffles in raceways was determined from the odds-ratio statistic (Fienberg 1989). For fat levels, frequencies for the 3 and 4 index categories were combined before analysis. Since the number of agonistic displays or actions was zero for both treatments, statistical analysis of the behavioral observations was not warranted. Similar homogeneity in HCP data also made statistical analysis unnecessary for certain parameters, such as the spleen. Feed conversions (feed weight fed/fish weight gained) were calculated for both raceways of a treatment (i.e., only one value per treatment), so statistical analysis was not performed.

Results

Fish in control and baffled raceways had similar mean weights and parameters of the health-and-condition profile (Table 1). There were no significant differences in fin condition, fat levels, and liver and eye abnormalities between fish in baffled raceways and controls. Fin condition was equally poor for fish raised in either system. Eye abnormalities were principally blindness and orbital emphysema caused by nitrogen gas supersaturation of the well water (110%; Poston et al. 1973). Spleen abnormalities were all enlargements, and liver abnormalities were entirely fatty livers characterized by a "coffee-with-cream" color. The kidney and opercle parameters were 100% normal for each sample in both treatments.

The alternating bottom profile of the baffle moved waste out of the raceway effectively; however, no additional effort was required to clean waste from the control raceways. All raceways were scraped clean during monthly sampling when the fish were crowded to the head of each raceway. Daily cleaning was performed by pulling out the standpipe and dropping the water level. Slightly more filamentous algae grew on the walls of race-

TABLE 2.—Dissolved oxygen concentrations (mg/L) at three locations and two depths in two control raceways without baffles and two raceways with baffles.

Location and depth	Control raceways		Baffled raceways	
	1	2	1	2
Head end				
Shallow	7.5	7.0	7.2	7.3
Deep	7.7	7.0	7.2	7.4
Center				
Shallow	6.3	5.6	6.0	6.4
Deep	6.4	5.5	5.9	6.6
Foot end				
Shallow	5.4	5.6	5.3	5.5
Deep	5.3	5.4	5.1	5.6

ways with baffles than on the walls of control raceways. Mortality was greater in control raceways (4.6%) than in baffled raceways (3.7%; $P = 0.03$, $G^2 = 4.91$), although the strength of the association was weak ($\alpha = 1.009 \pm 0.008$). Feed conversions were similar in baffled raceways (1.62) and control raceways (1.69).

Dissolved oxygen (DO) concentrations did not differ between depths in raceways with baffles or without them (Table 2). At different locations along the axis of the raceway, DO concentrations did not differ between baffled and control raceways.

No agonistic interaction or territorial behavior was observed in either baffled or control raceways. Fish movement into and out of the camera's field of view suggested that fish commonly moved among compartments of the baffled raceways. Similar fish movement was observed in the control raceways. Fish tended to congregate in the compartments downstream from the baffles that directed flow to the center of the raceway. Most of the fish in these compartments occupied high-velocity areas, and faced upstream; the remainder swam about the low-velocity areas without orienting themselves to the current.

Discussion

The similarity of oxygen concentrations near the surface and bottom in the baffled raceways indicates adequate mixing and, thus, a water quality in the compartments similar to that in control raceways.

The lack of observed agonistic behavior in both control and baffled raceways may have been due to the time of day in which observations were made. The videos were recorded during midday, when sunlight was optimal for filming. Territorial behavior might be expected to be greater during the morning when fish regain territory after being inactive during the night (Stringer and Hoar 1955; Kalleberg 1958). It is also possible that aggressive interactions are more frequent during morning and evening feedings (Keenleyside and Yamamoto 1962; Noakes 1980). Despite possible diel variation in agonistic behavior, territorial behavior should still have been present at midday. No fish was observed defending a territory in either treatment. Higher densities may have influenced behavior, reducing territory size or eliminating territorial behavior entirely (Kalleberg 1958; Keenleyside and Yamamoto 1962; Whoriskey and Fitzgerald 1987). Densities of rainbow trout in this study were 309–312 fish/m^3.

Lack of agonistic behavior was not consistent with the poor fin condition observed. Abbott and Dill (1985) attributed erosion of dorsal and caudal fins to aggressive nipping after the authors observed pairs of juvenile steelhead (*Oncorhynchus mykiss*). It is possible that other factors such as nitrogen gas supersaturation (Stroud et al. 1975) may influence fin erosion, although results of tests here at the Fisheries Experiment Station (Wagner, unpublished data) showed no improvement in fin condition in raceways where nitrogen gas was stripped by oxygen injection. Bacterial infection (Bullock 1968) and nutritional deficiencies (Halver 1954; Ketola 1983) have also been implicated in fin erosion problems. Fin nipping may also be incidental to feeding, given the density of fish in the raceways. No improvement in dorsal fin quality of fish in baffled raceways was observed in this study. Further observations of agonistic behavior in the raceway environment are needed.

The lack of any effect of the baffles on growth or parameters of the health-and-condition profile (Goede and Barton 1990) was similar to the findings of Kindschi et al. (1991). In the present study, mortality was statistically higher in control raceways, but the difference is probably not biologically significant. Kindschi et al. (1991) observed no difference in rainbow trout mortality between baffled and unbaffled raceways other than a mass suffocation that occurred when a duck frightened the fish to the foot of a baffled raceway. Domestic rainbow trout in one of the baffled raceways were visited by herons in the spring, as evidenced by a dead heron found trapped under the screen cover. Although herons probably visited the other raceways, no mass mortalities occurred.

Kindschi et al. (1991) noted that feed conversion was more efficient in control raceways, but no differences were observed in this study.

The lack of any negative effects indicates that fish culturists could find baffles a useful tool for eliminating wastes. In this study, however, no additional effort was necessary to remove waste from control raceways. If waste solids are not flushed by the standpipe removal method, baffles will collect the solids at the end of the raceway where they can be removed mechanically (Boersen and Westers 1986). Baffles may also benefit rearing units where waste movement is inadequate.

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