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Embryo Survival and Fry Emergence from Two Methods of Planting Brown Trout Eggs

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ABSTRACT

Survival of larval trout through the swim-up stage was determined for eyed eggs of brown trout (*Salmo trutta*) planted both in the streambed and in Whitlock Vibert boxes. Tests were made in first-, second-, and third-order streams and intragravel environmental factors were evaluated. Direct plants produced 2 times more sac fry than box plants and 3.5 times more swim-up fry. Sediment deposition was approximately 100% greater in first- and second-order streams than in third-order streams, and sediments accumulated disproportionately in box plants. This seemed to account for survival differences between planting techniques and among stream orders.

Egg planting is recommended to sportsmen's groups as the most effective way to introduce, re-stock, or supplement populations of stream salmonids. This is surprising, and perhaps unwise, considering the decided lack of field studies on the relative success of fry and fingerling introductions and various egg-planting techniques.

Results from a recent study (Harshbarger and Porter 1979) indicated that the box plants were less suited for introducing eggs into stream gravels than direct plants because they seemed to encourage sediment deposition and fungal growths on eggs. Survival to swim-up was very low for both types of plants, but this may have been due to an unusually harsh winter. To determine if these findings were typical of the particular techniques employed, another study was established. As before, this study was designed to compare survival of brown trout (*Salmo trutta*) eggs and embryos to swim-up fry from direct intragravel plants and boxes. It differed from the previous study in that (1) four streams of three orders (Strahler 1957) were used instead of one; (2) all box plants were in two-compartment Whitlock Vibert (WV) boxes (Federation of Fly Fishermen 1975); (3) an attempt was made to quantify intragravel permeability, dissolved oxygen, and apparent velocity which are known to influence survival of salmonid eggs, embryos, and emerging fry; and (4) the composition of substrates was determined.

METHODS

In the fall of 1977, tributaries to the South Mills River in Transylvania County, North Carolina, were surveyed for potential egg-planting sites on the basis of suitable spawning-size gravels, apparent subsurface flow, and protection from freezing. Clawhammer Creek, a third-order stream with first- and second-order tributaries, was selected for egg planting, as was Poplar Creek, a nearby second-order stream, which contained known brown trout spawning sites. All planting locations had similar gravel size and topographic features.

At each of the four locations, 10 sites were prepared by digging depressions 1 m in diameter and 25 cm deep in the streambed with a potato rake. During the first week in December, five plants of two WV boxes each containing 500 eyed eggs and five direct plants of 2,000 eyed eggs each were randomly assigned to the prepared sites, for a total of 40 WV boxes and 20 direct plants. All sites were marked for later sampling. Measures of intragravel dissolved oxygen, permeability, and apparent velocity were obtained by using Mark VI standpipes (Terhune 1958) placed 10 cm behind a WV box plant and a direct plant at each location. Ryan Model J Thermographs[1] were used to monitor

[1] Mention of trade names does not constitute an endorsement by the USDA or the U.S. Forest Service.

Table 1. Mean number and percentage of hatching success and emergent fry from sites planted with eyed, brown trout eggs in Whitlock Vibert boxes and direct plants in first-, second-, and third-order streams.

Stream order	Whitlock Vibert boxes: Number examined	Survival: Number	Survival: Percent	Survival: SD	Direct plant: Number examined	Survival: Number	Survival: Percent	Survival: SD
				Hatching success				
1	6	29.8	6	31.1	2	517.0	26	132.9
2	13	83.5	17	112.1	4	780.2	39	404.4
3	6	122.8	25	168.0	2	398.0	20	45.2
All sites	25	80.1	16	116.0	8	618.9	31	323.6
				Emergent fry				
1	4	17.2	3	19.9	2	170.9	9	98.6
2	6	41.2	8	48.4	2	978.0	49	441.2
3	2	69.0	14	38.2	1	211.0	11	0.0
All sites	12	37.8	8	40.6	5	584.5	29	421.2

water temperatures at the gravel-water interface at each planting location. To estimate the number of fry leaving the gravel, two planting sites of each type were randomly selected at each location and enclosed with fry traps (Phillips and Koski 1969).

Eggs hatched in the first week in January. Three box plants (six WV boxes) and three direct plants were excavated at each location to count sac fry. Dislodged eggs and alevins were collected in a semicircular fine-mesh seine placed immediately downstream from the excavation.

Fry emergence began the last week in March and was essentially completed by April 5. After swim-up, size composition of the substrate was quantified with a streambed core sampler (McNeil and Ahnell 1964) at two box plants and two direct plants at each location. Five additional samples were randomly collected from the planting area of each location. Samples were sieved wet through standard sorting screens. Each fraction was weighed and its volume determined by water displacement.

Results and Discussion

Performance

Only 16% of the eggs in WV boxes hatched compared to 31% for direct plants (Table 1). High water in early March washed out the fry traps over four WV boxes and three direct plants. Data on fry leaving the gravel were based on the remaining traps. Survival of swim-up fry from eggs planted directly into the gravel was 3.5 times greater than that from WV box plants. In WV boxes, survival of sac fry and swim-up fry was greatest in the third-order stream, intermediate in the second-order streams, and lowest in the first order. For eggs planted directly into stream gravels, survival was greatest in second-order streams. Numbers of swim-up fry were very similar from direct plants in the first- and third-order streams. Chi-square tests for heterogeneity showed that there was a highly significant difference ($P < 0.01$) in the mean number of sac fry produced and in the mean number of swim-up fry from WV boxes and direct plants, independent of stream order. The observed ratios of performance for WV vs. direct planting were:

Hatching success	1:1.9
Preemergence fry mortality	1:1.0
Fry entrapment	1:0.25
Emergent fry	1:3.5

Temperature

Water temperature did not seem to be responsible for the observed differences in survival in box vs. direct planting. Minimum water temperature in the second-order tributary of Clawhammer Creek was typical of temperatures in all streams for the period from egg planting to fry emergence (Fig. 1). Although minimum temperatures in the first-order stream ranged between 0.5 and 4.0 C, there was no evidence that any planting site froze or that freezing contributed

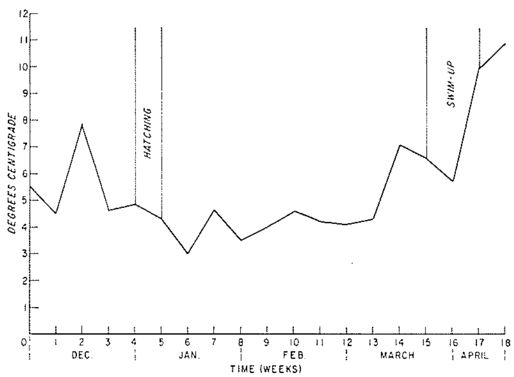

Figure 1. Weekly minimum water temperature in the second-order tributary of Clawhammer Creek during the intragravel residency of planted, eyed brown trout eggs.

to the low numbers of fry that ultimately emerged.

Intragravel Environment

Early March flooding displaced many of the Mark VI standpipes precluding further intragravel environmental measurements. However, based on standards established for dissolved oxygen (Silver et al. 1963), permeability (Coble 1961), and apparent velocity (Shumway et al. 1964), intragravel parameters appeared adequate for survival of brown trout eggs and sac fry in both WV box and direct plants (Table 2). Unless unusual conditions prevailed after the last measurements were taken, the intragravel environment was adequate for fry survival. A concurrent study showed that these intragravel parameters seldom limited survival of eggs and fry in this particular stream system (Dechant 1979).

Table 3. Mean percentage of composition by weight of substrate in core samples, by particle size class, obtained from 16 planted and 20 adjacent unplanted sites after fry emergence.

Particle size class (mm)	Planted sites		Unplanted sites	
	Mean	SD	Mean	SD
>25.4	47.58	11.84	49.42	12.36
4.76–25.4	18.75	5.51	24.75	4.79
0.84–4.76	21.78	10.36	13.08	4.32
0.42–0.84	6.92	3.20	7.67	4.44
<0.42	3.75	1.42	5.42	3.45

Substrate Analysis

Fines (particles < 0.83 mm) alter permeability (McNeil and Ahnell 1964) and, in excess of 20% by volume, they have been found to affect the survival of coho salmon (*Oncorhynchus kisutch*) eggs and preemergent fry (Koski 1966; Hall and Lantz 1969). At all our planting locations, composition of fines (<0.83 mm) in artificial redds and nonredds was similar (Table 3). A *t*-test indicated that there was no significant difference ($P > 0.05$) in the mean weight of fines in planted and adjacent unplanted sites. Fines in both situations were below levels known to directly affect survival of salmonid eggs and fry by reducing oxygen supply and inhibiting waste removal. However, similar tests of other sieved fractions showed that there was a significant difference ($P < 0.05$) between planted and unplanted sites in the weight of material in the 4.76–25.4 mm and 0.84–4.76 mm classes. The former differ-

Table 2. Comparison of intragravel permeability, dissolved oxygen, and apparent velocity of sites planted directly and with Whitlock Vibert (WV) boxes.

Time of sampling	Permeability (cm/hour)		Dissolved oxygen (mg/liter)		Apparent velocity (cm/hour)	
	Mean	Range	Mean	Range	Mean	Range
Hatching period (weeks 4–5)						
WV box	2,000	1,800–2,200	10.5	10.0–11.0	31.3	22.0–42.0
Direct plant	1,933	1,600–2,100	10.7	10.2–11.2	31.3	24.0–39.0
Between hatching and fry emergence (weeks 6–15)						
WV box	1,900	1,800–2,000	10.3	9.8–10.8	31.7	23.0–45.0
Direct plant	1,833	1,500–2,000	11.0	10.4–11.4	22.7	18.0–35.0

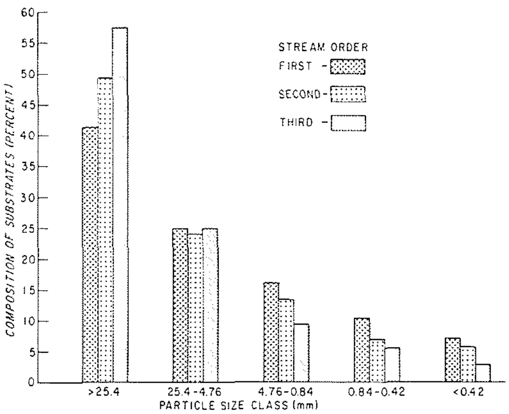

Figure 2. Mean percentage of composition by weight of substrate in particle size classes found in first-, second-, and third-order streams where eggs were planted.

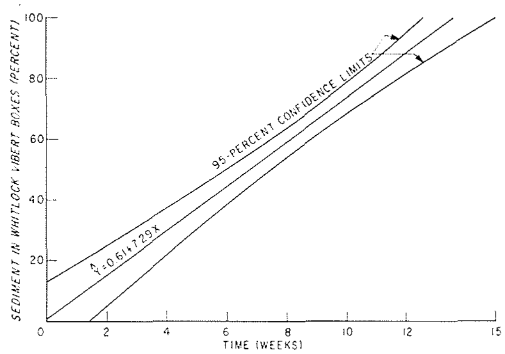

Figure 3. Linear regression, with 95% confidence limits, of observed sedimentation-time relationship in Whitlock Vibert (WV) boxes.

ence was most likely an artifact of planting as substrates of larger size were used to cover the eggs when planted. The latter difference, however, has biological significance because particles of this size (0.84–4.76 mm) can hinder or block emergence (Platts et al. 1979). Substrates smaller than 4.76 mm were removed when egg pockets were excavated and were not reintroduced on top of plants. Substrates present at the conclusion of this 5-month study accumulated through bedload sedimentation and could account for the low number of swim-up fry (Table 1).

Particle Size Class

Analysis of variance showed that the 0.84–4.76 mm particle size class was the only size range of substrates that differed significantly ($P < 0.05$) with stream order (Fig. 2). The third-order stream had significantly less of this size material (Duncan's new multiple range test, $P < 0.05$) than the first- and second-order streams (Table 4). The WV box planting sites, irrespective of stream order, consistently contained two to three times more substrate material of this size class than did direct plant sites. This size of material in planting sites did not differ significantly from undisturbed sites. Sand particles between 1.0 and 6.35 mm have been shown to impede the emergence of salmonid fry from spawning gravels (Bjornn 1969; Hall and Lantz 1969; Phillips et al. 1975), and emergence is likely to be reduced from gravel containing more than about 20% sand (Hausle and Coble 1976). These studies provide evidence that siltation may account for the difference between planting techniques.

Table 4. Mean percentage of substrates in the 0.84–4.76-mm particle size class at eight sites directly planted, eight sites with Whitlock Vibert (WV) box plants, and 20 adjacent unplanted sites.

Stream order	WV box	Direct plant	Unplanted
1	32.00	14.00	16.25
2	30.00	18.50	13.50
3	28.75	7.40	9.50
All sites	30.25	13.30	13.08

Sediment Accumulation

Observations of sediment accumulation in WV boxes as a function of time were available for 66 plants; 34 in this study and 32 from our previous study (Harshbarger and Porter 1979). These were plotted and described by a linear equation:

$$y = 0.61 + 7.29x$$

The r^2 value of 0.69 was significant at the 5% level (Fig. 3). This equation indicates that WV boxes with an approximate volume of 655.6 cm^3 accumulated 46 cm^3 of sediment per week during the study. Sediment in WV boxes was correlated with the number of dead eggs and dead fry found in boxes. According to Spearman's rank correlation coefficient, $r_s = 0.63$ and $r_s = 0.70$, respectively.

Entrapment

The number of live fry trapped by sediment in WV boxes beyond the time of swim-up ranged from 3 to 28 with a mean of 14. Similarly, the number of these fry found in direct plants ranged from 0 to 28 with a mean of 14.1. These figures represent 2.8% and 0.7% trapped (fourfold difference) of the potential from 500 eggs per WV box and 2,000 eggs in each direct plant, respectively. By comparison, the percentage of dead fry found in WV boxes and direct plants was almost identical after swim-up; i.e., 4% of the planted eggs. Although dead fry can disappear rapidly from the intragravel environment (McNeil et al. 1964; Heard 1978), the decomposition rate of dead fry in boxes should be similar. If scavaging by predators were the same in the two planting situations, the percentage of dead fry found after swim-up should be similar.

The rapid disappearance of dead fry in our planting sites tends to mask the overall effect of entrapment. However, it is noteworthy that fry were being trapped in both direct plants and WV box plants. Direct plants had an egg distribution similar to that in natural redds. Sac fry from such plantings should be distributed similarly. If fry from plants are being entrapped by sediments, there is reason to believe that fry in natural redds are experiencing the same fate. Sediment entrapment may partially explain the observations that only 10–30% of the fry in wild brown trout redds leave the gravel environment in many North Carolina streams (Dechant 1980).

Conclusion

These data demonstrate that planting trout eggs directly into stream gravels is superior to planting eggs in WV boxes. Apparently these advantages resulted from significantly greater sedimentation of 0.84–4.76 mm sand in the WV box planting sites compared to sites that were planted directly. Furthermore, deposition of this size material in direct plant sites was approximately 100% greater in first- and second-order streams than in the third-order stream. Undisturbed substrates in the third-order stream contained about 50% less of this size material than did counterparts in first- and second-order streams. Apparently, third-order streams lack sufficient water velocity to move sediment to the same extent. Sediments smaller than 0.84 mm probably remained entrained in all streams. We conclude that the greatest planting success will probably occur when direct plants are made in third-order streams.

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