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Effects of a Small Suction Dredge on Fishes and Aquatic Invertebrates in Idaho Streams

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Abstract

A typical dredge (intake diameter 7.6 cm) was operated on four small Idaho streams during July–September 1980 to evaluate some of the effects on aquatic organisms that may result from the use of small suction gold-dredges. Mortality of eggs, sac fry, and fingerlings of several species of trout was monitored, as was that of benthic invertebrates that were entrained through the dredge. The ability of invertebrates to recolonize a dredged area was assessed, and the performance of the dredge was evaluated.

Un-eyed cutthroat trout (*Salmo clarki*) eggs experienced 100% mortality within 1 hour after entrainment. Eyed cutthroat trout eggs showed means of 29% and 35% for 1-hour and 36-hour mortalities, respectively. The 19% mortality of eyed eggs of hatchery rainbow trout (*Salmo gairdneri*) after 10 days was similar to that of the control group. Hatchery rainbow trout sac fry experienced 83% mortality after 20 days as compared with 9% for the controls. Yolk sacs were detached from approximately 40% of the fry during entrainment. Fewer than 1% of the 3,623 invertebrates entrained showed injury or died within 24 hours. Most of the dead were *Centroptilum* mayflies that were undergoing emergence at the time of dredging.

Most of the recolonization of dredged plots by benthic invertebrates was completed after 38 days. The unmodified dredge moved the equivalent of 0.043–0.055 m^3 of substrate per hour, about 2% of the manufacturer's maximum rating. In the study areas, approximately 0.76 m^3 of sediment less than 0.5 mm in diameter could be moved in 100 hours of dredging operation.

Recent increases in gold prices have led to a rapid proliferation of suction dredging in streams in the western states and provinces. Although this trend is generally perceived by biologists to be a threat to aquatic resources, comprehensive studies have not been conducted to assess the potential impacts. Regulatory decisions regarding dredging must often be made arbitrarily.

This study was designed to evaluate some of the effects on aquatic organisms that may result from the use of small dredges. In Idaho, as in many western states, a legal distinction has been made by administrative agencies between small, portable dredges normally used by hobbyists and the large machines run by full-time operators. The former, which were designated "recreational" dredges in Idaho when this study was begun, had intakes of 7.6 cm or less in diameter. A single statewide permit was required, and about 1,000 were issued in 1980. Some streams were closed to dredging during parts of the year. In open areas, there was no restriction on the number of dredges or the duration of their operation.

Our primary objective was to assess the ability of aquatic invertebrates and early life stages of trout to survive entrainment through small suction dredges. Secondarily, we sought to (1) determine the time required for aquatic invertebrates to recolonize a dredged area, and (2) evaluate the performance of a small dredge under field conditions.

Study Streams

Field studies were conducted on four streams in the mountains of southeastern Idaho during July and August 1980. Study sites (elevations 1,550 to 1,950 m) were typical of stream sections being worked by recreational dredgers in the state, and dredging is permitted on each of those streams during portions of the year. Burns Creek (Bonneville County) is a third-order tributary of the South Fork of the Snake River and is a major spawning area for cutthroat trout. It flows through a wooded canyon and its headwaters are without roads and largely undisturbed. The average stream gradient is 3% and water quality is excellent. Most of the substrate is rubble and gravel with little fine sediment being present. Yankee Fork (Custer County) is a major sixth-order tributary of the

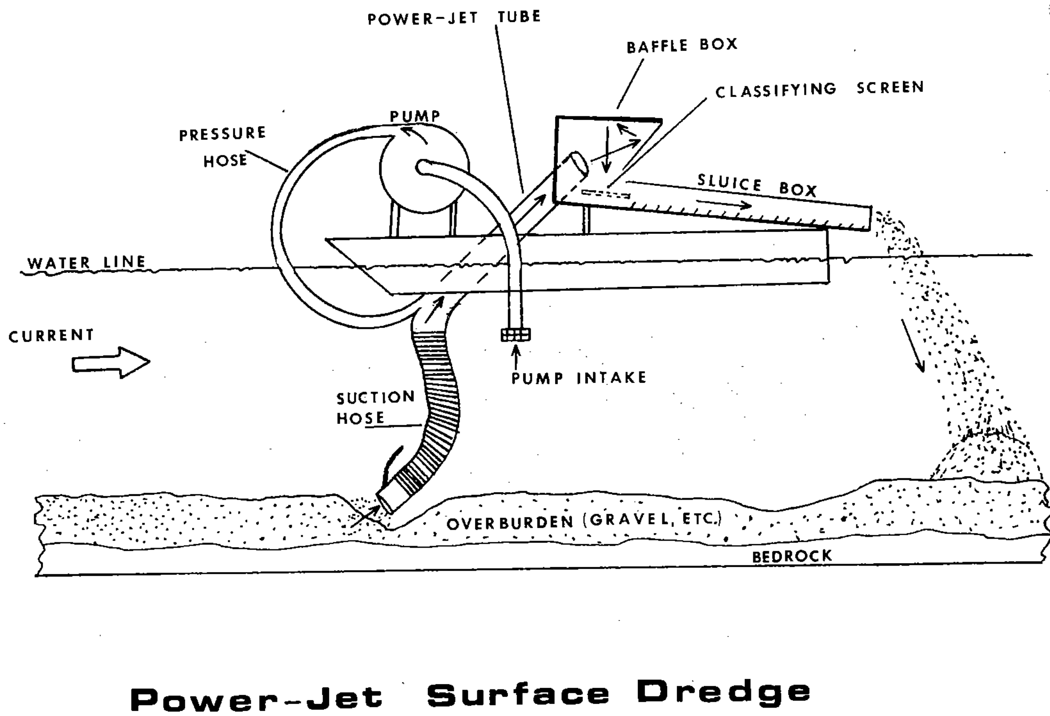

FIGURE 1.—*Cross section of a typical power-jet suction dredge, showing key components.*

upper Salmon River and has had mining activity in its drainage for over 100 years. A site near the mouth of the stream having gravel and sand deposits among the boulders and cobbles was selected. Water quality of the Yankee Fork is good and spawning by steelhead trout (*Salmo gairdneri*) and chinook salmon (*Oncorhynchus tshawytscha*) occurs.

Napias Creek (Lemhi County) is a fourth-order tributary that drains into the main Salmon River via Panther Creek. Past and present mining activity has exposed much silt and sediment within its drainage, and during run-off or surface activity the stream is discolored. Napias Creek has a substrate of mostly gravel and sand with some rubble present. Summit Creek (Custer County) is a highly productive, spring-fed, second-order stream that flows over an alluvial valley floor until it reaches the Little Lost River. Its substrate is largely gravel and sand and aquatic vegetation is abundant. In all streams, we dredged relatively shallow (<0.8 m) areas and did so without moving large rocks that would have required mechanical equipment to displace.

Dredge Description

The dredge we used, a 6.4-cm Keene Engineering Model 2503P, is typical of surface suction dredges and is one of the most common in use. The 3-horsepower engine, pump, and sluice box (26 cm wide × 132 cm long) are contained on a flotation assembly (Fig. 1). The pump, rated at a maximum of 7.9 liters/second, moves water through a single power-jet eductor, or venturi tube, to create suction. Substrate particles and aquatic organisms are sucked into the opening (5.1 cm diameter) of the suction hose and then into a baffle box in which the current direction is reversed and turbulence increased. Flow then continues either past or through a classifier screen with 1-cm openings and finally over the Hungarian riffles and Ozite matting of the sluice box.

Methods

Survival of trout eggs, sac fry, and fingerlings

Survival of both wild cutthroat trout (*Salmo clarki*) and hatchery rainbow trout (*Salmo gaird-*

neri) eggs was evaluated after passage through the dredge. Cuttthroat trout eggs were dredged from natural redds in Burns Creek on 4 and 14 July 1980. Three groups of both eyed and un-eyed eggs, approximately 100 in each group, were taken from separate redds. Care was taken not to disturb the redds before dredging. They were first located by snorkeling and then excavated so that both eggs and gravel passed through the dredge. A collection basket of 1-mm mesh was held slightly downstream in the sluice outfall, and largely submerged to prevent crushing of eggs by gravel spilling from the sluice. Collection baskets were covered and held in the stream. The number of dead eggs was recorded after 1 hour and after 36 hours. Midday water temperatures ranged from 11 to 12 C.

Similar procedures were carried out in a commerical hatchery with eyed rainbow trout eggs (18 days old) and sac fry (28 days old, 3 days post-hatch) in 12 C water. Two groups of 100 eggs and 3 groups of 100 fry were selected. One group of each was placed in a container with gravel, passed through the dredge along with the gravel, and held in a hatchery trough for 10 days. The second group of eggs and fry was held as a control, and the third group of fry was passed through the dredge and immediately preserved in formalin. By the end of the 10-day period, all live eggs had hatched and fry had almost completely absorbed their yolk sacs.

A smaller number of larger trout were similarly passed through the dredge. Twenty underyearling brook trout (*Salvelinus fontinalis*) 4.2–5.9 cm long were collected by electrofishing in Napias Creek, held overnight to observe their recovery, passed through the dredge, and observed for 48 hours in live-cages in the stream. Similar procedures were followed for six larger brook trout (13.5–15.1 cm) and 10 rainbow trout (7.8–9.1 cm).

Survival of benthic invertebrates

Invertebrates in both Burns and Napias creeks were entrained through the dredge and held to assess short-term survival. A series of 0.1-m² plots were dredged to a depth of 15 cm in each stream. Invertebrates were collected in a 0.5-mm-mesh net held slightly downstream from the sluice and largely submerged so that the gravel would not accumulate in the net and crush the invertebrates.

In Burns Creek, nine plots were dredged from a riffle. Invertebrates from four of the plots were held in collection nets for 1 hour, examined under 10× magnification for mortality or injury, and then preserved for later identification to genera and counts. Organisms from the remaining five plots were immediately transferred to 1-mm-mesh baskets containing gravel and held in the stream for 24 hours, at which time they were examined and preserved. Holding these organisms longer than 24 hours may have resulted in non-dredge mortality due to lack of food, predation, crowding, or stress from reduced water velocity (Merritt and Cummins 1978).

In Napias Creek, three plots from each of three habitats (pool, riffle, and run) were sampled. Each group of invertebrates was held for 24 hours to monitor short-term survival using the same procedures employed in Burns Creek.

Recolonization of a dredged area

Five 0.25-m² plots in a riffle in Summit Creek were dredged to a depth of 15 cm on 15 August 1980, and a marker was placed at the center of each plot. After 38 days, the time at which substantial recolonization would be expected (Townsend and Hildrew 1976), each of the plots was sampled with a modified Hess net (Waters and Knapp 1961). Similar samples were taken in adjacent, undredged portions of the riffle. All samples were preserved and subsequently identified to genera and counted.

Measurement of dredge performance

The actual rate of removal of overburden was determined by collecting all material that passed through the dredge, as well as that accumulating in the sluice box during 10-minute trials on Napias Creek and Yankee Fork. The volume of this material was measured and fractionated into nine size classes of particles based on the classification of Cummins (1962). Optimum rate of removal of overburden by the dredge was determined by recording the time required to move measured quantities of loose gravel of 2-cm diameter or less. Water velocities at the suction-tube intake and across the sluice box were measured with a Thermo-velocity Model 1630S-12 current meter.

Turbidity resulting from dredge operation was measured in Napias Creek and Yankee Fork. Water samples were taken at intervals

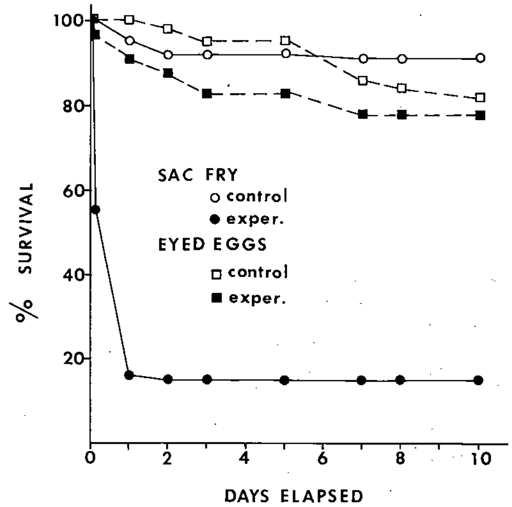

FIGURE 2.—*Survival of hatchery rainbow trout eyed eggs and sac fry over a period of days after passing through a suction gold dredge. One hundred individuals were used in each test and control group.*

from the dredge outfall to 100 m downstream while the machine operated in typical gravel substrate. Control samples were collected 5 m upstream from the dredge. In the laboratory, samples were analyzed with a Hach 2100A turbidimeter.

Results

Survival of trout eggs, sac fry, and fingerlings

Un-eyed cutthroat trout eggs from Burns Creek experienced 100% mortality after entrainment through the dredge (Table 1). Mortality apparently resulted from rupture of the vitelline membrane, and all eggs became opaque within a 5-minute period following entrainment.

TABLE 1.—*Short-term mortality of eyed and un-eyed cutthroat trout eggs dredged from redds in Burns Creek, July 1980.*

			Cumulative mortality after			
			1 hr		36 hr	
Life stage	Trial	Number	Number	Percent	Number	Percent
Un-eyed eggs	U1	132	132	100		
	U2	100	100	100		
	U3	116	116	100		
Totals		348	348	100		
Eyed eggs	E1	180	40	22	53	29
	E2	93	18	19	22	24
	E3	81	43	53	50	62
Totals		354	101	29	125	35

TABLE 2.—*Survival of 1,126 benthic invertebrates in Burns Creek 1 hour and 24 hours after passage through a recreational gold dredge. Four 10-minute dredge samples (0.1 m² by 15 cm deep) were used in the 1-hour trial and five were used in the 24-hour trial.*

	1-hour trial		24-hour trial	
	Alive	Dead	Alive	Dead
Ephemeroptera	236	0	280	0
Ameletus				
Baetis				
Cinygmula				
Ephemerella				
Plecoptera	21	0	56	0
Hesperoperla				
Isogenoides				
Kogotus				
Paraleuctra				
Zapada				
Trichoptera	91	0	192	0
Brachycentrus				
Glossosoma				
Limnephilus				
Neothremma				
Odontoceridae				
Rhyacophila				
Diptera	13	0	13	0
Antocha				
Chironomidae				
Hexatoma				
Simulium				
Tipula				
Coleoptera	11	0	13	0
Optioservus				
Miscellaneous	94	0	106	0
Gyraulus				
Lumbriculus				
Nematoda				
Turbellaria				
Totals	466	0	660	0

Eyed cutthroat trout eggs experienced a mean of 29% and 35% mortality after 1 hour and 36 hours, respectively. Mortality in one group of eggs (Trial E3) was approximately double that of the other two groups. As with un-eyed eggs, most of the eggs that were killed due to dredge damage died within a few minutes after entrainment.

The mortality of eyed hatchery rainbow trout eggs was 19% after 10 days (Fig. 2), by which time all other live eggs had hatched. Mortality

TABLE 3.—*Survival of 2,497 benthic invertebrates in Napias Creek 24 hours after passage through a recreational gold dredge. Three 10-minute dredge samples were taken at each of three habitats and pooled for analysis.*

	Habitat					
	Run		Pool		Riffle	
	Alive	Dead	Alive	Dead	Alive	Dead
Ephemeroptera	407		711		481	
Ameletus						
Baetis						
Centroptilum		12[a]		4[a]		
Cinygmula						
Epeorus						1
Paraleptophlebia						
Rhithrogena						1
Plecoptera	45		184	0	27	
Capnia		1				1
Hesperoperla						
Isogenoides						
Paraleuctra						
Zapada						
Trichoptera	69	0	96	0	37	
Arctopsyche						1
Brachycentrus						
Hydropsyche						
Limnephilus						
Diptera	23	0	187	0	63	0
Chironomidae						
Hexatoma						
Simulium						
Tipula						
Coleoptera	43		65		10	0
Heterlimnius						
Optioservus		3		1		
Miscellaneous	0		23	0		0
Hydracarina		1			1	
Sphaerium						
Turbellaria						
Totals	580	17	1,269	5	622	4

[a] Emerging adults.

of the control group was 18% after 10 days. Mortality among the controls occurred gradually throughout the period but most of the mortality of the test group occurred in the first three days after entrainment.

Rainbow trout sac fry experienced 83% mortality after passage through the dredge as compared with 9% mortality for the controls (Fig. 2). Virtually all of the mortality in the test group occurred within 24 hours. The major cause of death was the detachment of the yolk sac from the body of the fry, which occurred in 42% of the fry entrained. In the group of fry that was preserved immediately after entrainment, a similar proportion (40%) of individuals had detached yolk sacs. Fry that survived to the end of the holding period appeared normal and were capable of normal movement. All larger brook trout survived.

Survival of benthic invertebrates

The benthic organisms tested represented most of the common genera found in the mountain streams of Idaho (Newell and Minshall 1977, 1979; Andrews and Minshall 1979a, 1979b). Short-term survival of the benthos after passing through the dredge was almost 100%. Of 3,623 invertebrates (Tables 2 and 3) examined, only 26 (<1%) either were dead or had severe injuries such as body-wall extrusions. Most of the dead belonged to the mayfly genus *Centroptilum*, that were emerging at the time of

TABLE 4.—*Densities of benthic invertebrates per square meter in Summit Creek within and adjacent to the dredged area on 22 September 1980, 38 days after dredging.*

	Within dredged area		Adjacent to dredged area	
Order	Number	Percent of total	Number	Percent of total
Ephemeroptera	6,160	55.8	6,768	54.6
Plecoptera	336	3.1	800	6.5
Coleoptera	528	4.8	736	5.9
Trichoptera	192	1.7	144	1.2
Diptera	576	5.2	592	4.8
Miscellaneous[a]	3,248	29.4	3,344	26.9
Totals	11,040		12,384	

[a] Mostly *Lumbriculus* and *Physa*.

TABLE 5.—*Turbidity (in Nephelometric Turbidity Units) in Napias Creek and Yankee Fork at control sites (5 m above dredge) and at intervals below dredge, August 1980.*

Distance below dredge (meters)	Napias Creek	Yankee Fork
1	2.2	0.7
5	1.8	0.7
10	2.0	0.7
20	1.8	
30	1.6	
40	1.7	
50	2.0	0.6
60	1.8	
70	1.7	
80	1.4	
100	1.6	0.6
Control	1.6	0.8

dredging. Only eight individuals (33%) of this genus escaped physical injury such as decapitation or detachment of legs. More than 2,100 mayflies were examined and only two additional individuals (one *Epeorus* and one *Rhithrogena*) were injured.

Recolonization of a dredged area

The dredged sample plots in Summit Creek were substantially recolonized by benthic invertebrates after a 38-day period (Table 4). Mean numbers of 12,384 and 11,040 invertebrates per square meter were found in the undredged and dredged areas, respectively. A comparison of numbers between orders in the populations of these two areas showed no significant difference (Student's t test). Similarly, there was no significant difference among numbers of the five key taxa (*Baetis, Ephemerella, Physa,* Chironomidae, and *Lumbriculus*) that together accounted for 80% of the invertebrates in both areas.

Dredge performance

The dredge consistently moved the equivalent of 0.043–0.055 m^3 of substrate per hour in Napias Creek and Yankee Fork. In the trial with loose gravel to estimate an optimal rate, a value of 0.127 m^3 per hour was obtained at the standard engine speed of 2,400 rpm. At this speed, the water velocity at the suction-tube intake was 30 cm/second; 61 cm/second across the sluice box.

Turbidity below the dredge in Napias Creek and Yankee Fork was nearly undetectable (Table 5). A turbidity plume was noticeable only a few meters below the dredge in Napias Creek, and no plume was seen in Yankee Fork. Fine sediment less than 0.5 mm in diameter comprised 18% and 13%, by weight, of the overburden dredged in Yankee Fork and Napias Creek, respectively. Sediment less than 4 mm comprised 58% of the material dredged in both streams.

Impact of Dredging

Of those life stages of trout tested in this study, un-eyed eggs are clearly the most susceptible to damage from entrainment through suction dredges. Trout eggs are extremely sensitive to shock 1–2 days after fertilization until they eye up, the most sensitive period being just before they are one-third of the way between fertilization and hatching (Hayes 1949). From our results, we would anticipate total mortality for trout eggs of any species if they were entrained during that period. This period normally is approximately 10–20 days, depending upon species and water temperature.

A substantial proportion of the eyed cutthroat trout and rainbow trout eggs survived passage through the dredge. In these eggs, the vitelline membrane has been replaced by layers of cells and they can withstand the shock created by turbulent flows through the dredge. Those eyed eggs that did not survive entrainment were most likely those that struck either the rear of the baffle box, the solid portion of the classifier screen, or the sluice box riffles.

There was considerable variation in mortality (24–62% after 36 hours) among the three groups of eyed cutthroat trout eggs tested. One possible factor is that the redd from which Group E3, the last group tested, was taken was in an area of intensive spawning and redds had been superimposed upon each other. As a result, some of these eggs may have been disturbed and thus stressed before the experiment. The 36-hour mortality values may underestimate the actual total mortality, since the 10-day tests on rainbow trout eggs showed some mortality that continued through the third day. Although mortality of the eyed eggs of hatchery rainbow trout was indistinguishable from that of the control after 10 days, we interpret the difference in timing of the mortality to be indicative of dredge-induced effects, but this would be on the order of 10% at the most. The mortality of eyed eggs of other salmonid species after dredge entrainment may be different from those species we worked with. Eggs of chinook salmon, for example, are generally considered more resistant to shock and might be less affected.

Trout sac fry are extremely susceptible to damage from entrainment, and our data indicate only about one of four newly hatched fry would be expected to survive. As the fish grow and the size of the yolk sac decreases, the probability of survival should increase and we would expect nearly complete survival of free-swimming fry. The period of susceptibility to damage would be about 10–15 days, again depending upon species and temperature. Fingerling and larger trout would not normally be entrained since they could easily avoid the 30 cm/second intake velocity. If they enter a dredge such as the one used in our tests, they should survive.

Aquatic invertebrates were surprisingly resistant to damage from entrainment. Although our short-term mortality values may underestimate overall long-term mortality, we feel the lack of physical damage to gills and appendages of even the more fragile of the Ephemeroptera argues against that possibility. In a similar test on Clear Creek, California, Lewis (Memorandum, California Fish and Game Department, Sacramento, California, 1962) found 7% mortality after entrainment of 149 benthic invertebrates through a 10-cm suction dredge. However, a substantial amount of gravel accumulated in the collection sack with the invertebrates, and Lewis attributed some of the mortality to physical damage that incurred after, rather than during, entrainment. In general, only the emerging insects appear to be prone to damage from dredge passage. The exact length of this critical period varies among species and extends from 1 day to several weeks (Merritt and Cummins 1978).

A number of other factors affect the overall impact of dredge operation on aquatic invertebrates. First, the mortality of their eggs and early instars should be considered; second, since the bulk of the invertebrates are in the top 10 cm of the substrate, dredging a large area to a shallow depth would entrain more organisms per unit of effort than would dredging a narrow but deep pit to the depth of the bedrock; and third, our data are based upon the use of a standard dredge as equipped by the factory. Many dredgers modify their equipment by adding additional classifier screens, enlarging the sluice box, or increasing engine speed. Any such modification should increase the mortality of entrained aquatic organisms.

A fourth factor, which applies to the early life stages of trout as well as invertebrates, is the fate of organisms that survive entrainment. We noticed, as did Lewis in California, that most settled to the substrate within 10–20 m of the dredge. Their subsequent survival would depend upon factors such as predation and the suitability of the habitat which they entered.

The dredge used for these tests was rated by the manufacturer as capable of moving up to 3.1 m^3 of overburden per hour. We operated at about 2% of this rating under field conditions, with the engine set at the maximum speed allowed by its governor. Factors that affect (and limit) dredge performance include compaction of the substrate, the need to "feed" gravel to prevent plugging of the suction hose, and loss of power due to elevation and temperature. A more experienced operator would have exceeded our rate, but could not possibly have approached the manufacturer's rating.

In our study areas, approximately 0.76 m^3 of fines (<0.5 mm in diameter) was moved downstream during each 100 hours of dredge operation. Although the porosity of the dredged area would be improved (R. Lewis, California Department of Fish and Game, Department Memorandum, 1962), this sediment could affect aquatic organisms downstream from the dredge.

Our recolonization study indicated that adjacent areas furnished enough individuals to repopulate the dredged plots in slightly more than a month under summer conditions. Recolonization might occur more slowly during other seasons and if larger areas were disturbed by dredging. Minshall et al. (in press) found the rate of recolonization of the North Fork of Idaho's Teton River depended in part on the distance upstream to a source or pool of invertebrates. One station on the Teton River 50 m downstream from an undisturbed section took 90 days to recolonize, while another located 5.5 km below the source took 439 days.

In conclusion, we should point out that suction dredging could impact aquatic systems in a number of ways other than those examined in this study. Examples include the trampling of aquatic organisms by the dredge operators themselves and consequences of altering stream channel configuration by moving boulders. Also, streams having higher sediment levels than those we studied would be expected to show more substantial sediment "plumes" below dredges. We also point out that our results are based on small "recreational" dredges used largely by hobbyists. Since dredge capacity quadruples as intake diameter doubles, the impacts from larger dredges may be substantially greater.

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