Journal
of the Fisheries
Research
Board
of Canada

Journal
de l'office
des recherches
sur les pêcheries
du Canada

Volume 33, No. 9, September 1976 Volume 33, n° 9, septembre 1976

Effects of Sand Sedimentation on Colonization of Stream Insects[1]

R. J. LUEDTKE[2] AND M. A. BRUSVEN

Department of Entomology, University of Idaho, Moscow, Idaho 83843, USA

LUEDTKE, R. J., AND M. A. BRUSVEN. 1976. Effects of sand sedimentation on colonization of stream insects. J. Fish. Res. Board Can. 33: 1881–1886.

Driftnets, basket samplers, and artificial streams were used to investigate the influence of heavy sand accumulations on insect drift, colonization, and upstream movements in Emerald Creek, northern Idaho. Most riffle insects successfully passed through low-velocity, sandy reaches 80 m long. Upstream movements on sand were impeded by flows as low as 12 cm/s, except for the heavily cased caddisfly *Dicosmoecus* sp.

LUEDTKE, R. J., AND M. A. BRUSVEN. 1976. Effects of sand sedimentation on colonization of stream insects. J. Fish. Res. Board Can. 33: 1881–1886.

Nous avons utilisé des filets de dérive, des paniers d'échantillonnage et des cours d'eau artificiels dans nos recherches sur l'influence de fortes accumulations de sable sur la dérive, la colonisation et les mouvements en amont des insectes dans le ruisseau Emerald, Idaho septentrional. La plupart des insectes de radiers franchissent avec succès des étendues sablonneuses de faible vélocité de 80 m de longueur. Les mouvements en amont sur le sable sont entravés par des écoulements aussi lents que 12 cm/s, sauf ceux de l'éphémère *Dicosmoecus* sp., protégé par une lourde enveloppe.

Received January 22, 1975
Accepted June 1, 1976

Reçu le 22 janvier 1975
Accepté le 1 juin 1976

HEAVY sedimentation caused by commercial and private mining of garnets from Emerald Creek in northern Idaho is potentially detrimental to the benthic organisms and food chain relationships in the stream. Of greatest concern are long, sandy reaches formed during low, midsummer flows. These reaches serve as potential ecological blockages in the colonization cycle by impeding insect drift and upstream dispersion.

Insect drift is the major means of colonizing natural and altered streams (Leonard 1942; Müller 1954; Waters 1964). Distances insects drift are extremely variable, influenced by the insect species, substrate type, current velocity, and other stream characteristics (Elliott 1971a).

---

[1] Published with the approval of the Director of the Idaho Agricultural Experiment Station as Research Paper No. 7566.

[2] Present address: Fisheries Bioassay Laboratory, Department of Chemistry, Montana State University, Bozeman, Mont., USA.

Printed in Canada (J4164)
Imprimé au Canada (J4164)

Upstream migration by insects has been reported to be from 5 to 30% of downstream drift and could serve to colonize rehabilitated reaches of a stream (Bishop and Hynes 1969; Brusven 1970a; Elliott 1971b; and Hultin et al. 1969).

Field and laboratory dispersion studies were conducted to determine how benthic insects are affected by long sandy reaches in Emerald Creek. The studies were designed to obtain information on distance traveled by drifting and crawling insects, upstream dispersion, the capability of low water velocities to effectively aid insect movement for long distances, and the ecological impact of heavily sanded reaches on colonization.

Materials and Methods

STUDY AREA

Emerald Creek is a major tributary of the St. Maries River in northern Idaho. It is a low-gradient stream through its intermediate and lower reaches, dropping 1.6 m/km. Stream width varies from 3.4 to 10.7 m. Average riffle depth is 5.1–15.2 cm; pools are 0.6–1.2 m deep during midsummer flows. The average summer discharge is 442 liters/s (Prather 1971). The upper and middle reaches of Emerald Creek and its tributaries have been extensively mined by rock hounds seeking gem quality garnets. The lower reach is influenced by a commercial dredge mining operation and has heavily sanded runs (mean particle size 1.27 mm) and pools.

FIELD STUDY

Basket samplers and driftnets were used concurrently to determine if riffle insects successfully passed through long, low-velocity sandy runs, and if so, by what means (i.e. drifting or crawling). A sandy run, approximately 80 m long, occurring between distinct riffles, was investigated. Nets, 30 × 60 cm with 0.8-mm pore size, were used to measure drift. Baskets (30 × 30 × 15 cm, made of 5.1 × 10.2 cm hardware cloth) filled with 12–15-cm rocks were used as colonization sites for drifting and crawling insects.

Single driftnets (nets A, B, and C) were positioned in center channel approximately 24 m apart in the sandy reach. A control net was placed in a riffle immediately upstream from the first test net (A). On three successive nights the control net and one test net were employed to sample insect drift. The lowermost net (C) was used on the first night and nets B and A during the next two nights, respectively. Drift results from the three test nets were compared with drift in the control net for the respective days. Drift was taken for a 10-h period starting before dark and ending after sunrise. Nets were emptied at 5-h intervals to avoid possible overloading by debris and insects. Volume of flow through each drift net was determined and insect drift enumerated as the number of insects per cubic meter of water.

Two basket samplers were placed in the center channel at each test and control driftnet site. These were positioned in the stream at the onset of the drift sampling period and emptied 24 h later. To prevent loss of insects during sampling, a net was placed immediately downstream from the basket to collect insects dislodged during basket removal. Rocks were emptied from the baskets and washed clean of insects.

Upstream dispersion was investigated in the field using an open-ended, linear channel (1.2 × 9.8 m) constructed of plywood boards and positioned in the thalweg of a sandy run. Water velocity in the channel was 21 cm/s and water depth 17.8 cm. Driftnets were positioned at the downstream end of the channel. Late-instar larvae of *Dicosmoecus* sp. and nymphs of *Pteronarcys californica* Newport and *Acroneuria* sp. were used as test specimens. Daytime tests were conducted between 1300 and 1600, night tests 1 h after sunset to 0100. Ten specimens of each species were used for each test (replicated 3 times). The insects were introduced into the middle of the channel and observed continuously for 15 min. A fluorescent tagging technique developed by Brusven (1970b) permitted visual observations of tagged insects at night.

LABORATORY STUDY

In an attempt to better describe insect movement on sandy reaches, tests were conducted in a laboratory channel employing McLay's (1970) model to describe patterns of insect drift and settle-out.

$$N_x = N_o e^{-RX}$$

where: N_x = number of insects in the drift sampler,
N_o = initial number of drifting insects,
e = base of natural logarithms,
R = rate of return to the bottom,
X = distance upstream from the sampler (i.e., the origin of drifting insects).

Effect of different insect species, current velocity (12.2, 21.3 and 30.5 cm/s) and light conditions (light and dark) on R (rate of return to bottom) was investigated.

The laboratory stream consisted of two sections (2.4 and 3.1 m long, 25.4 cm wide and 20.5 cm high) connected by a flexible joint to permit slope adjustment. Both sections were of similar construction having a plywood base and 0.6-cm plexiglass sides. The channel was divided into eight, 60-cm test sections. A net was positioned at the outflow to collect test specimens drifting out of the channel. The water was 5–6 cm deep during the test; mean particle size of the sediment was 1.27 mm.

Four insect species, *Arcynopteryx* sp., *Brachycentrus* sp., *Ephemerella grandis* (Eaton) and *Pteronarcella badia* (Hagen) were used in laboratory tests. Test specimens were collected in the field and acclimated in a circular laboratory stream described by Brusven (1973). Twenty insects of a single species were introduced into the middle of the water column at the upstream end of the channel. Duration of each test was 15 min, after which the insects were re-

TABLE 1. Field drift analysis for number of species, total numbers of insects, and drift densities (number per cubic meter) for Emerald Creek in July and August 1972. Recorded values represent means for two, 5-h sampling periods.

Date	Net position	No. species	Total no.	Drift density (*No./m³*)	Current velocity (*cm/s*)
July 7, 1972	Control	23	631	0.95	49.4
	C	16	158	0.95	12.5
July 8, 1972	Control	28	1076	1.35	63.4
	B	21	361	0.70	30.5
July 9, 1972	Control	26	645	0.75	60.1
	A	22	363	0.70	19.2
Aug. 17, 1972	Control	18	271	0.75	30.2
	C	9	39	0.50	6.4
Aug. 18, 1972	Control	18	314	0.85	31.1
	B	15	96	0.50	12.2
Aug. 19, 1972	Control	22	303	0.90	28.7
	A	15	85	0.45	7.0

covered and recorded from each 60-cm section of the stream and outflow net. Three replications were made for each species at each water velocity of 12.2, 21.3, and 30.5 cm/s under light and dark conditions.

Results and Discussion

DRIFT AND BASKET COLONIZATION STUDIES

Field drift and colonization results during July 1972 exhibited noticeable variability for the 3-day test period (Table 1). Numbers of species, total numbers of insects, and drift densities were approximately equal at test nets A and B. Net C yielded higher drift density but fewer species and total numbers. Increased drift at the control net on the second night is believed to have been influenced by a late-afternoon rain shower that caused increased flow. Similar conditions described by Anderson and Lehmkuhl (1968) caused increases in drift numbers. Basket sample counts at the driftnet sites indicated the control site increased during each successive sampling period while counts at test site B were substantially higher than those from sites A and C (Table 2).

The mayflies *E. hecuba* Eaton and *E. teresa* Traver and the beetle *Optioservus seriatus* LeConte were the most abundant species in both control and test driftnet samples during July; however, only *E. teresa* was abundant in basket samples (Table 3). The mayflies *Centroptilum* spp. A and B, *Epeorus albertae* (McDunnough) and *Baetis tricaudatus* Dodds, and the Chironomidae (Diptera) were the most common insects in basket samples, indicating colonization was not proportional to drift densities for these species. The standing crop in the sandy run was composed primarily of dipterans (Chironomidae and *Hexatoma* spp.) and the mayfly *Centroptilum* sp. A. Other species reported in Table 3 are common riffle inhabitants.

TABLE 2. Mean basket sample count from two baskets at each site for a number of species and total number of insects from Emerald Creek in July and August 1972.

Date	Basket position	No. species	Total no.
July 7, 1972	Control	13.0	44.0
	C	10.5	20.0
July 8, 1972	Control	11.0	50.5
	B	13.0	47.5
July 9, 1972	Control	13.0	65.5
	A	7.0	15.0
Aug. 17, 1972	Control	10.0	46.5
	C	9.0	31.0
Aug. 18, 1972	Control	9.0	72.0
	B	8.5	36.0
Aug. 19, 1972	Control	8.0	63.5
	A	8.0	26.0

August drift was much less variable than July drift. Drift at the control site was reasonably consistent during the test period (Table 1). Nets A and B had similar numbers of species and total numbers while net C had the fewest. Drift density was much less variable among the three test nets (Table 1). Basket colonization during August reflected fewer species than in July but slightly greater numbers (Table 2).

The mayfly *Centroptilum* sp. B, caddisfly *Brachycentrus* sp., and stonefly *Arcynopteryx* sp. were the most common insects in the August test and control drift samples (Table 3 and 4).

The dominant drift species (i.e. *Centroptilum* sp. B, *Arcynopteryx* sp. and *Brachycentrus* sp.) were prominent in basket samples at the control

TABLE 3. Percent composition of insects from July 1972 net (N) and basket (B) samples for selected species.

Insect		Net and basket position					
		A	Control	B	Control	C	Control
Coleoptera							
Optioservus seriatus	N	18	16	33	29	43	23
	B	—	1	0	0	0	3
Diptera							
Chironomidae	N	5	2	4	2	1	<1
	B	—	19	14	26	3	18
Simulium sp.	N	<1	<1	0	<1	0	0
	B	—	16	3	9	6	13
Ephemeroptera							
Baetis tricaudatus	N	8	4	5	3	4	3
	B	—	17	12	8	3	6
Centroptilum sp. A	N	1	<1	1	<1	<1	<1
	B	—	0	3	0	32	0
Centroptilum sp. B	N	4	4	1	1	2	3
	B	—	8	15	2	23	12
Ephemerella hecuba	N	30	35	26	26	16	27
	B	—	3	7	<1	3	0
E. flavilinea	N	2	2	2	4	2	6
	B	—	2	1	13	0	7
E. teresa	N	10	15	12	13	15	19
	B	—	1	5	10	6	9
Epeorus albertae	N	2	3	2	3	3	3
	B	—	12	8	11	6	9
Trichoptera							
Brachycentrus sp.	N	8	6	6	6	3	4
	B	—	6	5	7	3	9
Micrasema sp.	N	0	<1	0	0	1	0
	B	—	6	9	13	0	9

site. However, as in July, the dominant drift species was not the dominant insect from the respective test basket sample. *Centroptilum* sp. A and Chironomidae, common to the sandy run, were the most common insects in the three sets of test basket samples.

Drift and basket colonization results indicated appreciable downstream movement (drifting and crawling) by insects on a sandy substrate despite low current velocities. Most riffle drifting insects successfully moved through the test reach as evidenced by similar drift densities and species composition for the three test nets. The relative species composition appeared to be similar for both driftnet and basket samples from the test sites. However, dominant "drift" species were not the dominant "basket" species. Variability in colonization of the baskets probably reflects species-specific responses to the habitat afforded by the baskets, dominant species in the immediate area of the baskets, and mode of displacement i.e. passive or active, by drifting insects. Baskets were found to be most frequently colonized by insects that were either common to the immediate area of the basket (e.g. Chironomidae and *Centroptilum* sp. A at the test sites) or were strong swimming species (e.g., *Centroptilum* sp. B, *Baetis tricaudatus* and *E. albertae*). *Ephemerella hecuba* and *O. seriatus*, considered to be weak swimmers, were the dominant drift species in July but were not abundant in either control or test baskets. In contrast, August drift was partially dominated by actively swimming forms (e.g. *Centroptilum* sp. B and *Arcynopteryx* sp.) which were the principal species in control basket samples.

ARTIFICIAL STREAM STUDIES

Laboratory simulation studies provided additional insight into insect movement and "return to substrate rates" (R) on sand substrates. Highest R values for the mayfly *E. grandis* and the stonefly *P. badia* (Hagen) were under lighted conditions and the low current velocity of 12.2 cm/s (Table 5). The stonefly *Arcynopteryx* sp. and the caddisfly *Brachycentrus* sp. exhibited highest R values under lighted conditions and higher current velocity (21.3 and 30.5 cm/s).

TABLE 4. Percent composition of insects from August 1972 net (N) and basket (B) samples for selected species.

Insect		Net and basket position					
		A	Control	B	Control	C	Control
Coleoptera							
Optioservus	N	4	2	3	1	6	1
seriatus	B	0	3	0	1	0	0
Diptera							
Chironomidae	N	7	4	9	3	9	5
	B	14	2	33	6	33	8
Hexatoma sp.	N	0	0	0	0	0	0
	B	0	0	1	0	8	0
Ephemeroptera							
Baetis	N	4	2	3	2	1	5
tricaudatus	B	3	3	4	3	1	4
Centroptilum	N	3	<1	4	<1	10	1
sp. A	B	22	1	6	1	32	0
Centroptilum	N	25	14	30	22	17	18
sp. B	B	15	51	25	46	10	43
Hemiptera							
Sigara sp.	N	3	1	3	<1	0	1
	B	4	0	0	0	0	0
Plecoptera							
Alloperla sp.	N	4	1	8	2	9	2
	B	0	1	0	0	0	0
Arcynopteryx sp.	N	15	11	7	9	14	10
	B	13	6	7	3	6	8
Pteronarcella	N	2	6	6	7	4	6
badia	B	0	5	0	<1	0	1
Trichoptera							
Brachycentrus sp.	N	22	51	18	45	13	44
	B	3	15	18	32	3	29
Hydropsyche sp.	N	2	2	2	2	5	1
	B	0	4	2	4	0	1

Return to substrate rates for all test species except *P. badia* were distinctly lower under dark conditions. Values of R for dead insects were nearly zero for all test species (Table 5).

Different species displayed different mechanisms for drifting. *Ephemerella grandis* folded its legs to initiate drift, then extended them to engage the substrate and stop. *Pteronarcella badia* displayed a "tuck and roll" behavior to begin drift. *Arcynopteryx* sp. initiated drift by releasing the substrate and holding its legs in an extended, fixed position.

From these results we contend that "return to substrate" by the species studied was "active" and not "passive." Both live and dead specimens made numerous contacts with the substrate as they drifted. Difference in R values for live and dead specimens indicated that the return to substrate values was largely dependent on the physical activity of the insects e.g. swimming, grasping, and gliding behavior.

We initially hypothesized that the rate of return to substrate on sand would be lower than on pebble or cobble substrates. Values we obtained, however, are comparable to those reported by Elliott (1971a) from a small cobble stream. Relatively high rates in this study can be partially attributed to the shallow water column (5–6 cm) and short drift distance of the artificial channel.

UPSTREAM DISPERSION

Upstream dispersion studies conducted in the field revealed that the stoneflies *Pteronarcys californica* and *Acroneuria* sp. did not move upstream on a sand substrate with low current velocities of 21 cm/s. After several unsuccessful attempts, most specimens actively swam downstream, usually reaching the end of the channel (4.9 m) within 2–3 min. In contrast, the heavy-cased caddisfly *Dicosmoecus* sp. moved in a random manner (i.e. upstream, downstream, and

TABLE 5. Return to the substrate rates (R) for living and dead *Ephemerella grandis*, *Arcynopteryx* sp., *Brachycentrus* sp., and *Pteronarcella badia* in a laboratory stream at three water velocities in light and dark conditions.

Water velocity (*cm/s*)	*E. grandis*		*Arcynopteryx* sp.		*Brachycentrus* sp.		*P. badia*	
	Light	Dark	Light	Dark	Light	Dark	Light	Dark
Settle-out rates (R) for live insects								
12.2	1.16	0.96	1.08	0.81	0.45	0.21	0.59	0.49
21.3	0.68	0.61	1.02	1.08	0.60	0.44	0.43	0.46
30.5	0.41	0.27	1.13	0.78	0.59	0.16	0.22	0.26
Settle-out rates (R) for dead insects								
12.2	0.05	—	0.41	—	0.07	—	0.06	—
21.3	0.03	—	0.04	—	0.00	—	0.00	—
30.5	0.00	—	0.07	—	0.00	—	0.01	—

cross-channel). Many were noted moving upstream, often reaching the upper end of the channel in 5–10 min. This behavior suggests that this species can successfully colonize an upstream habitat when subjected to an unfavorable substrate at a lower reach. Tests conducted at night produced essentially the same results as those conducted in daylight for the species studied.

Limited upstream movement was also noted in laboratory streams. *Ephemerella grandis*, *Brachycentrus* sp. and *Pteronarcella badia* showed no tendency to move upstream on sand substrates (mean particle size 1.27 mm) at current velocities of 12.2, 21.3 and 30.5 cm/s. Some stonefly nymphs of *Arcynopteryx* sp. were successful at moving upstream; however, most showed a net movement downstream.

Results from these field and laboratory studies indicated that many common riffle insects are unable to move upstream on sand substrates. Pebble and cobble may be necessary for upstream by most insects even at low current velocities. A layer of water with zero velocity has been shown to exist at rock–water interfaces (Ambühl 1959). McClelland (1972) reported that many insects apparently live in this zone and do not experience the direct forces of current. This zone is probably thin on fine, loosely compacted sediments. The combination of exposure to current and instability of sand grains is believed responsible for restricting upstream movement by insects on sandy reaches such as occur in Emerald Creek and other streams having heavy sand deposition.

Acknowledgments

This research was supported by the U.S. Department of the Interior as authorized under the Water Resources Act of 1964, Public Law 88-379.

AMBÜHL, H. 1959. Die Bedeutung der Strömung als ökologischer Faktor. Schweiz. Z. Hydrol. 21: 133–264.

ANDERSON, N. H., AND D. M. LEHMKUHL. 1968. Catastrophic drift of insects in a woodland stream. Ecology 49: 198–206.

BISHOP, J. E., AND H. B. N. HYNES. 1969. Upstream movements of benthic invertebrates in the Speed River, Ontario. J. Fish. Res. Board Can. 26: 279–298.

BRUSVEN, M. A. 1970a. Drift periodicity and upstream dispersion of stream insects. J. Entomol. Soc. B.C. 67: 48–59.

1970b. Fluorescent pigments as marking agents for aquatic insects. Northwest Sci. 44: 44–49.

1973. A closed system Plexiglass stream for studying insect–fish–substrate relationships. Prog. Fish Cult. 35: 87–89.

ELLIOTT, J. M. 1971a. The distances traveled by drifting invertebrates in a Lake District stream. Oecologia 6: 350–379.

1971b. Upstream movements of benthic invertebrates in a Lake District stream. J. Anim. Ecol. 40: 235–252.

HULTIN, L., B. SVENSSON, AND S. ULFSTRAND. 1969. Upstream movements of insects in a South Swedish small stream. Oikos 20: 553–557.

LEONARD, J. W. 1942. Some observations on the winter feeding habits of brook trout in relation to natural food organisms present. Trans. Am. Fish. Soc. 71: 219–227.

MCCLELLAND, W. T. 1972. The effects of introduced sediment on the ecology and behavior of stream insects. Ph.D. Dissertation. Univ. Idaho, Moscow, Idaho. 167 p.

MCLAY, C. 1970. A theory concerning the distance traveled by animals entering the drift of a stream. J. Fish. Res. Board Can. 27: 359–370.

MÜLLER, K. 1954. Investigations on the organic drift in North Swedish streams. Rep. Inst. Freshwater Res. Drottningholm 35: 133–148.

PRATHER, K. V. 1971. The effects of stream substrates on the distribution and abundance of aquatic insects. M.Sc. Thesis. Univ. Idaho, Moscow, Idaho. 62 p.

WATERS, T. F. 1964. Recolonization of denuded stream bottom areas by drift. Trans. Am. Fish. Soc. 93: 311–315.