The Effects of Reduced Stream Discharge on Insect Drift and Stranding of Near Shore Insects[1]

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Abstract. The effects of seasonally reduced stream discharge on insect drift and stranding were studied in two experimental channels on the Grande Ronde River, Oregon. Five experiments were conducted (spring, summer and fall, 1980 and spring and fall, 1981) at three test flows (0.57, 0.28 and 0.03 m^3/sec). Insect samples were taken with a modified Hess sampler and standard drift nets. Reduced stream discharge caused catastrophic drift in the test channel with drift peaking at night. *Simulium* sp. and *Baetis tricaudatus* were the principal drift components. Evidence of stranded insects in the dewatered zone was greatest in the fall, least in the spring.

Increased demand on water resources for electricity, irrigation, flood control, domestic water supplies, navigation and recreation in the western United States has resulted in reduced discharge in many rivers. Minimum flows are critical to stream ecosystems, but are often of secondary importance to water fluctuations below hydroelectric facilities (Brusven, MacPhee & Biggam 1974; Kroger 1973).

Drift is a daily occurrence in the life of many benthic invertebrates in streams. Current velocity is one of the major factors affecting diel periodicities (Waters 1969). Anderson and Lehmkuhl (1968), Bailey (1966) and Ciborowski, Pointing and Corkum (1977) reported increases in drift with increasing velocities. Decreasing flows have also resulted in catastrophic increases in insect drift (Brusven et al. 1974; Minshall & Winger 1968; Ruediger 1980). Pearson and Franklin (1968) reported that reduced discharge caused lateral migration of insects and depletion of near-shore densities.

Brusven et al. (1974) reported that reduced stream flows in the Hell's Canyon reach of the Snake River in Idaho caused considerable dewatering of near-shore habitat and exposure and death of many aquatic invertebrates. Kroger (1973), studying the Snake River below Jackson Lake, Wyoming, found that rapid fluctuations left many insects stranded and dead. Trotsky and Gregory (1974) reported that extreme water level fluctuations on the Upper Kennebec River in Maine were limiting to most benthic invertebrates. Because of regional and seasonal variability in the aquatic insect fauna, it is critical that biologists examine the effects of reduced stream discharge on a spatial and temporal basis, especially where a fishery is of importance and insects serve as an essential food base. This study was undertaken to evaluate the response of aquatic insects to seasonal flow reductions in an eastern Oregon river that supports a significant anadromous fishery.

MATERIALS AND METHODS

The Troy Experimental Channels are located on the Grande Ronde River

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approximately 10 km southwest of Troy, Wallowa County, Oregon (Fig. 1). Tests were conducted in two parallel concrete channels, each 62.3 m long and 6 m wide. The channels were partially filled with river gravel and shaped to simulate riffles and runs in a natural stream. Grande Ronde River water diverted into the channels was controlled by head gates. During the winter of 1980-81, the channels were reconstructed to maximize changes in wetted perimeter with each flow reduction. This was accomplished by creating a V-shaped stream cross section. The original cross section was more trapezoidal.

Five experiments were conducted during the study at three test flows (Table 1). The test and control channels were maintained at a base flow of 0.57 m^3/sec for four weeks prior to the initial flow reduction to allow for invertebrate colonization. At the conclusion of the colonization period, flows in a randomly selected test channel were reduced from 0.57 to 0.28 m^3/sec. Flows were reduced in equal increments every 30 min over a 3 h period and monitored by using a predetermined stage-discharge curve. Two weeks after the initial

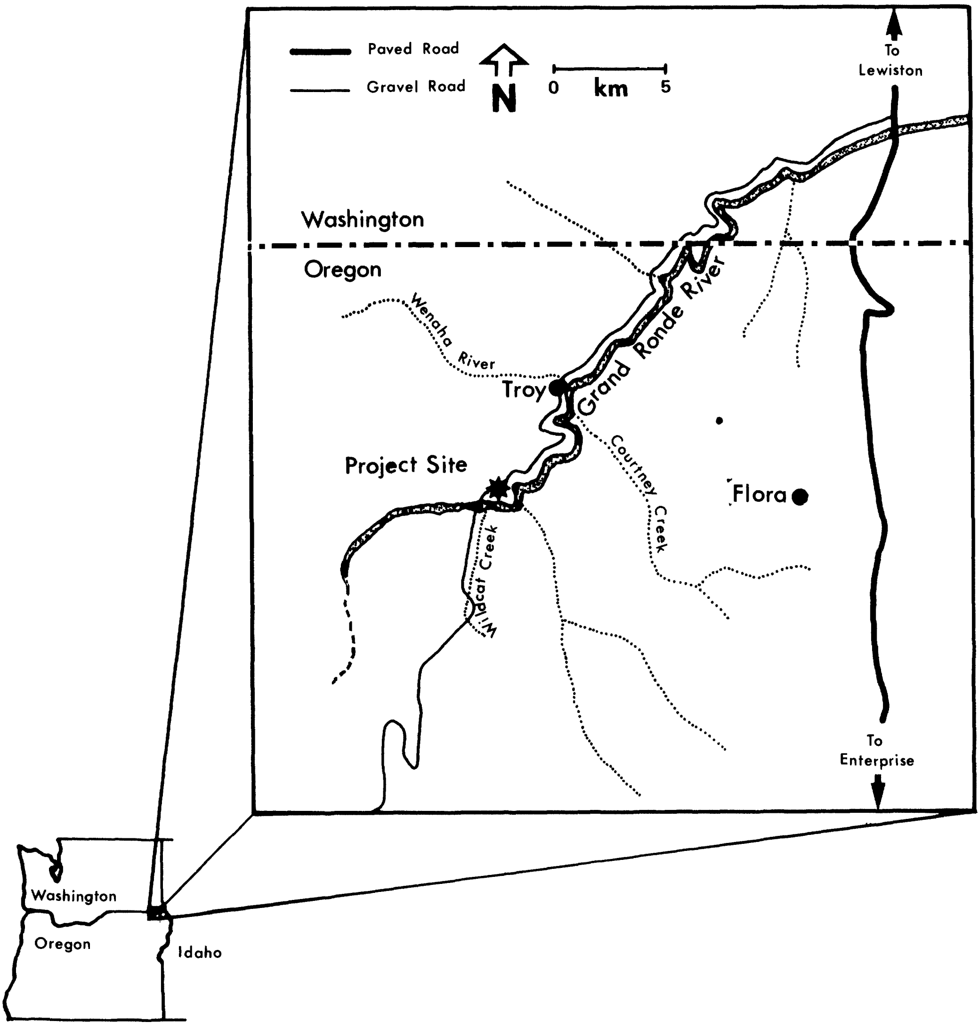

Fig. 1. Location of the study area on the Grande Ronde River, Wallowa County, Oregon.

TABLE 1

Dates of test and control flows from five experiments at the Troy channels, Troy, Oregon, 1980-1981.

Season, Year	Dates	Control Flow (m^3/sec)	Test Flow (m^3/sec)
Spring, 1980	21 Mar - 19 Apr	0.57	0.57
	19 Apr - 15 May	0.57	0.03
Summer, 1980	21 May - 18 Jun	0.57	0.57
	18 Jun - 2 Jul	0.57	0.28
	2 Jul - 16 Jul	0.57	0.03
Fall, 1980	2 Aug - 30 Aug	0.57	0.57
	30 Aug - 13 Sep	0.57	0.28
	13 Sep - 26 Sep	0.57	0.03
Spring, 1981	9 Mar - 4 Apr	0.57	0.57
	4 Apr - 17 Apr	0.57	0.28
	17 Apr - 2 May	0.57	0.03
Fall, 1981	9 Aug - 5 Sep	0.57	0.57
	5 Sep - 19 Sep	0.57	0.28
	19 Sep - 3 Oct	0.57	0.03

flow reduction, flows were reduced from 0.28 to 0.03 m^3/sec. Flows were maintained at this level for two weeks, at which time the experiment was terminated (Table 1). Flows in the control channel were maintained at 0.57 m^3/sec. This schedule was adhered to in four of the five experiments. During the spring 1980 experiment excessive runoff caused us to shorten the experiment by bypassing the intermediate flow of 0.28 m^3/sec (Table 1).

To assess changes in the diel periodicity of drifting organisms, two, 30 cm^2 drift nets set in tandem, (mesh diameter of 750 and 250 μm, respectively) were placed at the downstream end of the test and control riffle. The 250 μm net was placed approximately 30 cm downstream from and partially overlapped the 750 μm net. This was done to facilitate the capture of early instars and/or small insects that may have passed through the larger mesh net.

Thirty minute drift samples were taken 24 h prior to, during and 24 h after each flow reduction in the test and control channels. During the 24 h period prior to and after each flow reduction, drift was taken at 1200, sunset, 2400 and 30 min before sunrise. Flow reductions were initiated at 0800 and completed at 1100. Drift was taken immediately preceeding the flow reduction from 0730-0800 and at the intermediate reduction point from 0915-0945. Current velocity (cm/sec) and stream depth (cm) were taken immediately in front of the drift nets to measure discharge through the nets.

To determine if insects were stranded due to flow reductions, four Hess samples (0.093 m^2) were systematically taken in the test and control dewatered zones one day prior to and two to three hours following each flow reduction. The dewatered zone was designated as the area in the riffle, adjacent to the shoreline, which was exposed following each flow reduction. The dewatered zone was sampled with a Hess sampler and a hydraulic pump which flushed the insects into the net. The insect stranding experiments were conducted during the spring and fall of 1981.

RESULTS

Drift

In four of the five experiments conducted (spring, summer and fall 1980 and spring 1981), reduced stream discharge clearly caused a catastrophic increase in insect drift density (Fig. 2). The initial flow reduction (0.57 to 0.28 m^3/sec) triggered a minor pulse at

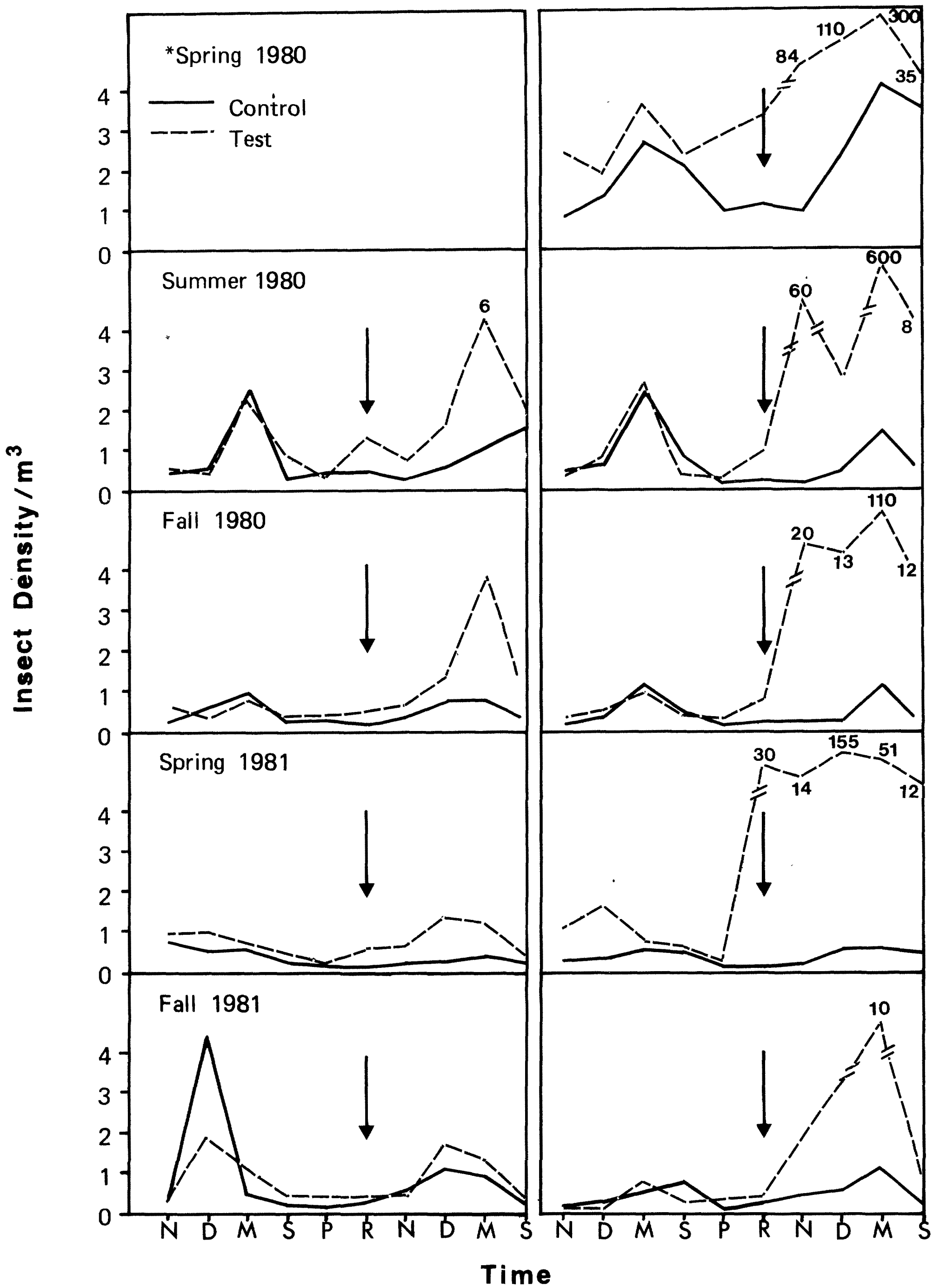

Fig. 2. Insect density (No./m^3) from five experiments. Left arrow indicates reduction from 0.57 to 0.28 m^3/sec; right arrow from 0.28 to 0.03 m^3/sec. Control flow = 0.57 m^3/sec. Double vertical lines denote a two week lapse. N = noon; D = dusk; M = midnight; S = sunrise; P = prereduction and R = reduction. *Spring had only one reduction from 0.57 to 0.03 m^3/sec.

midnight, especially during the summer 1980 experiment. Increased drift density was most evident, however, following the second flow reduction from 0.28 to 0.03 m^3/sec.

A variety of drift responses were noted following the second flow reduction. An immediate response to flow reduction was seen in the spring 1981 experiment (Fig. 2). During the spring, summer and fall 1980 experiments, the first major pulse occurred at noon, one hour after incremental flow reductions were complete. In all of the experiments, however, the greatest drift pulse occurred under the cover of darkness and generally at midnight.

Although a plethora of insects drifted, two species were particularly important, the mayfly, *Baetis tricaudatus* Dodds, and the dipteran *Simulium* sp. In the unregulated control channel, *B. tricaudatus* displayed a high propensity to drift at night (Fig. 3). In the test channel, when flows were reduced from 0.28 to 0.03 m^3/sec, *B. tricaudatus* displayed a delayed catastrophic response at midnight following the flow reduction. *Simulium* sp. showed no consistent drift trend in the unregulated control channel, but responded catastrophically to the second flow reduction (0.28 to 0.03 m^3/sec) in the test channel. *Simulium* sp. entered the drift by noon, only one hour after the completion of incremental flow reductions (Fig. 4).

Insect Stranding

Reduced stream discharge caused peripheral areas of the test riffle to become dewatered and resulted in stranding of benthic insects. Following the initial flow reduction (0.57 to 0.28 m^3/sec) in the spring experiment, only a few insects were stranded (Fig. 5). The second, and more drastic flow reduction (0.28 to 0.03 m/sec) resulted in considerably more insects being stranded. However, greater than half of the insects still managed to reach the refuge of running water (Fig. 5). The principal insect that avoided stranding was the mayfly *B. tricaudatus* (Table 2). "Key" species stranded were the mayfly, *Rhithrogena hageni* Eaton, and the dipterans Chironomidae and *Simulium* sp. Insect density in the control channel dewatered zone remained relatively unchanged throughout both flow reductions (Fig. 5).

Stranding of insects due to reduced stream discharge was much more apparent in the fall 1981 experiment. Both flow reductions (0.57 to 0.28 m^3/sec and 0.28 to 0.03 m^3/sec) resulted in many "key" species becoming stranded, particularly the hydropsychid caddisflies (*Hydropsyche* and *Cheumatopsyche*) and Chironomidae (Table 3). As in the spring experiment, *B. tricaudatus* avoided stranding.

DISCUSSION

Waters (1972), in his review on drift of stream insects, identified three types of drift: catastrophic, behavioral and constant. All three types were observed during this study, however, catastrophic drift was especially apparent because of its role in destabilizing the system and potentially altering trophic dynamic processes.

Generally, a diel periodicity was observed in the control channel with a single peak at midnight. Much work has been conducted showing that most insects are night active (Waters 1972) and that drift is triggered by light intensity (Anderson 1966; Chaston 1968). Other peaks may have occurred during the night, but because of the sampling schedule these were not apparent. The initial flow reduction (0.57 to 0.28 m^3/sec) caused about 8% loss in wetted perimeter and may be the reason why we did not witness a large surge in insect drift. However, catastrophic drift was evident following the second flow reduction (0.28 to 0.03 m/sec), at which time about 31% of the dewatered zone was exposed. Corning (1969) found that as wetted perimeter decreased, insect density increased. Although we lack data to verify this, we believe that the second flow reduction (0.28 to 0.03 m^3/sec) likely caused a short term increase in insect densities because of species and

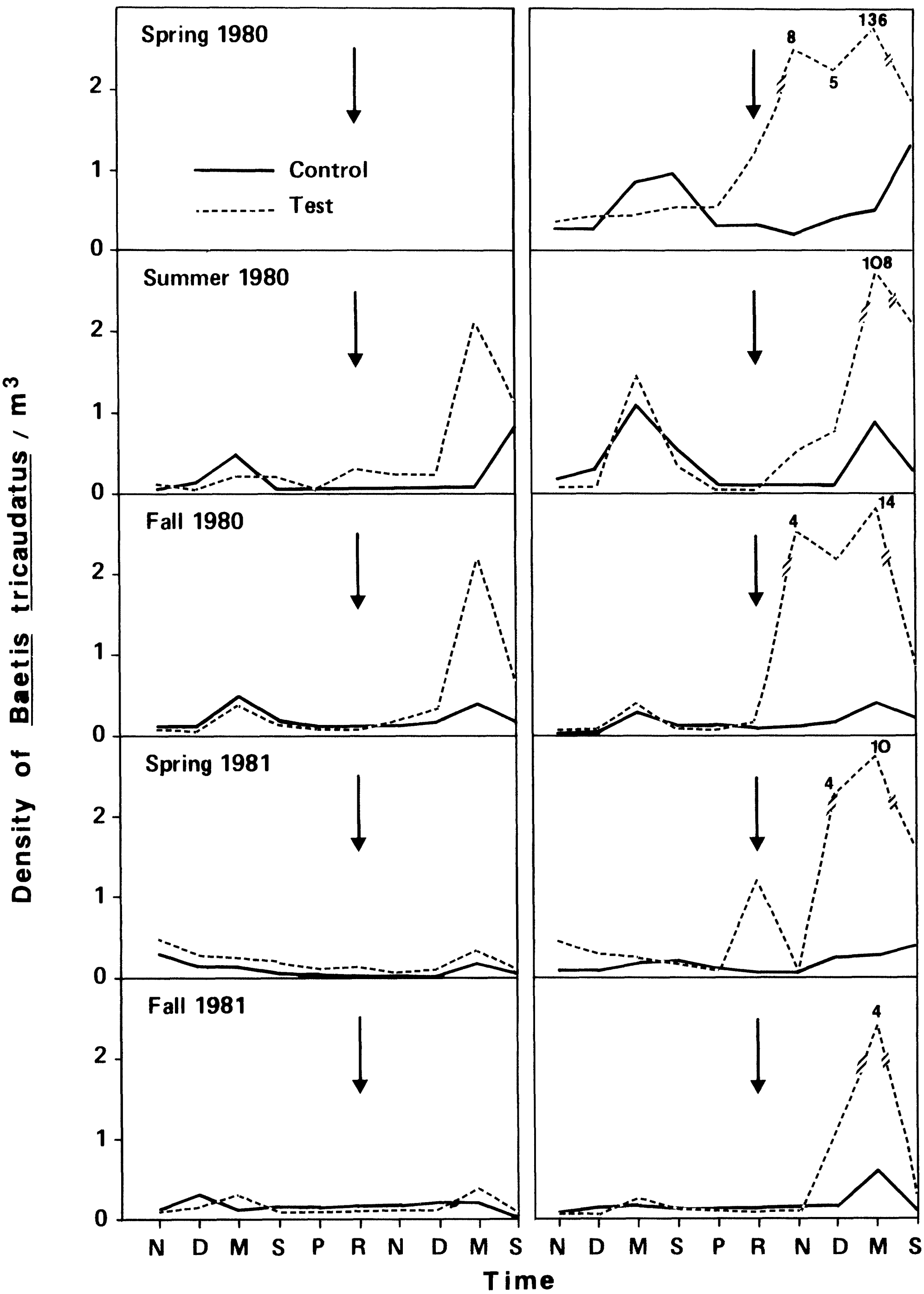

Fig. 3. Density of *Baetis tricaudatus* / m^3 from five experiments. Left arrow indicates reduction from 0.57 to 0.28 m^3/sec; right arrow from 0.28 to 0.03 m^3/sec. Control flow = 0.57 m^3/sec. Double vertical lines denote a two week lapse. N = noon; D = dusk; M = midnight; S = sunrise; P = prereduction and R = reduction. *Spring 1980 had only one reduction from 0.57 to 0.03 m^3/sec.

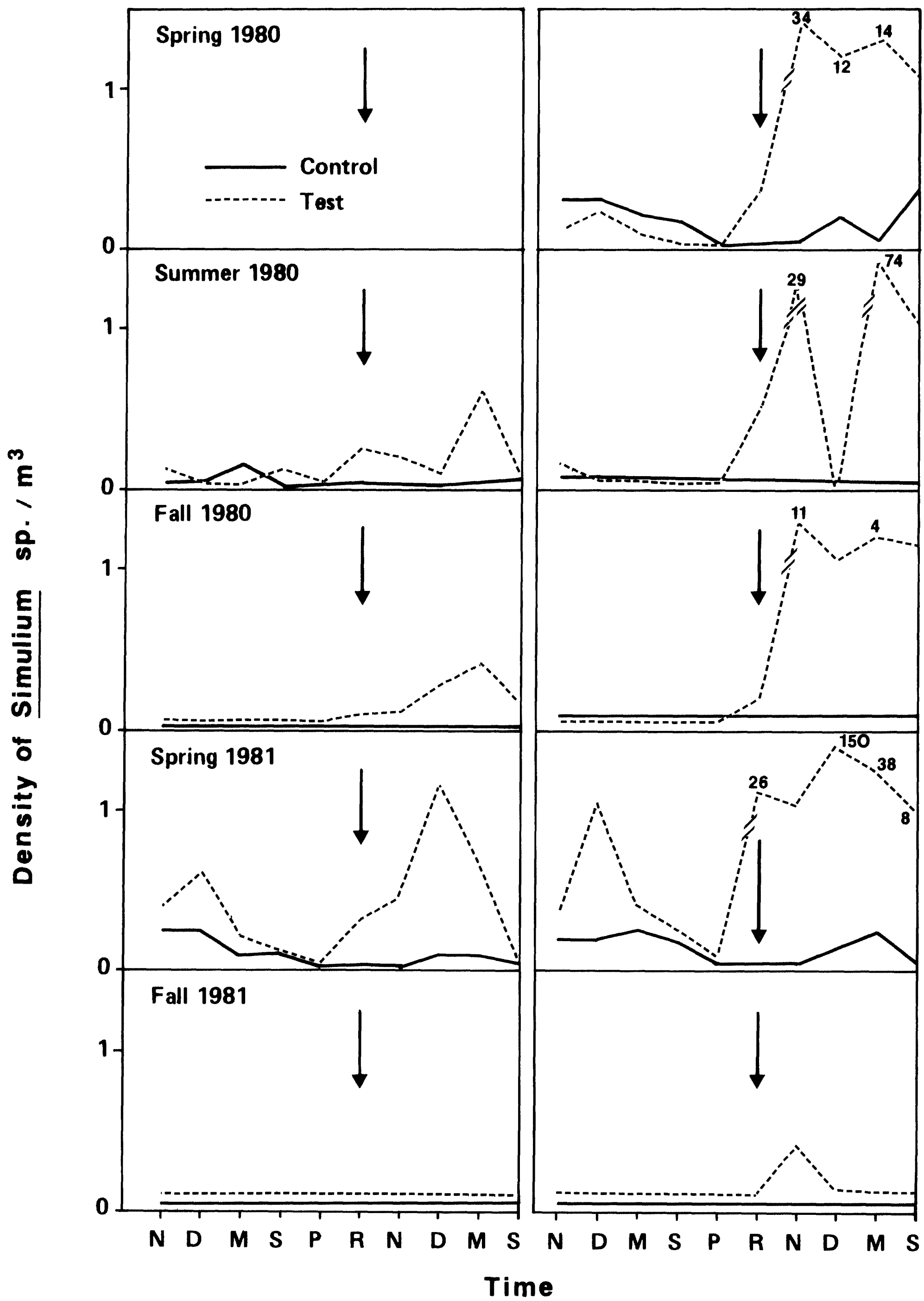

Fig. 4. Density of *Simulium* sp. /m^3 from five experiments. Left arrow indicates reduction from 0.57 to 0.28 m^3/sec; right arrow from 0.28 to 0.03 m^3/sec. Control flow = 0.57 m^3/sec. Double vertical lines denote a two week lapse. N = noon; D = dusk; M = midnight; S = sunrise; P = prereduction and R = reduction. *Spring 1980 had only one reduction from 0.57 to 0.03 m^3/sec.

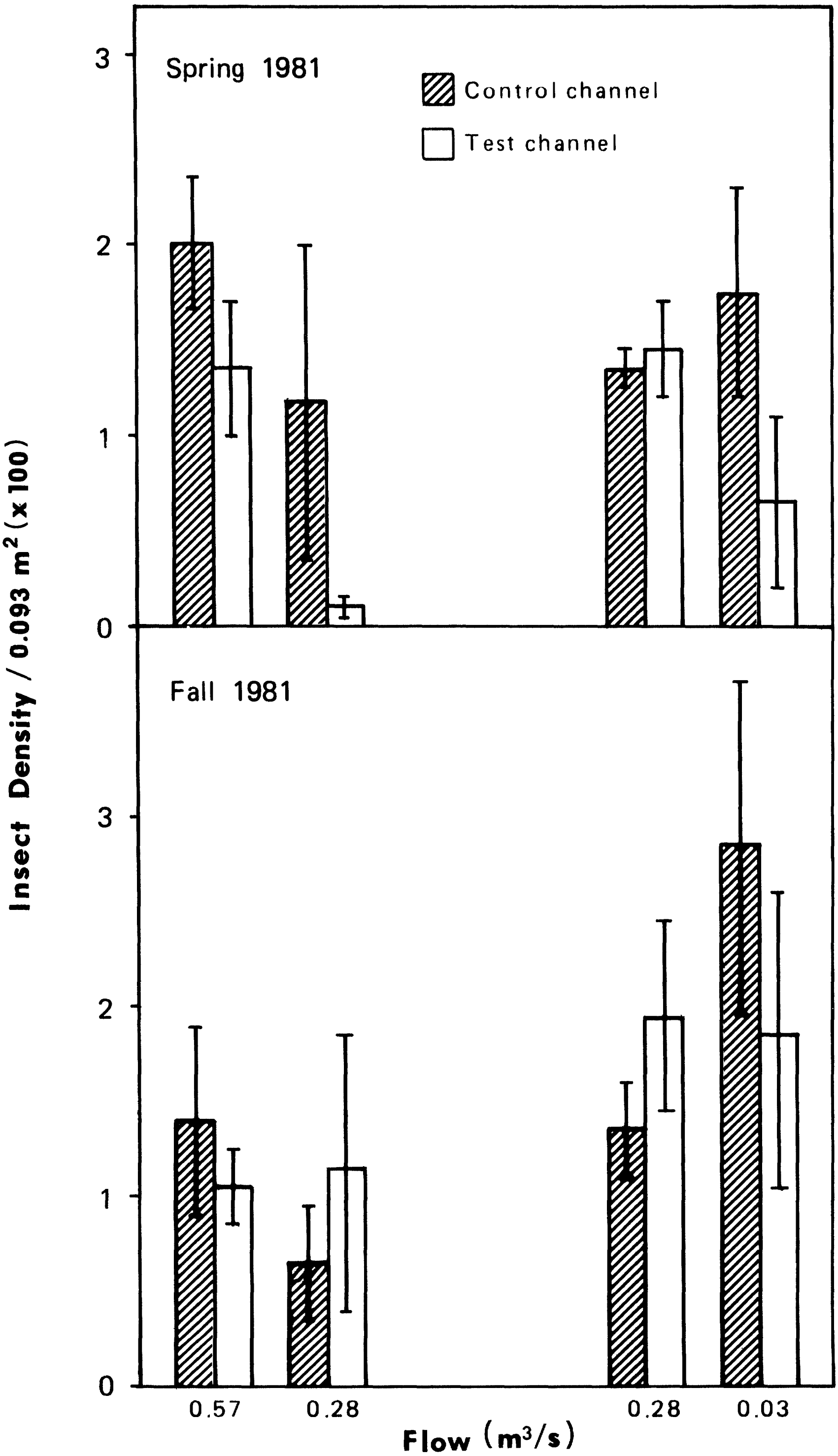

Fig. 5. Mean insect densities / 0.093 m^2 ($\pm$ std. error) from the dewatered zone when test flows were reduced from 0.57 to 0.28 m^3/sec and from 0.28 to 0.03 m^3/sec. Control flow = 0.57 m^3/sec. Spring and fall 1981, Troy channels, Troy, Oregon.

TABLE II

Number/0.37 m^2 of "key" species found in the test and control dewatered zone before and after each flow reduction. Flow reductions were from 0.57 to 0.28 m^3/sec and from 0.28 to 0.03 m^3/sec. Control flow = 0.57 m^3/sec. Spring 1981 experiment, Troy channels, Troy, Oregon.

	Flow Reductions (m^3/sec)			
	0.57	0.28	0.28	0.03
TEST				
Baetis tricaudatus	366	14	282	28
Ephemerella inermis	27	1	21	10
Heptagenia spp.	0	0	1	0
Rhithrogena hageni	53	6	52	38
Hydropsychidae	3	0	1	7
Chironomidae	31	5	188	110
Simulium sp.	2	1	8	51
Total	482	27	453	244
CONTROL				
Baetis tricaudatus	457	312	326	282
Ephemerella inermis	17	9	2	11
Heptagenia spp.	0	0	1	0
Rhithrogena hageni	123	57	37	45
Hydropsychidae	5	0	0	0
Chironomidae	43	46	79	250
Simulium sp.	47	2	13	57
Total	685	426	457	645

TABLE III

Number /0.37 m^2 of "key" species found in the test and control dewatered zone before and after each flow reduction. Flow reductions were from 0.57 to 0.28 m^3/sec and from 0.28 to 0.03 m^3/sec. Control flow = 0.57 m^3/sec. Fall 1981 experiment, Troy channels, Troy, Oregon.

	Flow Reductions (m^3/sec)			
	0.57	0.28	0.28	0.03
TEST				
Baetis tricaudatus	55	11	68	10
Ephemerella inermis	1	1	12	18
Heptagenia spp.	4	6	6	3
Rhithrogena hageni	23	5	95	28
Hydropsychidae	122	144	440	562
Chironomidae	145	266	78	60
Simulium sp.	20	3	0	0
Total	370	436	759	681
CONTROL				
Baetis tricaudatus	77	41	64	71
Ephemerella inermis	8	3	5	17
Heptagenia spp.	25	8	5	4
Rhithrogena hageni	19	14	49	115
Hydropsychidae	177	23	255	541
Chironomidae	204	131	115	255
Simulium sp.	4	0	0	0
Total	514	210	493	905

density "packing" in the more restricted habitat. A temporary "packing" condition would theoretically cause increased density dependent responses, hence, increased drift.

In most of the experiments, insect drift increased before noon following the second flow reduction (0.28 to 0.03 m^3/sec). Minshall and Winger (1968) also noted an increase in daytime drift due to flow reductions. Most of the increase in daytime drift was attributable to *Simulium* sp. Hynes (1970) reported *Simulium* having a very narrow tolerance range to current velocities (80-90 cm/sec). Since *Simulium* is a filter feeder, it congregates in places where the flow is laminar. Because *Simulium* sp. has specific current velocity requirements, sudden flow reductions would likely cause immediate drifting.

The greatest drift pulse following the second flow reduction occurred under the cover of darkness, usually at midnight. Brusven et al. (1974) also observed a delayed catastrophic response to changing stream discharge. We believe that most insects delayed drifting because of the strong overriding influence of light as a triggering mechanisms causing behavioral drift (Anderson 1966; Chaston 1968; Elliot 1965; Müller 1963; Waters 1972). *Baetis tricaudatus* was the most abundant drift component throughout the study. Peters (1973), Redford and Hartland-Rowe (1971) and Ruediger (1980) also reported *Baetis* having a high propensity to drift, especially in response to reduced flows. Without exception, *B. tricaudatus* showed a delayed catastrophic response at midnight following the second flow reduction (0.28 to 0.03 m^3/sec).

After each incremental flow reduction, a substantial amount of riffle was dewatered. This condition was especially evident in 1981 when the riffle was more V-shaped than the trapezoidal cross-section used in 1980. Most insects stranded in the spring experiment were *Rhithrogena hageni,* Chironomidae and *Simulium* sp. Pearson and Franklin (1968) also found *Simulium* readily stranded. In the fall, Chironomidae and the hydropsychid caddisflies were the most abundant insects stranded. Brusven et al. (1974) reported taxonomically similar insects stranded during the flow reduction studies on the Snake River, Idaho.

In the spring, relatively cool air and water temperatures permitted some near-shore insects to survive dewatering. Greater survivability was at least partially attributed to their larger size and greater mobility at this time of the year. In the fall, however, warm air and water temperatures caused rapid drying of the exposed mineral substrate and attached algae mats. Consequently, fall dewatering caused nearly 100% stranding of near-shore insects. At this time, only *B. tricaudatus* effectively avoided stranding. Its greater mobility apparently allowed it to maintain contact with the water column, and contributed to its high drift rate. Pearson and Franklin (1968) observed *Baetis* sp. moving towards deeper water, usually crawling, but occassionally swimming, when subjected to reduced flows.

Insect drift was consistent in its response to reduced stream discharge in all except the fall 1981 experiment. Reasons for the lack of a pronounced behavioral or catastrophic drift during the later experiment are speculative. Walker (1972) found drift to be lowest in the fall on the Clearwater River, Idaho. Many of the insects found in the Troy Channels during the fall were quite small. We believe that small, early instar nymphs were not as mobile as their larger and older counterparts. As a consequence, they were more readily stranded. Since most of the insects in the dewatered zone were stranded in the fall 1981 experiment, they were not available to drift. One might ask, why the disproportionately large drift in the fall 1980 experiment? Due to the trapezoidal shape of the original channels, dewatering was not a major problem with respect to large changes in wetted perimeter, therefore, insects were not likely to be stranded and were able to drift.

Our results clearly show that seasonally reduced stream discharge has a variety of impacts on benthic invertebrates. Season-specific responses to flows are important for proper management of regulated lotic systems. Fortunately, manipulated flow reductions are not common in the spring for most streams since ample water is available from winter snowpacks. We feel that summer and fall are the most critical times for stream insects subjected to flow reductions. Warm air and water temperatures combined with the inability of many early instars and/or small insects to reach the refuge of running water could result in high rates of mortality for many insects. The least damaging time of day to reduce flows would be at night since most insects are night drifters. Cooler nighttime air and water temperatures would retard evaporation and allow more time for insects to escape or to be rewatered if the system were subjected to daily fluctuations. Other management considerations should include species present, geographic location and sight feeding fish dependent upon benthic insects as a food source.

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