The Effects of Water Flow Manipulation Below a Hydroelectric Power Dam on the Bottom Fauna of the Upper Kennebec River, Maine[1, 2]

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ABSTRACT

We studied the effect of severe fluctuations in flow on the distribution of bottom fauna of the upper Kennebec River. During the years 1964–1970, discharges below Wyman Dam ranged from 8.5 m^3/sec to an average daily high of about 170 m^3/sec. Slow currents resulting from low flows appeared to limit the diversity and abundance of swift-water aquatic insects on the river-bottom below the dam. Sampling stations above the impoundment averaged 19 aquatic insect genera, while those below the dam averaged 11. About 19 genera were found at stations where the current near bottom fluctuated from 0.5 m/sec to 0.9 m/sec while only 4 genera were found at stations where the fluctuations were from 0.1 to 0.5 m/sec. Aquatic insects adapted for swift water such as *Rhyacophila, Chimarra, Iron, Blepharocera, Acroneuria,* and *Paragnetina* were more abundant above the impoundment than below, and were absent from those stations below the impoundment with the lowest current velocities.

The purpose of this study, conducted in 1970, was to determine the effects of severe fluctuations in flow on the bottom fauna in the Kennebec River.

From 1964–1967 the water flow pattern below Wyman Dam changed from a continuous discharge of large volumes to one of severe daily fluctuations. Daily low flows of less than 8.5 m^3/sec were held for periods of 1 to 6 hr, whereas daily high flows averaged about 170 m^3/sec. In 1968, the Maine Department of Inland Fisheries and Game reported (unpublished) that the rainbow trout (*Salmo gairdneri*) sport fishery of the upper Kennebec River had substantially declined. Severe daily water flow fluctuations below the hydroelectric power generation stations along the river were suspected as one of the causes of this decline.

Powell (1958) showed that power dam water releases were detrimental to a downstream fishery because their flushing action dislodged bottom organisms from the substrate and reduced bottom fauna populations. Aquatic insect weights per 0.1 m^2 above the reservoir were up to 32 times greater and never less than 2.5 times greater than weights per 0.1 m^2 below the dam. Aquatic insect populations increased at greater distances downstream from the dam. Maciolek and Needham (1951), Lake (1957), and Kennedy (1967) found that severe floods dislodged bottom organisms as the increased water velocity scoured the stream bottom and flushed members of the aquatic community from their normal niches. Maciolek and Needham reported that the greatest number of drifting foods was always found during periods of peak flow. The drift organisms captured during periods of peak flow were generally the smaller ones of weak attachment while fluctuating flows dislodged large numbers of aquatic organisms.

STUDY AREA

The Kennebec River originates in Moosehead Lake in west-central Maine and pursues a southerly course for some 212 km to the head of Merrymeeting Bay (Fig. 1). Here it joins the Androscoggin River and continues for 32 km more to its confluence with the Atlantic Ocean.

The study area encompassed a 47-km section of the upper Kennebec River, from the Forks, at the confluence of the Dead River and Kennebec River, downriver to Williams

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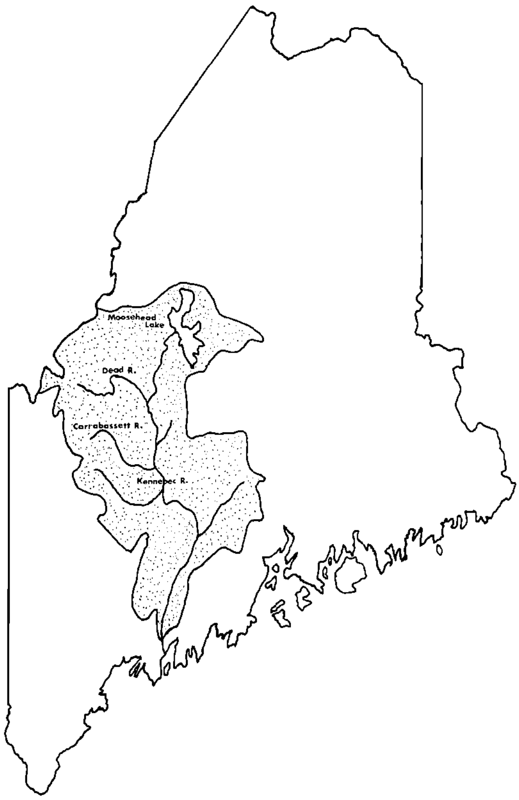

FIGURE 1.—Extent of the Kennebec River drainage in Maine.

Dam at Solon. Two major hydroelectric power dams inundate 27 km or 59% of this section of river (Fig. 2). Wyman Dam and Williams Dam have gross static heads of 43.3 and 14.6 m, respectively and have no fish passage facilities. The Wyman Dam impoundment is 21 km in length. Above the Wyman impoundment, the Kennebec River has an average gradient of 5.8 m/km. Below the impoundment the average gradient is about 3.7 m/km.

Two riffles on the Carrabassett River were sampled for qualitative comparisons to the Kennebec bottom fauna. The Carrabassett River is a large tributary of the Kennebec which enters below Solon. There are no hydroelectric power dams on the Carrabasset River and water flows are determined by the amount of precipitation and rate of natural runoff. Seasonal fluctuations in water flow occur but daily fluctuations are minimal.

WATER FLOW

Water flows below the Forks are regulated by the Harris Station hydroelectric power dam at Indian Pond and to a lesser degree by Long Falls Dam on the Dead River, a tributary of the Kennebec (Fig. 2). The turbines at Harris Station operate at peak during daylight hours and drop to much lower generating rates about midnight. Low flows around 5.7 m^3/sec at Harris Station last about 5 hr. High flows during daylight hours averaged around 56.6 m^3/sec. The gates of Harris Dam are opened wide at 7:00 AM and the increase in flow is observed at the Forks by 10:00 AM.

Water flows below the Wyman impoundment are regulated by Wyman Dam. Turbines operate at peak during the daylight and evening hours only, and stream flow is drastically reduced from midnight to 7:00 AM. In 1970, the average of the daily minimum instantaneous discharges for June through September was 7.8 m^3/sec. The average of the daily maximum instantaneous discharges for this same period was over 170 m^3/sec.

Water storage was well above normal for most of the 1970 water year (October 1969 through September 1970). Mean monthly discharges measured by the U. S. Geological Gauging Station at Bingham were above normal from November through March. Unseasonably warm weather and heavy rains at the end of December 1969 resulted in flooding, and discharges peaked at 963 m^3/sec on 30 December. In the spring, high run-off occurred from 24 April through 23 May 1970. Water spilled over the top of Wyman Dam throughout this period. The ice went out of Wyman Lake on 4 May, and discharges peaked at 858 m^3/sec.

SAMPLING STATIONS

Nine riffle areas were chosen for sampling (Fig. 2). Three sampling stations, A, B, and C, were located above the Wyman impoundment, and six stations, D through I, were located below. The width of the river at all sampling stations ranged from 46 to 137 m. At each station the river bottom was composed mainly of rubble ranging in size from 7 to 30 cm in diameter, with some sand and coarse gravel.

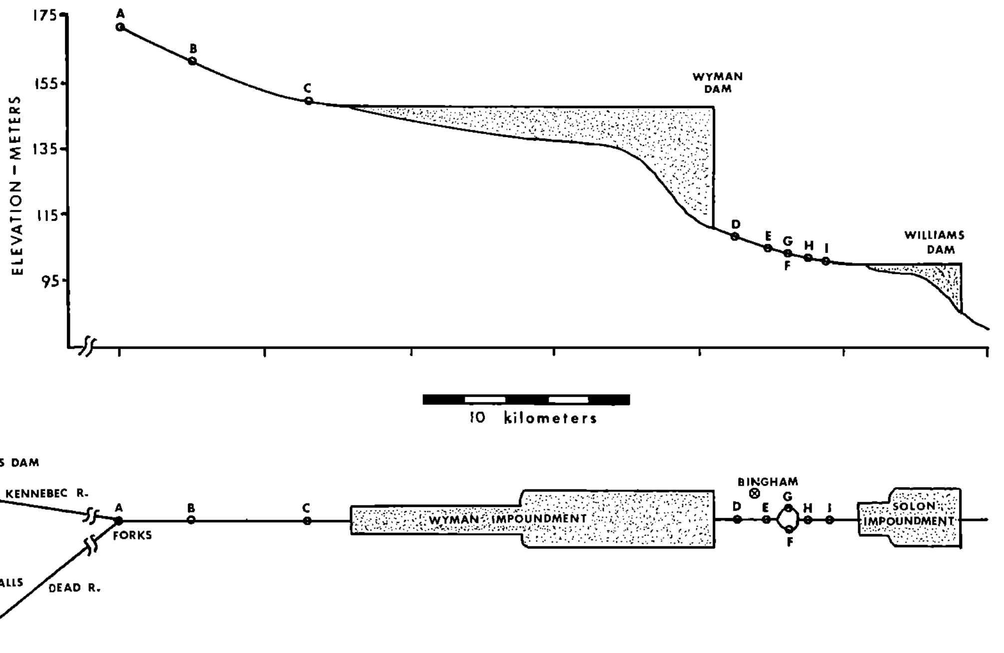

FIGURE 2.—Diagrammatic representation of study area showing location of sampling stations and hydroelectric dams.

The two riffles sampled on the Carrabassett River were about 23 m wide and the substrate was composed mainly of rubble ranging in diameter from 7 to 30 cm.

METHODS AND MATERIALS

The river below Wyman Dam was accessible for bottom sampling only during the first few hours of daylight, before the gates of the dam were opened, and the number of samples that could be taken was limited. Sampling was biased in favor of rocks with exposed, overhanging leeward edges and such biases were employed at every sampling station.

Five 0.1-m^2 bottom samples were collected from each station on the Kennebec River at approximately 20-day intervals during June and July 1970. Stations F and H were sampled only twice because of continuous high flows. Thirty-one samples were collected from the Carrabassett River at irregular intervals throughout the summer. The 0.1 m^2 samples were preserved individually in 70% ethyl alcohol and returned to the laboratory for numerical and volumetric analysis.

Each sample from the Kennebec was sorted according to taxonomic groups and the volume of each insect order determined. Insects were then sorted to genera. Most aquatic Diptera were identified to family and other organisms identified to classes. Bottom samples from the Carrabassett River were analyzed qualitatively only.

Current velocities were measured with a #622 Gurley Current Meter at each sampling station except F on the Kennebec. Continuous high flows prevented measurements of current at Station F. Current velocities were measured 5 cm from the bottom at each station during low flow and while the river was rising to determine the rate of change.

RESULTS

Over 6,000 bottom organisms, mostly insects, were collected from the Kennebec River, 3,302 above the Wyman impoundment and 3,131 below. The majority of these aquatic invertebrates were insects. The orders Trichoptera, Ephemeroptera, Plecoptera, and Diptera made up most of the standing crop of

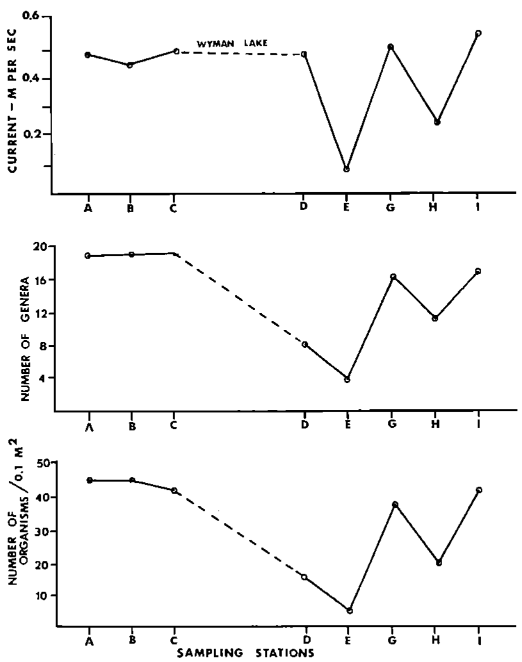

FIGURE 3.—Graphs showing the relationship of current velocity to numbers and diversity of aquatic organisms on the bottom of the river.

There were nine genera each of Trichoptera and Ephemeroptera and five genera of Plecoptera. Diptera larvae were represented by six families.

Stations A, B, C, G, and I had a much higher number of organisms per 0.1 m^2 of bottom than stations D, E, and H. Stations D and E had very meager bottom fauna. The average for the three stations above the Wyman impoundment was considerably higher than the average for the six stations below the dam.

Sampling stations having the lowest currents during periods of low flow (Fig. 3) were found to be impoverished both in numbers and diversity of aquatic insect fauna. The number of genera averaged 19 for stations above the impoundment and 11 for stations below the impoundment. Stations D and E below Wyman Dam were particularly impoverished. Station E had only four genera throughout the entire sampling period.

Trichoptera.—Caddis larvae made up the major portion of the biomass in samples in both sections of the river and were dominant both in number and volume (Table 1). *Hydropsyche* and *Cheumatopsyche* were dominant and were present at all sampling stations except E. The percentages of *Rhyacophila* and *Chimarra* were much higher for stations above the impoundment than those below (Table 1). *Rhyacophila* was present at all stations above the impoundment, but was found only at G below. *Chimarra* was present at all stations above the impoundment but was absent from Stations D, E, F, and H below.

TABLE 1.—*Percent composition by number and volume of major groups of stream bottom organisms in the Kennebec River above and below the Wyman impoundment*

Bottom fauna	Above the Wyman impoundment		Below the Wyman impoundment	
	Numbers	Volume	Numbers	Volume
Trichoptera	45	40	41	55
Hydropsyche	23		28	
Cheumatopsyche	12		9	
Chimarra	6		0.7	
Lepidostoma	3		2	
Rhyacophila	0.7		0.001	
Ephemeroptera	36	20	31	19
Ephemerella	6		8	
Iron	18		3	
Paraleptophlebia	1		6	
Heptagenia	3		6	
Ameletus	7		7	
Plecoptera	5	17	6	7
Alloperla	2		5	
Acroneuria	2		1	
Diptera	8	2	15	9
Tendipedidae	4		12	
Simulidae	0.9		2	
Blepharocera	2		0	
Coleoptera	1.4		0.3	
Elmidae	1		0.3	
Annelida				
Hirudinea	2	21	1	5

Ephemeroptera.—Mayfly nymphs ranked second in abundance and volume above and below the Wyman impoundment. Mayfly counts might have been somewhat higher since it is likely that some minute nymphs escaped detection and capture. *Ephemerella* was present at each sampling station. Nymphs of *Rhithrogena* with well developed wing pads were present at all stations except D and E during the first sampling series in early June. They had emerged before the third series of samples was taken in July (Table 2). *Iron* was present at all stations except D and E and decreased in numbers in the third series of samples in July. *Iron* was six times more abundant above than below the Wyman impoundment (Table 1). *Heptagenia* was absent in the first series of samples taken in early June. They appeared at all stations as very small nymphs during the second series and were larger and had better developed wing pads by mid-July when the third series of samples was taken (Table 2). *Paraleptophlebia* was six times more abundant below the Wyman impoundment than above (Table 1).

Plecoptera.—Nymphs of Alloperla were present at all stations during the first and second sampling series, but absent from most samples in July (Table 2). Adults emerged during the early morning hours in June. *Alloperla* was the only organism present in a few of the samples taken at station E with nymphs comprising 63% numerically of all organisms present in the first series of samples, and 91% numerically of all organisms present in the second series. *Alloperla* was twice as abundant below the Wyman impoundment. Collectively, nymphs of *Acroneuria*, *Paragnetina*, and *Neophasganophora* were more than twice as abundant above the Wyman impoundment than below (Table 1). They were absent from stations D, E, and G below the impoundment. Below the impoundment 40 of the 41 specimens were found at stations G and I.

Other Insects.—The larvae and adults of the coleopteran family Elmidae were three times more abundant above the Wyman impoundment. Dipteran larvae of the family Tendipedidae were three times more abundant below the Wyman impoundment. The larvae and pupae of *Blepharocera* were only found at stations A, B and C.

Carrabassett River.—A qualitative comparison of insect genera showed the bottom fauna of the Kennebec and Carrabassett Rivers was similar. Some exceptions were noted. The caddis larva *Pycnopsyche* and the dragonfly nymph *Ophiogomphus* were commonly found in slow flowing water and at the edge of pools in the Carrabassett River. Both were absent from the Kennebec fauna. The mayfly nymph *Isonychia*, a food strainer, and the caddis larva *Macronemum*, a net spinner, were commonly found on riffles in the Carrabassett River, but only in isolated instances in the Kennebec River. The caddis larva *Helicopsyche* was present in the Carrabassett fauna but absent from the Kennebec fauna.

TABLE 2.—*Changes in abundance of different insect genera in bottom samples throughout the sampling period. Figures represent percent of total samples*

Organism	Station	Sampling periods: 1st series 6/4–6/17	2nd series 6/19–7/1	3rd series 7/8–7/23
Alloperla (stonefly)	B	8	5	0.6
	D	14	14	0
	E	63	91	0
Rithrogena (mayfly)	A	2	0	0
	B	10	4	0.4
	C	3	1	0
	I	3	0	0
Heptagenia (mayfly)	A	0	3	9
	C	0	1	6
	G	0	0	7
	I	0	1	10

DISCUSSION

In 1969, the Maine Department of Inland Fisheries and Game recommended to the Central Maine Power Company that minimum flows in the Kennebec River below Wyman Dam be kept above 14 m^3/sec (Foye, Ritzi, and AuClair 1969). Records obtained from the U.S. Geological Survey showed that daily minimum instantaneous flows below Wyman Dam averaged 7.8 m^3/sec from June through September 1970. Minimum flows were below 8.5 m^3/sec on 100 nights during this period and dropped below 5.6 m^3/sec on 11 nights. During these low flows, approximately one-fourth of the riverbottom was dewatered, resulting in reduced bottom fauna production. Several side channels were completely dewatered.

From an ecological standpoint, the Kennebec River is essentially two different rivers. During low flows, with discharges at about 7.8 m^3/sec, it consists of riffles and pools, similar to the Carrabassett River. The Kennebec River below Wyman Dam at high flows, when discharges reach 170 m^3/sec, may be considered as one long uninterrupted stretch of swift flowing water.

Station E below the Wyman impoundment showed low species diversity and few individuals although the substrate appeared suitable for colonization. During the daily low flows the current near bottom at station E dropped to 0.1 m/sec (meters per second), the lowest at any station. During the daily high flows, the current near bottom increased to 0.5 m/sec. Riffle organisms cannot survive for long in reduced flows and pool organisms cannot remain long in high flows (Ruttner 1953; Philipson 1955). Consequently, very few organisms could accommodate themselves to these daily fluctuating flows.

The biota of standing water contrasts sharply with that of rapidly flowing water. Ruttner (1953) states, "With respect to the biotas of the bottom of streams, the slower the current is, the more the composition and configuration of these communities approach those of standing water. If representatives of a torrential fauna are transplanted into standing water, many of them perish with symptoms of suffocation even after a few hours."

Philipson (1955) showed that swift water species of caddis larvae of the genera *Rhyacophila* and *Hydropsyche* can tolerate low oxygen concentrations in flowing water but will be readily immobilized in still waters even at relatively high oxygen concentrations. *Rhyacophila* was not found at stations E and H below the Wyman impoundment, the two stations having the lowest current velocities during the periods of low flow, 0.11 and 0.24 m/sec respectively.

Caddis larvae from the families Hydropsychidae and Philopotamidae are confined to running water and spin silk nets to catch their drifting planktonic prey. Philipson (1955) showed that members of these two families will not spin nets in slower flowing and still water. Thus, *Chimarra,* a net-spinner, was absent from station E and H. *Hydropsyche,* another net-spinner, was absent from 80% of the samples taken at station E.

Thus, low water flows are a limiting factor in the Kennebec River below Wyman Dam for *Rhithrogena, Iron, Acroneuria, Paragnetina, Rhyacophila, Blepharocera,* all adapted for swift water. Only a few organisms such as the stonefly nymph of *Alloperla* were able to tolerate the wide variations in waterflow.

Conversely, high flows may eliminate organisms adapted to slow flowing or still water. The dragonfly nymph *Ophiogomohus,* and the caddis larva *Pycnopsyche* were present in considerable numbers in the slower flowing waters and pools in the Carrabassett River. Both organisms were conspicuously absent from the Kennebec River. These two species could probably survive in the Kennebec River during periods of low flow, only to be swept away by the daily flow increases.

The mayfly nymph *Paraleptophlebia* is a cavity dweller and inhabits the spaces between the rubble, withdrawn from the full force of the current. Its body is streamlined so it can dart from place to place. This species was six times more abundant below than above the Wyman impoundment and is probably able to tolerate lower currents better than the nymphs of *Rhithrogena* and *Iron.*

During daily periods of low flow, many riffles were shallow. During periods of high flow, the depth of the river increased from 0.6 to 0.9 m. Needham (1934) noted that deep swift riffles produced a smaller standing crop of bottom fauna than shallow swift riffles.

Most of the insects in streams exhibit an annual turnover (Armitage 1958). When a species emerges, most of the population is removed from the stream in a period of several days or a few weeks. Thus, the population of most insect species is reduced to zero and grows back to its peak in the subsequent year. Ordinarily the insect population of a stream is not reduced to zero as the period of emergence varies from species to species. The stonefly nymph *Alloperla* and the mayfly nymph *Rhithrogena* emerged before the end of June and were rarely found in the July samples. The mayfly nymph *Heptagenia* reached its peak of abundance in bottom samples in July and probably emerged later in the summer.

Although 42 genera were identified during this investigation, most individuals belonged to only a few genera. Over 90% of the caddis larvae belonged to the genera *Hydropsyche* and *Cheumatopsyche.* Nearly 90% of the stoneflies belonged to the genera *Alloperla* and *Acroneuria.* Tendipedidae accounted for most of the Diptera, and Elmidae for most of the Coleoptera.

Foye, Ritzi, and AuClair (1969) noted that the operation of the gates of a dam by fast power-operated units results in drastic changes in stream flow in a matter of minutes and does not allow sufficient time for stream animals to adjust. Powell (1958) showed that fast water releases from a power dam reduced insect populations in the river below and that insect populations increased at further distances downstream from the dam. A similar situation was found in the Kennebec River below Wyman Dam. Insect populations generally increased downstream from the dam (Fig. 3). Stations D and E closest to the dam had meager bottom faunas which may be attributed to the flushing and scouring effect of severe water flow fluctuations. At station E, flow near bottom increased fourfold in less than 1 hour.

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