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EVALUATION OF THREE BOTTOM GRAB SAMPLERS FOR COLLECTING RIVER BENTHOS[1]

PHILIP A. LEWIS, WILLIAM T. MASON, JR.[2] and CORNELIUS I. WEBER, Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, OH 45268

ABSTRACT. The performances of the standard Petersen, Ekman, and Ponar grabs were compared using 2 sets of samples collected from gravel, sand, silt, and mud substrates. The data obtained during this study show that estimates of macroinvertebrate populations may vary considerably depending on the grab utilized, the nature of the substrate, and the number of replicate samples collected. The Ekman sampler was rated as best in mud and also received a high rank in silt, while the Petersen received the highest rank only in sand. The Ponar sampler was the best overall grab on the basis of the numbers of individuals and taxa collected, precision, and mechanical operation.

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INTRODUCTION

The Petersen, Ekman, and Ponar grab samplers are the principal sampling devices used to collect bottom-dwelling macroinvertebrates in inland water quality investigations (American Public Health Association 1975, Mitropol'skiy and Mordukhay-Boltovskoy 1975). Reports by Flannagan (1970), Howmiller (1971), Hudson (1970), and Powers and Robertson (1967) have indicated that the Ponar grab is superior to the Ekman on compacted

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[2]Present address: U.S. Fish and Wildlife Service, Box 44, Kearneysville, WV 25430.

lake sediments because of its deeper penetration. Flannagan considered the Petersen grab to be less effective than the Ponar because the design of the Petersen does not allow free passage of water during descent, and organisms might be lost from the sample compartment during closure.

The Ekman is considered unsuitable for sampling in coarse and compacted substrates because of its closing mechanism and light weight (Weber 1973). Howmiller (1971), however, found that the Ekman grab performed better than the Ponar in soft sediments, probably because it produced less of a shock wave as it descended, and caused less "blowout" of surface-dwelling organisms before entering the substrate. Bakanov (1977) found that samples collected with an Ekman grab from the silty substrates of a reservoir contained more chironomids than samples obtained with a Petersen grab because it collected a greater volume of sediment.

There are no published reports, however, that compare the performances of these 3 grabs in the common river substrates. This study was conducted to determine the precision and comparability of data obtained by the 3 grabs from gravel, sand, silt and mud, in rivers.

METHODS AND MATERIALS

The grabs compared in this study were the Foerst modification of the Petersen (0.064 m^2; 24.1 × 26.7 cm cutting edge; 12.8 kg), the Ekman (0.023 m^2; 15.2 × 15.2 cm cutting edge; 5.5 kg), and the Ponar (0.052 m^2; 22.9 × 22.9 cm cutting edge; 20.9 kg). Two sets of samples were collected each from gravel, sand, silt, and mud substrates: Set I consisted of 4 replicates from each substrate collected in 1968 and 1969; Set II consisted of 6 replicates from each substrate collected in 1970 (fig. 1).

Using a winch, the Ponar and Petersen grabs were lowered slowly to the bottom to reduce the disturbance of the upper layer of sediment. The Ekman sampler was hand operated during the collection of both sets of samples. Upon retrieval, the samples were checked for evidence of disturbance and volume of material. Collections that were not considered representative were discarded. The Ekman grab was manually forced into the gravel substrate during the 1970 collection to determine if greater penetration and increased volume of material would substantially increase efficiency.

The samples were washed through a U.S. Standard No. 30 sieve (0.595 mm openings) and were treated as described in Standard Methods (American Public Health Association 1971). The organisms were identified to genus or species, except for worms, which were identified to family, and the counts were converted to number of individuals/m^2. Diversity was expressed as number of taxa/sample.

Welch's (1948) method for dry analysis of bottom sediment for particle size determination was used in conjunction with Cummins' (1962) modification of the Wentworth particle size classification (table 1). The silt-clay fraction, however, was considered silt if it was of a fine, loose consistency upon drying, and mud if it was of a sticky consistency and formed hard lumps.

RESULTS AND DISCUSSION

GRAVEL. In both sets of samples taken from gravel, the Ponar grab collected the largest number of taxa, the largest number of individuals/m^2, and had the lowest coefficient of variation (CV = standard deviation × 100/mean) of the 3 grabs tested (figs. 1 and 2, table 2). In Set I, the numbers of individuals collected with the Ponar were significantly larger than those collected by the other 2 grabs (table 3). Intact Ekman samples were obtained only after repeated mistrials caused when gravel lodged between the jaws.

In Set II, where the Ekman grab was manually forced into the substrate, the CV was smaller than in Set I, and the mean number of organisms collected/m^2 was not significantly different from the values obtained with the other 2 grabs. The Ekman still did not collect as many taxa as the other 2 grabs, however, probably because of the smaller area sampled (Paterson and Fernando 1971).

The percent abundance of chironomid larvae, mollusks, oligochaetes, and other taxa was similar in both sets of samples regardless of the grab used (table 2). The large percentage of "Other Taxa" for Set II samples was due to the abundance of larvae of the caddisfly, *Potamyia flava*.

Data from the 2 sets of samples indicated that to achieve a specified level of precision (Elliott 1971), fewer replicates would be needed with the Ponar than with

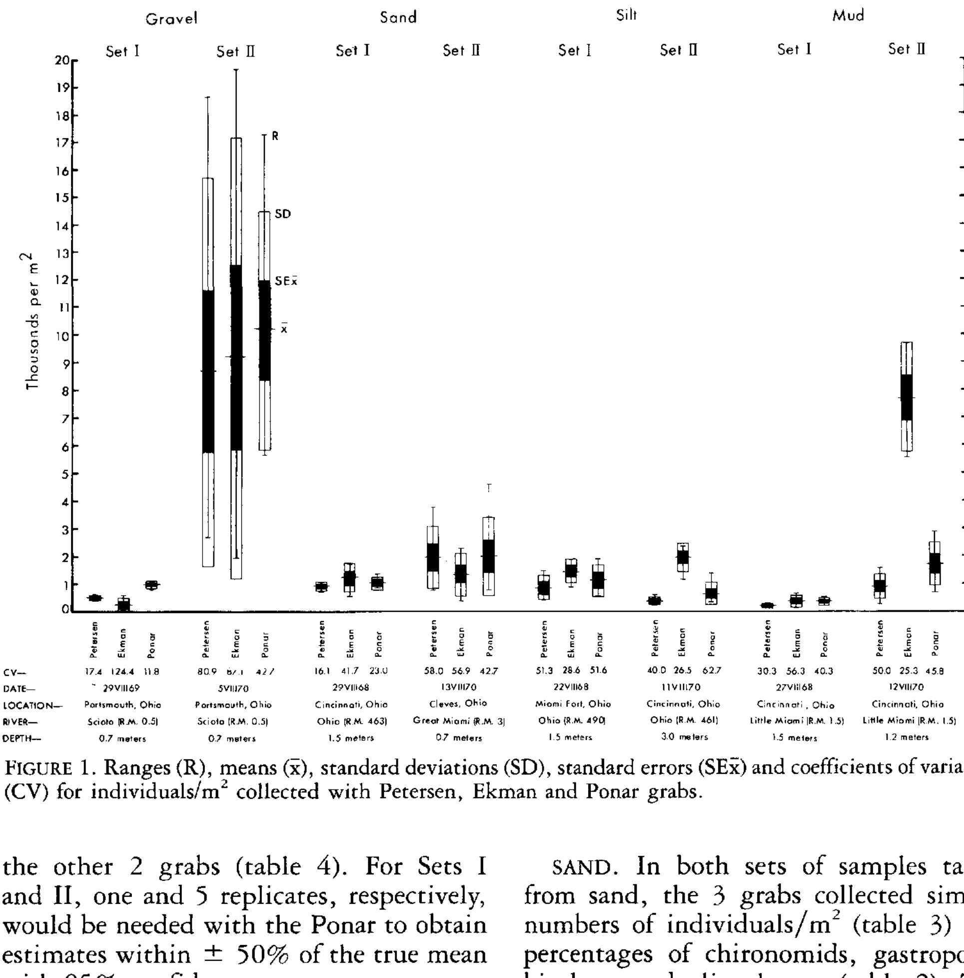

FIGURE 1. Ranges (R), means ($\bar{x}$), standard deviations (SD), standard errors ($SE\bar{x}$) and coefficients of variation (CV) for individuals/m^2 collected with Petersen, Ekman and Ponar grabs.

the other 2 grabs (table 4). For Sets I and II, one and 5 replicates, respectively, would be needed with the Ponar to obtain estimates within ± 50% of the true mean with 95% confidence.

SAND. In both sets of samples taken from sand, the 3 grabs collected similar numbers of individuals/m^2 (table 3) and percentages of chironomids, gastropods, bivalves, and oligochaetes (table 2). The

TABLE 1

Particle size analysis of substrates.

Substrate Type	Particle Size Range	% of Substrate in Each Size Range: Scioto River	Great Miami River	Ohio River	Little Miami River
Gravel	(2-64 mm)	84.4	2.0	0.3	0.0
Very Coarse Sand	(1-2 mm)	7.1	15.3	0.8	0.0
Coarse Sand	(0.5-1.0 mm)	4.1	34.8	0.8	0.2
Medium Sand	(0.25-0.5 mm)	3.3	40.6	8.4	0.6
Fine Sand	(0.125-0.25 mm)	0.3	1.7	5.8	2.3
Very Fine Sand	(0.0625-0.125 mm)	0.1	3.4	45.9	30.6
Silt-Clay Fraction	(0.0625 mm)	0.3	2.2	38.0	66.3
MAJOR CLASSIFICATION		Gravel	Sand	Silt	Mud

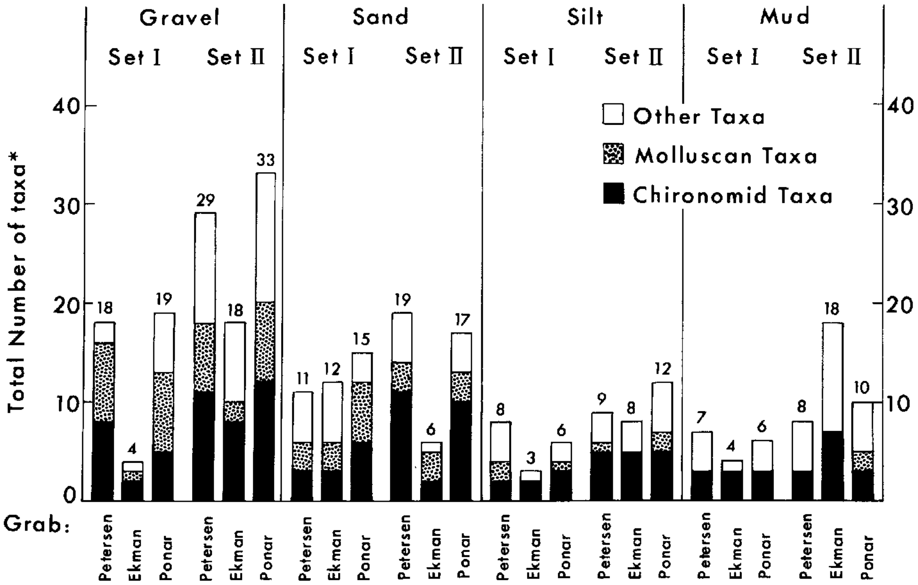

FIGURE 2. Number of chironomid, molluscan and other taxa collected by Petersen, Ekman and Ponar grabs from four substrate types. See figure 1 for dates and station locations. (Set I = 4 replicates, Set II = 6 replicates.)

CV's for Sets I and II revealed that no one grab consistently had a greater sampling precision (fig. 1). The Ekman samples, however, were obtained only after repeated mistrials because of the inadequacy of the closing mechanism.

In Set I, the numbers of taxa collected by the 3 samplers were not significantly different at the 5% level, whereas in Set II, the Ponar and Petersen collected significantly larger numbers of taxa than did the Ekman (table 3). Species present in the Ponar and Petersen grabs, but absent in the Ekman samples included: Chironomidae—*Psectrocladius* sp., *Conchapelopia* sp., *Ablabesmyia mallochi*, *Polypedilum halterale*, *Chironomus attenuatus* and *Rheotanytarsus* sp.; other Diptera-Ceratopogonidae; and Nematoda.

The data from sample Sets I and II indicate that 2 and 9 replicates, respectively, would be needed to obtain a ± 50% level of precision with the Petersen grab, whereas 3 and 13 replicates, respectively, would be needed with the Ponar (table 4).

SILT. In silt, both sets of Ekman samples contained a larger mean number of individuals/m^2 than did the Ponar or Petersen samples (fig. 1). In Set II, these differences were highly significant (table 3). The differences between the mean numbers of individuals/m^2 collected by the Petersen and Ponar grabs were not significant at the 5% level.

The Ekman grab collected fewer taxa/sample than did the Petersen and Ponar grabs in both sets of samples (fig. 2), and in Set II the difference between the Petersen and Ekman samples was significant at the 1% level (table 3). In Set I, the grabs collected similar numbers and percentages of chironomids and oligochaetes. In Set II, however, the Ekman samples contained about 6 times as many oligochaetes as did the other grabs (table 2). The Ekman grab produced the lowest CV values in both Sets I and II (fig. 1).

On the basis of the data from Sets I and II, the number of replicate Ekman grab samples necessary to obtain estimates

TABLE 2

Numbers (per M^2) of chironomids, bivalves, gastropods, and oligochaetes collected in two sets of Petersen, Ekman, and Ponar grabs from 4 types of river substrates.

Substrate	Sampler	Chironomids No.	%	Bivalves No.	%	Gastropods No.	%	Oligochaetes No.	%	Other Taxa No.	%	Total Individuals
Gravel	Petersen	248	13	75	4	1,550	79	43	2	43	2	1,959
Set I*	Ekman	172	20	0	0	646	75	0	0	43	5	861
	Ponar	1,119	28	140	4	2,421	62	108	3	108	3	3,896
	Petersen	28,858	56	129	0	1,173	2	258	1	21,517	41	51,935
Set II	Ekman	21,184	38	86	0	86	0	172	1	33,498	61	55,026
	Ponar	23,584	39	258	1	3,014	5	237	0	33,681	55	60,774
Sand	Petersen	527	15	603	16	194	5	2,271	62	75	2	3,670
Set I	Ekman	732	15	560	11	172	4	3,229	66	194	4	4,887
	Ponar	603	15	388	9	86	2	2,960	73	43	1	4,080
	Petersen	4,123	35	11	0	22	0	7,524	65	32	0	11,712
Set II	Ekman	3,186	40	0	0	646	8	4,133	52	0	0	7,965
	Ponar	6,954	59	0	0	237	2	4,682	39	43	0	11,916
Silt	Petersen	129	4	11	0	11	0	3,283	95	32	1	3,466
Set I	Ekman	129	2	0	0	0	0	5,683	98	0	0	5,812
	Ponar	108	2	22	0.5	0	0	4,316	97	22	0.5	4,468
	Petersen	388	17	22	1	0	0	1,830	81	32	1	2,272
Set II	Ekman	818	7	0	0	0	0	10,764	92	86	1	11,668
	Ponar	1,313	34	22	0.5	22	0.5	2,325	61	151	4	3,833
Mud	Petersen	269	33	0	0	0	0	495	62	43	5	807
Set I	Ekman	689	46	0	0	0	0	818	54	0	0	1,507
	Ponar	624	45	0	0	0	0	700	50	65	5	1,389
	Petersen	3,584	68	0	0	0	0	1,636	31	54	1	5,274
Set II	Ekman	33,282	72	0	0	0	0	12,357	27	517	1	46,156
	Ponar	8,837	86	43	1	0	0	1,152	11	194	2	10,226

*Set I = 4 replicates; Set II = 6 replicates.

of ± 50% of the true mean values would be 4 and 2, respectively (table 4), far fewer than the number of replicates required to achieve the same precision with the other 2 grabs.

MUD. In Set I, the Ekman grab samples taken from mud contained nearly twice as many individuals/m^2 as did the Petersen samples (table 2), but the difference was not significant at the 5% level. In Set II, however, the Ekman contained 9 times the number of individuals in the Petersen series and 4 times the number in the Ponar series, and these differences were highly significant (table 3). The CV's for total individuals/m^2 for both sets of samples showed, however, that no one grab had a consistently greater precision (fig. 1).

The Ekman series contained more chironomids (*Procladius*) and worms (Tubificidae) than were taken with the other 2 grabs (table 2). Although the Ekman series in Set I contained fewer taxa than the other grabs by a narrow margin, it collected nearly twice as many taxa in the Set II series (fig. 2).

On the basis of the data, the number of replicates required to achieve a ± 50% level of precision with the Ekman grabs for Sets I and II would be 14 and 2, respectively (table 4).

OVERALL PERFORMANCE. A chi-square test of the performance of the samplers in all 4 substrate types combined showed that it was very unlikely that the greater number of individuals in the Ponar samples, compared with the Petersen samples, and

TABLE 3

F-values for individuals per m^2 and taxa per sample collected by Petersen, Ekman and Ponar grabs.

Substrate	Sample Set	df	Petersen vs Ekman		Petersen vs Ponar		Ponar vs Ekman	
			Individuals*	Taxa	Individuals*	Taxa	Individuals*	Taxa
Gravel	I	1/6	3.5	45.9†	42.8†	0.5	7.3**	76.8†
	II	1/10	0.1	19.2†	1.0	0.2	0.9	15.8†
Sand	I	1/6	0.4	0.1	0.5	1.6	0.1	3.5
	II	1/10	1.1	13.6†	0.1	0.2	0.2	7.3**
Silt	I	1/6	3.6	3.9	0.5	1.1	1.2	1.5
	II	1/10	65.8†	1.6	2.7	1.0	22.8**	6.0
Mud	I	1/6	1.9	2.8	3.9	0.1	0.1	1.9
	II	1/10	67.5†	5.4**	4.4	3.9	44.8**	3.9

*Numbers of individuals transformed to Log_{10}.
**Differences significant at $P = .05$.
†Differences significant at $P = .01$.

the greater number of taxa collected in each series by the Ponar, compared with the Ekman, was due to chance alone. Differences in the area of the bite may account for the smaller number of taxa in the Ekman samples compared with the other grabs. The 3 grabs are rated according to their performances on the various substrate types in table 5. The ranks were based on a combination of numbers of individuals and taxa collected, coefficients of variation, and mechanical operation of the grabs.

The data obtained during this study show that estimates of macroinvertebrate populations obtained by grab samplers may vary considerably depending on the grab utilized, the nature of the substrate, and the number of replicates collected. Therefore, when using a given type of grab, it is important to select sampling stations with similar types of substrates. The kinds and numbers of organisms inhabiting that substrate type, and the number of replicates needed to obtain the desired level of precision should be determined during the initial stages of the project.

Samples collected with one type of grab may not be comparable with those obtained with other types of grabs, even from the same type of substrate. It is important, therefore, to use the sampler best suited to that substrate. During this study, the Ponar grab performed best in gravel substrates, the Ponar and Petersen did equally well in sand, the Ponar and Ekman both sampled silt substrates equally, and the Ekman was the most efficient sampler for mud substrates. The Ponar sampler was the best overall grab on the basis of the numbers of individuals and taxa collected, precision and mechanical operation.

TABLE 4

*Number of replicates required for specified levels of precision with 95% confidence.**

Substrate	Grab	Set I Error 20%	Set I Error 50%	Set II Error 20%	Set II Error 50%
Gravel	Petersen	8	2	108	18
	Ekman	396	64	124	21
	Ponar	4	1	31	5
Sand	Petersen	7	2	56	9
	Ekman	44	7	53	9
	Ponar	14	3	83	13
Silt	Petersen	66	11	27	4
	Ekman	22	4	12	2
	Ponar	69	11	64	11
Mud	Petersen	27	5	42	7
	Ekman	83	14	11	2
	Ponar	42	7	35	6

*(Elliott 1971 p. 137).

TABLE 5
Rating of the Ponar, Petersen and Ekman grab samplers in the order of performance on a comparative basis.

	Substrate				
Grab	Gravel	Sand	Silt	Mud	Overall Rank
Ponar	1*	1	1	2	1
Petersen	2	1	2	3	2
Ekman	3	2	1	1	2

*1 = highest rank and 3 = lowest rank.

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