

DFO - Library / MPO - Bibliothèque



08000387

Rates of Ingestion, Egestion and Gill Ventilation in Benthic Invertebrates

H. A. Morrison*

Ecotoxicology Division
Great Lakes Laboratory
for Fisheries and Aquatic Sciences
Bayfield Institute
867 Lakeshore Road
P.O. Box 5050
Burlington, Ontario
L7R 4A6



1995

**Canadian Data Report of
Fisheries and Aquatic Sciences
No. 955**



Fisheries
and Oceans

Pêches
et Océans

Canada

Canadian Data Report of Fisheries and Aquatic Sciences

Data reports provide a medium for filing and archiving data compilations where little or no analysis is included. Such compilations commonly will have been prepared in support of other journal publications or reports. The subject matter of data reports reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Data reports are not intended for general distribution and the contents must not be referred to in other publications without prior written authorization from the issuing establishment. The correct citation appears above the abstract of each report. Data reports are abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-25 in this series were issued as Fisheries and Marine Service Data Records. Numbers 26-160 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Data Reports. The current series name was introduced with the publication of report number 161.

Data reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport statistique canadien des sciences halieutiques et aquatiques

Les rapports statistiques servent à classer et à archiver les compilations de données pour lesquelles il y a peu ou point d'analyse. Ces compilations auront d'ordinaire été préparées à l'appui d'autres publications ou rapports. Les sujets des rapports statistiques reflètent la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports statistiques ne sont pas destinés à une vaste distribution et leur contenu ne doit pas être mentionné dans une publication sans autorisation écrite préalable de l'établissement auteur. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports statistiques sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros 1 à 25 de cette série ont été publiés à titre de relevés statistiques, Services des pêches et de la mer. Les numéros 26 à 160 ont été publiés à titre de rapports statistiques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 161.

Les rapports statistiques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Data Report of Fisheries

and Aquatic Sciences No. 955

1995

Rates of Ingestion, Egestion and Gill Ventilation
for Benthic Invertebrates

by

H. A. Morrison*

Ecotoxicology Division
Great Lakes Laboratory
for Fisheries and Aquatic Sciences
Bayfield Institute
867 Lakeshore Road
P.O. Box 5050
Burlington, Ontario
L7R 4A6

* Department of Biological Sciences, University of Windsor, Windsor, Ontario,
N9B 3P4

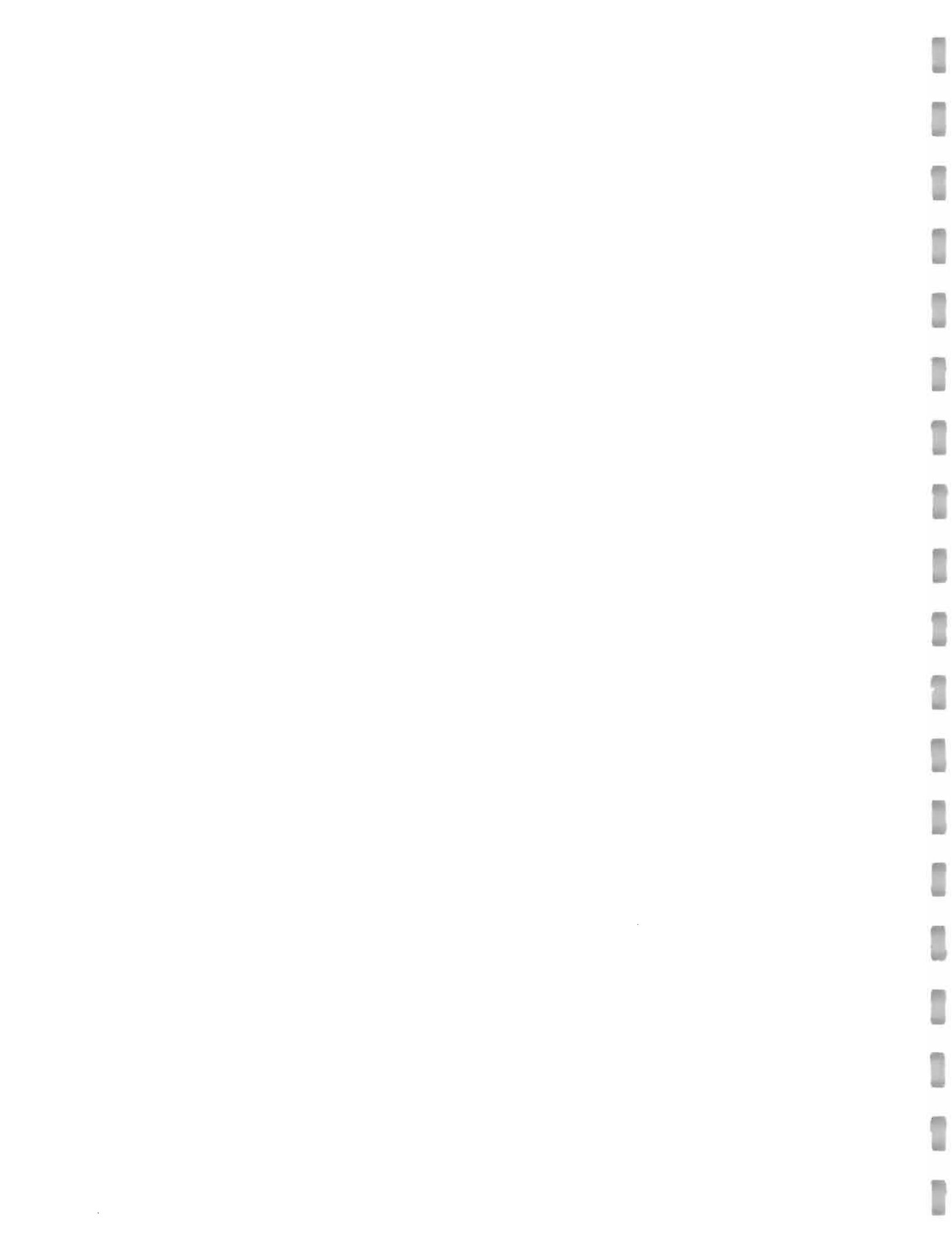
© Minister of Supply and Services Canada 1995
Cat. No. Fs 97-13/????? ISSN 0706-6465

Correct citation for this publication:

Morrison, H. A. 1995. Rates of ingestion, egestion and gill ventilation for benthic invertebrates. Can. Data Rep. Fish. Aquat. Sci.

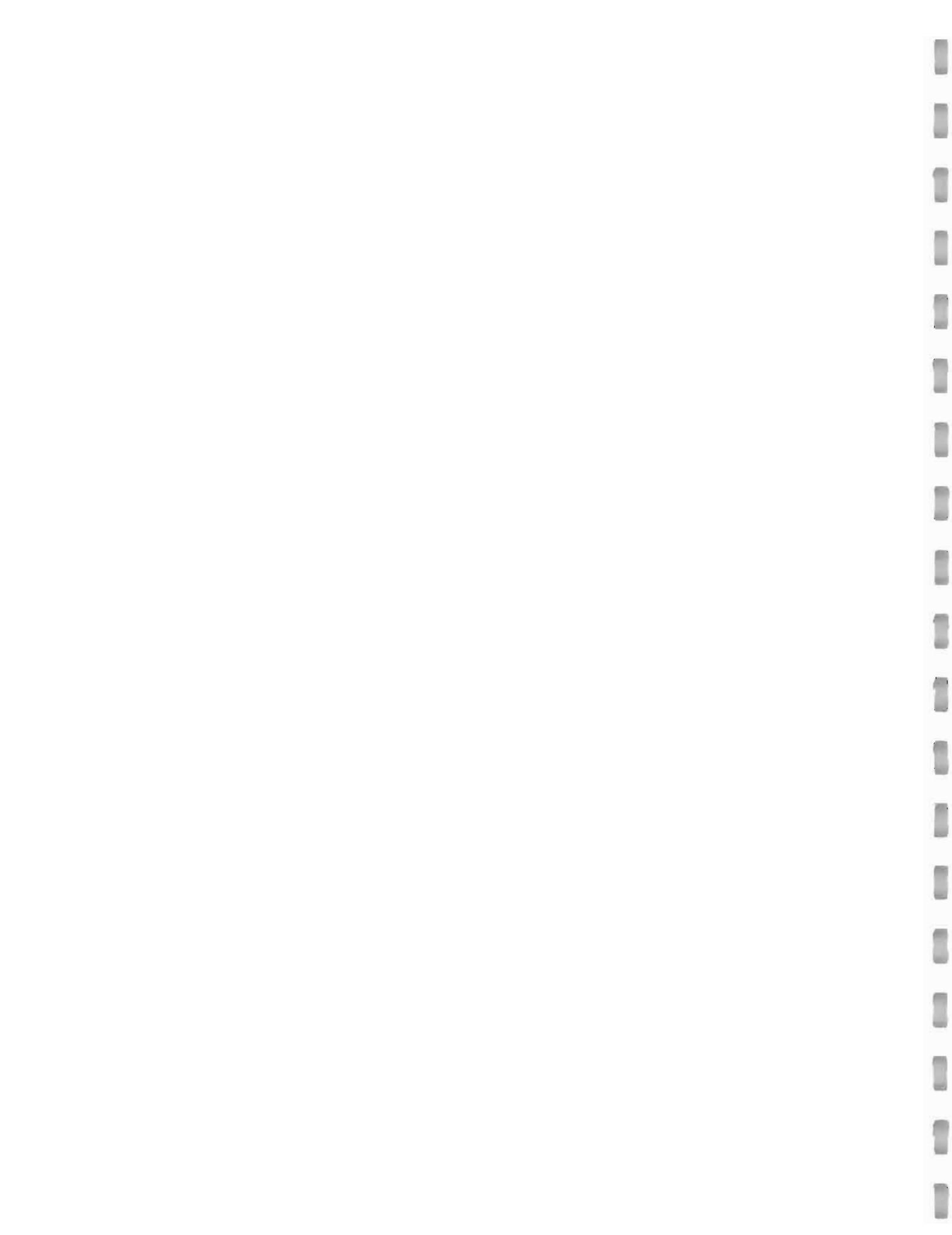
ABSTRACT

Data from the published literature on ingestion rates (IR), egestion rates (ER) and gill ventilation rates (GV) were compiled for benthic invertebrates. Data from 193, 101 and 261 individual laboratory and field tests were obtained for IR, ER and GV, respectively. For the ingestion and egestion tests, these data include genus species, dry weight, sample size, temperature, food type, method of measurement and measured ingestion or egestion rate on a dry weight and wet weight basis. For the gill ventilation tests, these data include genus species, dry weight, temperature and measured gill ventilation rate. Simple statistics, performed on some of the data indicated that dry weight of all benthic invertebrates, except crayfish, explained 62% and 52% of the variation in IR and ER on a wet weight basis, respectively. Crayfish dry weight explained very little of the variation in IR but explained 57% of the variation ER on a wet weight basis. Additionally, crayfish dry weight explained 67% of the variation in gill ventilation rates. There was no relationship between the dry weight of all other benthic invertebrates and GV.



RÉSUMÉ

Le présent rapport content une compilation de taux d'ingestion (IR), d'excrétion (ER) et de ventilation branchiale (GV) pour divers invertébrés aquatiques. Les valeurs de taux IR, ER et GV furent obtenues respectivement de 193, 101 et 261 études publiées de laboratoire et de milieu naturel. Pour les études d'ingestion et d'excrétion, nous indiquons les conditions expérimentales telles l'espèce utilisée, le poids sec en tissu l'effectif d'échantillonnage, la température, le type de nourriture fournie, les méthodes d'estimation des taux d'ingestion et d'excrétion, et les valeurs obtenues de ces taux sur une base de poids sec et de poids humide. Les taux de ventilation branchiale sont indiqués avec l'espèce utilisée, le poids sec en tissu et la température du test. Le poid sec individual de tout spécimen d'invertébré aquatique compilé dans ce rapport, à l'exception de l'écrevisse est vraisemblablement responsable respectivement de 62% et de 52% de la variation des taux IR et ER exprimés en poids humide. Pour l'écrevisse le poids sec explique vraisemblablement 0.65 et 57% de la variation des taux IR et ER sur une base de poids humide. Des plus, le poids sec de l'écrevisse explique vraisemblablement 67% de la variation des taux de ventilation branchiale de cette espèce.



INTRODUCTION

Data from the published literature was collected on ingestion rates (IR), egestion rates (ER) and gill ventilation rates (GV) for benthic invertebrates. Test conditions and results were reported. This paper explains how the information was compiled and reports the results of simple data analyses.

METHODS

To compile the data in this report, a computerized literature search was performed for 1982-1994 on Biological Sciences Information Service (BIOSIS PREVIEWS) and Wilson Search for the biological sciences and agriculture. Additionally, all relevant references, cited in papers identified by the computer search, were collected.

The minimum information required for a paper to qualify for this report was identification of species, some measure of benthic invertebrate size that enabled conversion to dry weight, food type, ingestion rate, egestion rate and some measure of oxygen consumption per unit time or filtering rate. If there was more than one individual used in a test, the weight recorded in this report is the mean weight. Most of the gill ventilation rates were calculated from oxygen consumption rates. Oxygen concentrations were assumed to be saturated if they were not reported. The concentrations of dissolved oxygen in freshwater, at different temperatures, were obtained from Benson and Krause (1980). Coordinate measurements were made if data was only available from graphs. Graphs were photomagnified to improve the precision of measurements.

Rates of ingestion, egestion and gill ventilation were compiled for marine and freshwater species.

Simple regression analyses were performed on the data to provide descriptive equations relating organism weight to ingestion rate, egestion rate and gill ventilation rate.

RESULTS

The dry weight of all benthic invertebrates, except crayfish, explained 62% and 52% of the variation in IR and ER on a wet weight basis, respectively (Figures 1, 2). Crayfish dry weight only explained 0.65% of the variation in IR on a wet weight basis (Figure 3) but explained 57% of the variation in ER on a wet weight basis (Figure 4). Crayfish dry weight explained 67% of the variation in GV (Figure 5). There was no relationship between the dry weight of all other benthic invertebrates and GV (Figure 6).

Table 1 lists the species and test conditions for the determination of ingestion rates and egestion rates. Organism dry weight and rates of ingestion and egestion are listed in Table 2. Table 3 provides references and comments on the ingestion and egestion tests. Table 4 lists species, test conditions, organism dry weight and gill ventilation rates. References and comments on the gill ventilation tests are listed in Table 5.

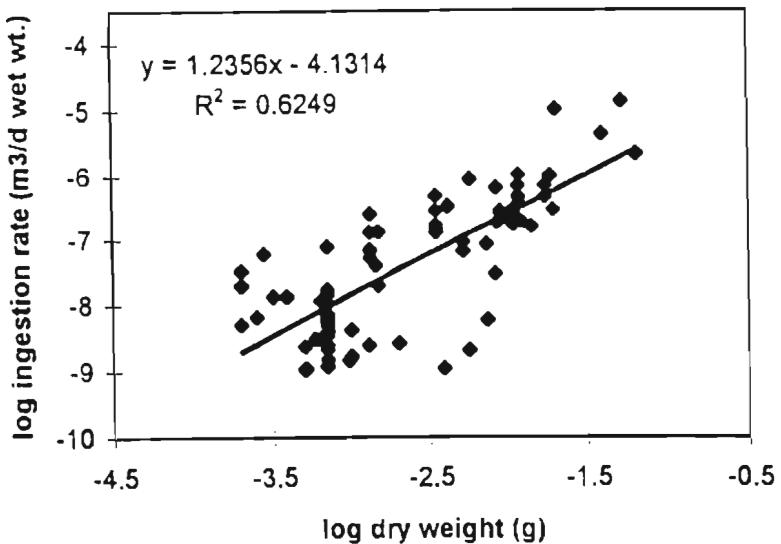


Figure 1: Ingestion rate versus dry weight for all benthic invertebrates except crayfish ($n = 92$). The following outliers were omitted from the analysis; reference # 3, 18 and 27.

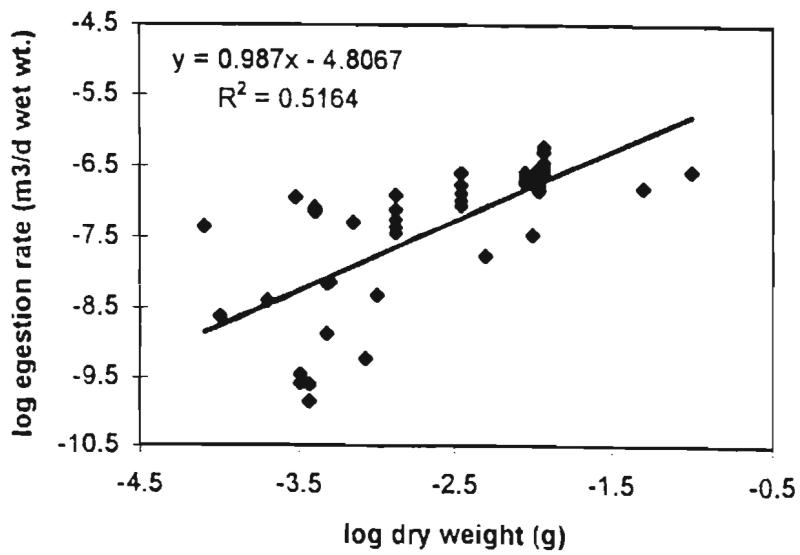


Figure 2: Egestion rate versus dry weight for all benthic invertebrates except crayfish ($n = 52$). The following outliers were omitted from the analysis; reference # 5, 17, 23, 24 and 25.

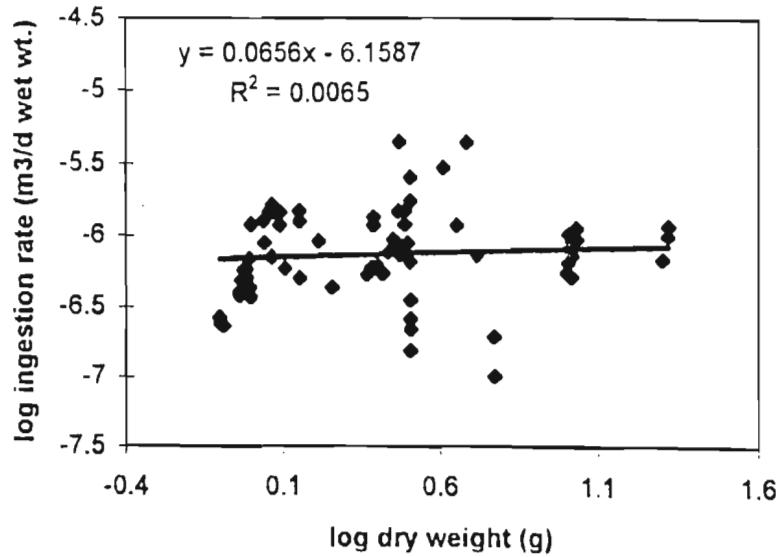


Figure 3: Ingestion rate versus dry weight for crayfish ($n = 79$). Reference #39 was omitted because it is an outlier.

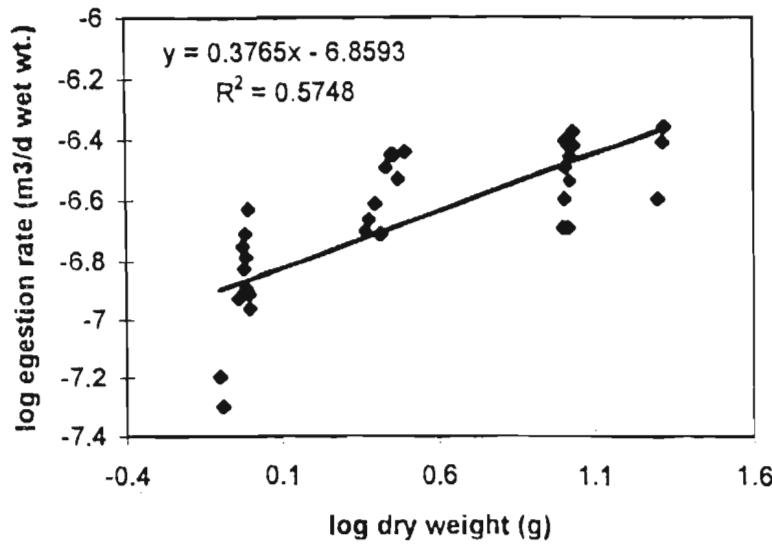


Figure 4: Egestion rate versus dry weight for crayfish ($n = 36$).

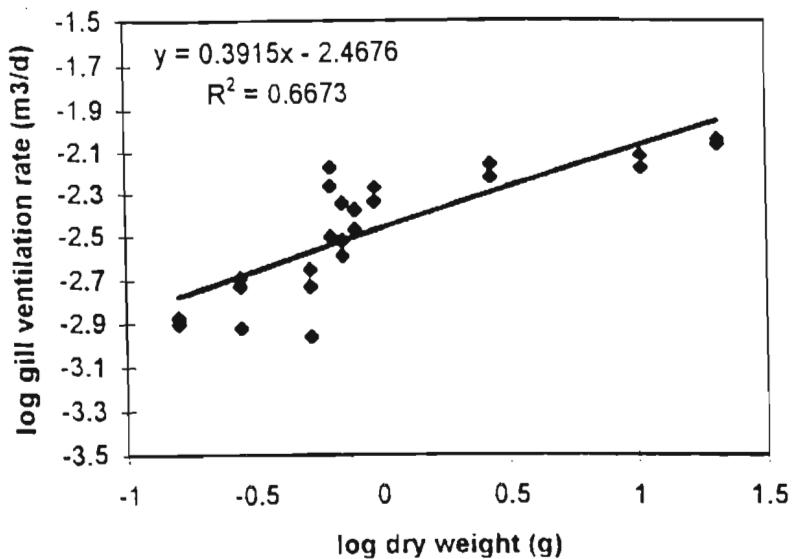


Figure 5: Gill ventilation rate versus dry weight for crayfish ($n = 24$).

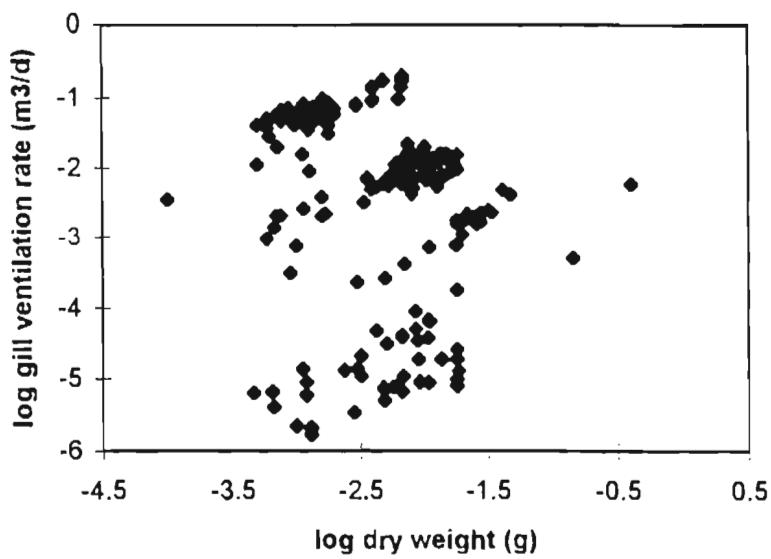


Figure 6: Gill ventilation rate versus dry weight for all benthic invertebrates except crayfish ($n = 237$).

Table 1: Species and test conditions for the determination of ingestion rates and egestion rates. Abbreviations refer to the following; A = quantity of food in a full gut and turnover time measured; B = amount and rate of faecal production quantified; C = amount and rate of tracer substance passing through the gut while feeding; D = reduction in quantity of food over time; * = estimates include any sediment and pseudofaeces that may have been deposited at the sediment surface; + = collection of rejected pellets and; ng = not given.

Ref. #	Organism	Genus Species	n	Temp. (°C)	Food Type	Test Type
1 amphipod	<i>Gammarus pseudolimnaeus</i>		3	5	leaves	B
			3	5	leaves	B
			3	10	leaves	B
			3	10	leaves	B
			3	15	leaves	B
			3	15	leaves	B
			3	5	leaves	B
			3	10	leaves	B
			3	15	leaves	B
			3	15	leaves	B
			3	15	leaves	B
			3	9	leaves	B
			3	9	leaves	B
			3	9	leaves	B
			3	9	leaves	B
2 polychaete	<i>Tubifex tubifex</i>		10	16 to 18	detritus	C
			5	17 to 30	algae on rocks	C
3 snail	<i>Littorina planaxis</i> Philippi		5	17 to 30	algae on rocks	C
4 polychaete	<i>Psammoryctes barbatus</i>		286	6.5	detritus	B
			67	10	detritus	B
polychaete	<i>Bythonomus lemani</i> (Grube)		433	6.5	detritus	B
			143	10	detritus	B
polychaete	<i>Peloscolex ferox</i>		755	6.5	detritus	B
			263	10	detritus	B
5 lugworm	<i>Abarenicola pacifica</i>		8	10 to 13	detritus	B,C
			8	10 to 13	detritus	B,C
6	<i>Arenicola marina</i> (L.)		ng	17.5	detritus	B,C
7 polychaete	<i>Amphitrite ornata</i> (Leidy)			15	detritus	B*
				15	detritus	B
polychaete	<i>Clymenella torquata</i> (Leidy)			15	detritus	B
8 polychaete	<i>Tubifex tubifex</i>		ng	15	detritus	B
9	<i>Pteronarcys scotti</i>		19	15	leaves	A
			19	15	leaves	A
			19	15	leaves	A
			19	15	leaves	A
			19	15	leaves	B
10 polychaete	<i>Peloscolex multisetosus</i>		6	13	detritus	B
			6	13	detritus	B
			6	13	detritus	B
11 amphipod	<i>Hyalella azteca</i>		1,2,3	15	detritus	B
			1,2,3	15	detritus	B
			1,2,3	15	detritus	B
			1,2,3	15	detritus	B
			1,2,3	15	detritus	B

Table 1 continued

Ref. #	Organism	Genus Species	n	Temp. (°C)	Food Type	Test Type
12	snail	<i>Hydrobia neglecta</i>	4	15	detritus	B
13	snail	<i>Hydrobia ventrosa</i>	4	15	detritus	B
14	polychaete	<i>Nereis succinea</i>	8,12	15	detritus	A
15		<i>Orchestia grillus</i>	ng	15	detritus	B
16		<i>Arenicola grubii</i>	ng	15	detritus	B
17	polychaete	<i>Thoracophelia mucronata</i>	ng	15	detritus	A,C
18	crab	<i>Ilyoplax pusilla</i>	1	ng	detritus	B+
	crab	<i>Scopimera globosa</i>	1	ng	detritus	B+
	crab	<i>Macrophthalmus japonicus</i>	1	ng	detritus	B+
19	mayfly	<i>Hexagenia limbata</i>	20	5	detritus	A
			20	5	detritus	A
			20	5	detritus	A
			20	10	detritus	A
			20	10	detritus	A
			20	10	detritus	A
			20	15	detritus	A
			20	15	detritus	A
			20	15	detritus	A
			20	20	detritus	A
			20	20	detritus	A
			20	20	detritus	A
			20	25	detritus	A
			20	25	detritus	A
			20	25	detritus	A
20	amphipod	<i>Mysis relicta</i>	ng	4	detritus	B
21	polychaete	<i>Limnodrilus hoffmeisteri</i>	14	23	detritus	C
			14	23	detritus	C
22	mayfly	<i>Hexagenia limbata</i>	5	10	detritus	C
			5	10	detritus	C
			5	10	detritus	C
			5	10	detritus	C
			5	16	detritus	C
			5	16	detritus	C
			5	16	detritus	C
			5	16	detritus	C
			5	16	detritus	C
			5	21	detritus	C
			5	21	detritus	C
			5	21	detritus	C
			5	21	detritus	C
			5	21	detritus	C
23	polychaete	<i>Pectinaria gouldii</i>	>100	18 to 20	detritus	B*
24	amphipod	<i>Mysis relicta</i>	9	10	copepods	B
			19	10	copepods	B
25	amphipod	<i>Mysis relicta</i>	20	6	detritus	D
			50	6	detritus	D
26	mayfly	<i>Tricorythodes minutus</i>	6	20	detritus	C

Table 1 continued

Ref. #	Organism	Genus Species	n	Temp. (°C)	Food Type	Test Type
27 amphipod	Asellus aquaticus		25,30	15	detritus	A
			25,30	15	detritus	A
			25,30	5	detritus	A
			25,30	15	detritus	A
amphipod	Gammarus pulex		25,30	15	detritus	A
			25,30	15	detritus	A
28 amphipod	Hexagenia limbata		5 ~ 10	15	detritus	C
			5 ~ 10	20	detritus	C
29 amphipod	Hyalella azteca		10	15	chara	B,D
			10	15	chara	B,D
			10	15	chara	B,D
			10	15	chara	B,D
			10	15	chara	B,D
			10	15	chara	B,D
			10	15	chara	B,D
			10	15	chara	B,D
			10	15	chara	B,D
			10	15	chara	B,D
			10	15	chara	B,D
			5	15	bacteria	C
			2	15	bacteria	C
			2	15	bacteria	C
			8	15	diatoms	C
			3	15	diatoms	C
			3	15	diatoms	C
30 amphipod	Anisogammarus pugettensis		3	15	green algae	C
			2	15	green algae	C
			1	15	detritus	C
			1	15	detritus	C
			1	15	detritus	C
31 mayfly	Stenonema pulchellum		8	20	bacteria	C
			8	10	bacteria	C
			8	20	bacteria	C
			8	10	bacteria	C
32 crayfish	Procambarus clarkii		15	20	diatom	C
			17	20	diatom	C
			10	20	diatom	C
			10	20	diatom	C
			6~9	24 to 27	commercial	D

Table 1 continued

Ref. #	Organism	Genus Species	n	Temp. (°C)	Food Type	Test Type
33 crayfish	<i>Orconectes propinquus</i>		5	18	chara	D
			4	18	physa	D
			6	18	chara	D
			3	18	physa	D
			6	18.5	chara	D
			6	18.5	physa	D
			6	19	chara	D
			5	19	physa	D
			5	10	chara	D
		<i>Orconectes virilis</i>	3	18	chara	D
	<i>Cambarus robustus</i>		1	18	physa	D
			3	18	chara	D
			3	18	physa	D
			2	18.5	chara	D
			3	18.5	physa	D
			3	19	chara	D
			3	19	physa	D
			2	10	chara	D
			1	10	physa	D
			2	18	chara	D
34 crayfish	<i>Astacus astacus</i>		3	18	physa	D
			3	18	chara	D
35 crayfish	<i>Orconectes virilis</i>		2	18	physa	D
			2	18.5	chara	D
36 crayfish	<i>Orconectes virilis</i>		3	18.5	physa	D
			2	19	chara	D
			3	19	physa	D
			3	10	chara	D
			ng	ng	macrophyte	
			ng	ng	shrimp	
			12	22-26	macrophytes	B,D
			12	22-26	macrophytes	B,D
			12	ng	macrophytes	B
			12	ng	macrophytes	B
			12	ng	macrophytes	B
			12	ng	macrophytes	B
37 crayfish	<i>Procambarus clarkii</i>		12	ng	macrophytes	B
			12	ng	macrophytes	B
			12	ng	macrophytes	B
			12	ng	macrophytes	B
			12	ng	macrophytes	B
			12	ng	macrophytes	B
			12	ng	macrophytes	B
			12	ng	macrophytes	B
			12	ng	macrophytes	B
			6 to 9	ng	commercial	B
			6 to 9	ng	diets	B
			6 to 9	ng	commercial	B
			6 to 9	ng	diets	B
			6 to 9	ng	commercial	B
			6 to 9	ng	diets	B
			6 to 9	ng	commercial	B
			6 to 9	ng	diets	B

Table 1 continued

Ref. #	Organism	Genus Species	n	Temp. (C)	Food Type	Test Type
38 crayfish		<i>Orconectes virilis</i>	8	20	zebra mussels	D
			4	20	zebra mussels	D
39 crayfish		<i>Astacus astacus L.</i>	1	20	leaves	D
			1	20	leaves	D
			1	20	leaves	D
			1	20	leaves	D
			1	20	leaves	D
			1	20	leaves	D
			1	20	leaves	D
			1	20	leaves	D
40 crayfish		<i>Orconectes propinquus</i>	13	20	zebra mussels	D
41 crayfish		<i>Pacifastacus leniusculus</i>	1	20	chicken	B,D
			1		chicken	B,D
			1		chicken	B,D
			1		chicken	B,D
			1		chicken	B,D
			1		chicken	B,D
			1		chicken	B,D
			1		chicken	B,D
			1		chicken	B,D
			1		chicken	B,D
			1		macrophytes	B,D
			1		macrophytes	B,D
			1		macrophytes	B,D
			1		macrophytes	B,D
			1		macrophytes	B,D
			1		chicken	B,D
			1		chicken	B,D
			1		chicken	B,D
			1		chicken	B,D
			1		chicken	B,D
			1		chicken	B,D
			1		macrophytes	B,D
			1		macrophytes	B,D
			1		macrophytes	B,D
			1		macrophytes	B,D
			1		macrophytes	B,D
			1		chicken	B,D
			1		chicken	B,D
			1		chicken	B,D

Table 2: Dry weight, ingestion and egestion rates for each test.

Ref. #	Dry Weight (g)	IR (m ³ dw/d)	IR (m ³ ww/d)	ER (m ³ dw/d)	ER (m ³ ww/d)
1	0.011	5.50E-08	1.83E-07	4.90E-08	1.63E-07
	0.011	5.20E-08	1.73E-07	4.80E-08	1.60E-07
	0.011	7.10E-08	2.37E-07	6.10E-08	2.03E-07
	0.011	7.70E-08	2.57E-07	7.10E-08	2.37E-07
	0.011	8.90E-08	2.97E-07	8.40E-08	2.80E-07
	0.011	9.10E-08	3.03E-07	9.10E-08	3.03E-07
	0.011	6.20E-08	2.07E-07	5.30E-08	1.77E-07
	0.011	6.60E-08	2.20E-07	6.70E-08	2.23E-07
	0.011	5.40E-08	1.80E-07	4.30E-08	1.43E-07
	0.011	9.00E-08	3.00E-07	7.80E-08	2.60E-07
	0.011	8.10E-08	2.70E-07	6.50E-08	2.17E-07
	0.009	8.50E-08	2.83E-07	6.70E-08	2.23E-07
	0.009	7.80E-08	2.60E-07	6.80E-08	2.27E-07
	0.009	6.20E-08	2.07E-07	5.90E-08	1.97E-07
	0.009	7.80E-08	2.60E-07	7.80E-08	2.60E-07
	0.009	6.00E-08	2.00E-07	5.40E-08	1.80E-07
2	0.0002	2.00E-09	5.00E-09	2.00E-09	4.00E-09
3	0.01			1.30E-08	
	0.05			3.50E-08	
4	0.000844			2.50E-10	6.00E-10
	0.000844			2.50E-10	6.10E-10
	0.000323			1.10E-10	2.60E-10
	0.000323			1.40E-10	3.49E-10
	0.000367			5.70E-11	1.40E-10
	0.000367			1.00E-10	2.50E-10
5	2.2			7.30E-05	1.77E-04
	2			4.90E-05	1.19E-04
6	6.5			3.30E-05	
7	0.9			3.40E-05	
	0.047			8.00E-06	
8	0.0007			2.10E-08	5.00E-08
9	0.005			6.00E-09	1.70E-08
	0.01			1.20E-08	3.40E-08
	0.05			5.60E-08	1.60E-07
	0.1			9.30E-08	2.70E-07
	0.0084	9.00E-09	3.00E-08		
10	0.00008			1.60E-08	4.44E-08
	0.0003			4.10E-08	1.14E-07
	0.0004			2.90E-08	8.06E-08
11	0.0004			2.90E-08	7.07E-08
	0.0001			1.00E-09	2.44E-09
	0.0005			3.00E-09	7.32E-09
	0.001			2.00E-09	4.88E-09
	0.00032	2.00E-09	1.33E-08		
12	0.0002	3.00E-09	2.00E-08		
13	0.0002	5.00E-09	3.33E-08		
14	0.0058	1.34E-07	8.93E-07		
15	0.0124	2.90E-08	1.93E-07		
16	0.0204	1.60E-06	1.07E-05		
17	0.04	1.50E-06	4.41E-06	1.53E-06	3.71E-06
18	0.053	2.00E-06	1.33E-05		
	0.065	3.30E-07	2.20E-06		
	2.05	3.12E-05	2.08E-04		

Table 2 continued

Ref. #	Dry Weight (g)	IR (m3 dw/d)	IR (m3 ww/d)	ER (m3 dw/d)	ER (m3 ww/d)
19	0.00133	1.79E-08	5.26E-08	1.47E-08	3.59E-08
	0.0035	4.39E-08	1.29E-07	3.59E-08	8.76E-08
	0.01183	1.29E-07	3.79E-07	1.05E-07	2.56E-07
	0.00133	2.24E-08	6.59E-08	1.80E-08	4.39E-08
	0.0035	5.36E-08	1.58E-07	4.29E-08	1.05E-07
	0.01183	1.54E-07	4.53E-07	1.22E-07	2.98E-07
	0.00133	2.39E-08	7.03E-08	2.29E-08	5.59E-08
	0.0035	5.69E-08	1.67E-07	5.33E-08	1.30E-07
	0.01183	1.66E-07	4.88E-07	1.47E-07	3.59E-07
	0.00133	4.42E-08	1.30E-07	3.17E-08	7.73E-08
	0.0035	9.73E-08	2.86E-07	7.06E-08	1.72E-07
	0.01183	2.48E-07	7.29E-07	2.04E-07	4.98E-07
	0.00133	8.59E-08	2.53E-07	5.07E-08	1.24E-07
	0.0035	1.64E-07	4.82E-07	1.04E-07	2.54E-07
	0.01183	3.56E-07	1.05E-06	2.43E-07	5.93E-07
20	0.00742	1.00E-09	6.00E-09		
21	0.000479			5.75E-10	1.39E-09
	0.000479			2.90E-09	7.03E-09
22	0.00039	2.00E-09	1.33E-08		
	0.00149	3.00E-09	2.00E-08		
	0.00523	1.00E-08	6.67E-08		
	0.0074	1.30E-08	8.67E-08		
	0.01431	2.40E-08	1.60E-07		
	0.00025	1.00E-09	6.67E-09		
	0.00144	6.00E-09	4.00E-08		
	0.00523	1.40E-08	9.33E-08		
	0.00857	2.90E-08	1.93E-07		
	0.01961	4.50E-08	3.00E-07		
	0.00028	9.00E-09	6.00E-08		
	0.0015	2.00E-08	1.33E-07		
	0.00418	5.10E-08	3.40E-07		
	0.00853	9.80E-08	6.53E-07		
	0.01884	1.55E-07	1.03E-06		
23	0.08			4.00E-06	2.67E-05
24	0.0052			8.26E-11	7.44E-10
	0.0033			4.00E-11	3.60E-10
25	0.0056	3.12E-10	2.08E-09	4.80E-11	1.17E-10
	0.0039	1.68E-10	1.12E-09	1.65E-11	4.02E-11
26	0.6375	1.70E-09	1.13E-08		
27	0.024	2.00E-12	1.33E-11		
	0.0009	3.00E-12	2.00E-11		
	0.012	7.50E-13	5.00E-12		
	0.012	1.90E-11	1.27E-10		
	0.024	2.26E-11	1.51E-10		
	0.0009	1.70E-12	1.13E-11		
28	0.0176	7.38E-08	4.92E-07		
	0.0176	1.09E-07	7.27E-07		

Table 2 continued

Ref. #	Dry Weight (g)	IR (m ³ dw/d)	IR (m ³ ww/d)	ER (m ³ dw/d)	ER (m ³ ww/d)
29	0.0007	8.78E-10	5.85E-09		
	0.0007	5.18E-10	3.45E-09		
	0.0007	3.19E-10	2.13E-09		
	0.0007	1.60E-09	1.07E-08		
	0.0007	2.10E-09	1.40E-08		
	0.0007	2.52E-09	1.68E-08		
	0.0007	7.20E-10	4.80E-09		
	0.0007	1.17E-09	7.80E-08		
	0.0007	2.31E-09	1.54E-08		
	0.0007	2.28E-09	1.52E-08		
	0.0007	7.32E-10	7.32E-09		
	0.0007	6.00E-10	6.00E-09		
	0.0007	6.00E-10	6.00E-09		
	0.0007	6.77E-10	6.77E-09		
	0.0007	1.20E-10	1.20E-09		
	0.0007	1.50E-10	1.50E-09		
	0.0007	5.28E-10	5.28E-09		
	0.0007	2.52E-10	2.52E-09		
	0.00062	4.61E-10	3.07E-09		
	0.00071	6.19E-10	4.13E-09		
	0.00058	4.61E-10	3.07E-09		
30	0.0005	2.33E-10	2.33E-09		
	0.0005	1.06E-10	1.06E-09		
	0.001	4.15E-10	4.15E-09		
	0.001	1.71E-10	1.71E-09		
31	0.00051	1.09E-10	1.09E-09		
	0.00096	1.46E-10	1.46E-09		
	0.00129	2.50E-10	2.50E-09		
	0.00201	2.70E-10	2.70E-09		
32	7.1	2.40E-07			
33	1.2	2.16E-07	1.44E-06		
o.p.	1.2324	2.16E-07	1.44E-06		
	1.1613	2.42E-07	1.61E-06		
	1.2324	1.76E-07	1.17E-06		
	1.0902	1.89E-07	1.26E-06		
	1.1613	2.18E-07	1.45E-06		
	1.1613	2.20E-07	1.47E-06		
	1.1613	1.06E-07	7.04E-07		
	0.9243	7.26E-08	4.84E-07		
	1.422	2.20E-07	1.47E-06		
	1.2798	8.80E-08	5.87E-07		
o.v.	1.1376	2.20E-07	1.47E-06		
	1.422	1.87E-07	1.25E-06		
	0.9954	1.78E-07	1.19E-06		
	1.1376	2.20E-07	1.47E-06		
	1.1376	2.20E-07	1.47E-06		
	1.422	7.48E-08	4.99E-07		
	1.8012	6.38E-08	4.25E-07		
	1.6353	1.34E-07	8.95E-07		
	2.4411	1.76E-07	1.17E-06		

Table 2 continued

Ref. #	Dry Weight (g)	IR (m ³ dw/d)	IR (m ³ ww/d)	ER (m ³ dw/d)	ER (m ³ ww/d)
33 con't	3.081	2.20E-07	1.47E-06		
	3.081	1.78E-07	1.19E-06		
	4.8111	6.60E-07	4.40E-06		
	2.4411	2.00E-07	1.33E-06		
	3.081	2.20E-07	1.47E-06		
	4.0764	4.40E-07	2.93E-06		
	2.9388	6.60E-07	4.40E-06		
	2.9388	2.20E-07	1.47E-06		
34	5.9	9.00E-09	1.96E-07		
	5.9	5.10E-07	1.01E-07		
35	4.3	3.47E-11	2.31E-10		
36	3.2	3.75E-07	2.50E-06		
	3.2	2.57E-07	1.71E-06		
	3.2	5.30E-08	3.53E-07		
	3.2	9.80E-08	6.53E-07		
	3.2	2.30E-08	1.53E-07		
	3.2	3.90E-08	2.60E-07		
	3.2	3.30E-08	2.20E-07		
	3.2	3.90E-08	2.60E-07		
	3.2	5.30E-08	3.53E-07		
	3.2	3.30E-08	2.20E-07		
37	3.3	3.77E-07			
	3.3	2.07E-07			
	3.3	1.87E-07			
	3.3	1.66E-08			
	3.3	1.28E-07			
	3.3	8.30E-08			
	3.3	7.70E-08			
	3.3	6.20E-08			
	3.3	5.60E-08			
38	5.2	7.26E-08	7.27E-07		
	4.5	1.18E-07	1.18E-06		
39	0.45	2.00E-05	6.67E-05		
	2.16	7.00E-05	2.33E-04		
	5.55	9.00E-06	3.00E-05		
	6.2	1.10E-04	3.67E-04		
	6.4	3.00E-05	1.00E-04		
	6.9	7.00E-05	2.33E-04		
	7.1	1.50E-04	5.00E-04		
	7.7	1.00E-04	3.33E-04		
40	1.1	8.80E-08	8.80E-07		

Table 2 continued

Ref. #	Dry Weight (g)	IR (m ³ dw/d)	IR (m ³ ww/d)	ER (m ³ dw/d)	ER (m ³ ww/d)
41	0.7969	3.60E-08	2.40E-07	1.40E-08	6.36E-08
	0.8104	3.50E-08	2.33E-07	1.10E-08	5.00E-08
	0.7906	4.00E-08	2.67E-07	1.40E-08	6.36E-08
	0.9496	6.90E-08	4.60E-07	3.30E-08	1.50E-07
	0.9904	5.60E-08	3.73E-07	2.40E-08	1.09E-07
	0.9155	5.70E-08	3.80E-07	2.60E-08	1.18E-07
	0.9669	6.20E-08	4.13E-07	2.80E-08	1.27E-07
	0.9844	6.50E-08	4.33E-07	2.70E-08	1.23E-07
	0.9119	6.00E-08	4.00E-07	2.60E-08	1.18E-07
	0.9828	1.02E-07	6.80E-07	5.20E-08	2.36E-07
	0.9627	7.60E-08	5.07E-07	3.60E-08	1.64E-07
	0.9404	8.60E-08	5.73E-07	3.90E-08	1.77E-07
	0.9593	8.70E-08	5.80E-07	4.30E-08	1.95E-07
	2.4968	9.50E-08	6.33E-07	5.40E-08	2.45E-07
	2.6241	8.20E-08	5.47E-07	4.30E-08	1.95E-07
	2.3266	8.00E-08	5.33E-07	4.40E-08	2.00E-07
	2.592	8.30E-08	5.53E-07	4.30E-08	1.95E-07
	2.3987	9.00E-08	6.00E-07	4.80E-08	2.18E-07
	2.9692	1.09E-07	7.27E-07	6.50E-08	2.95E-07
	2.7236	1.14E-07	7.60E-07	7.10E-08	3.23E-07
	2.8924	1.34E-07	8.93E-07	7.80E-08	3.55E-07
	3.136	1.31E-07	8.73E-07	8.00E-08	3.64E-07
	2.8242	1.39E-07	9.27E-07	7.80E-08	3.55E-07
	10.3946	7.80E-08	5.20E-07	4.50E-08	2.05E-07
	10.5495	1.43E-07	9.53E-07	7.70E-08	3.50E-07
	10.206	1.21E-07	8.07E-07	7.10E-08	3.23E-07
	10.142	9.70E-08	6.47E-07	5.60E-08	2.55E-07
	10.0438	8.30E-08	5.53E-07	4.50E-08	2.05E-07
	10.8294	1.41E-07	9.40E-07	8.40E-08	3.82E-07
	10.2006	1.53E-07	1.02E-06	8.70E-08	3.95E-07
	10.4926	1.09E-07	7.27E-07	6.40E-08	2.91E-07
	10.7782	1.69E-07	1.13E-06	9.30E-08	4.23E-07
	10.3895	1.37E-07	9.13E-07	8.40E-08	3.82E-07
	20.069	1.03E-07	6.87E-07	5.60E-08	2.55E-07
	20.8233	1.48E-07	9.87E-07	8.60E-08	3.91E-07
	20.9706	1.74E-07	1.16E-06	9.70E-08	4.41E-07

Table 3: References and comments on tests.

Ref. #	Reference	Comments
1	Marchant & Hynes, 1981	length to weight relationships for <i>Gammarus fossarum</i> (Franke, 1977)
2	Ivlev, 1939	detritus dw/ww = 0.34 and faeces dw/ww = 0.41 (Ravera, 1955)
3	North, 1954	
4	Ravera, 1955	
5	Hobson, 1967	faeces dw/ww = 0.41 (Ravera, 1955)
6	Jacobsen, 1967 from Hargrave, 1972	
7	Rhoads, 1967 from Hargrave, 1972	weight from 3-10 g
8	Wachs, 1967 from Hargrave, 1972	dw of organism (Sanders et al., 1962); faeces dw/ww = 0.41 (Ravera, 1955)
9	McDiffett, 1970	adult dw (Berg et al., 1962); faeces dw/ww = 0.35 leaves dw/ww = 0.30 (Marchant & Hynes, 1981)
10	Appleby and Brinkhurst, 1970	faeces dw/ww = 0.36
11	Hargrave, 1972	faeces dw/ww = 0.41 (Ravera, 1955)
12	Hargrave, 1972	detritus dw/ww = 0.15 (Marchant and Hynes, 1981)
13	Hylleberg, 1975 from Cammen, 1980	detritus dw/ww = 0.15 (Marchant and Hynes, 1981)
14	Cammen, 1980	detritus dw/ww = 0.15 (Marchant and Hynes, 1981)
15	Lopez, 1976	detritus dw/ww = 0.15 (Marchant and Hynes, 1981)
16	Kisseleva & Vityuk, 1970	detritus dw/ww = 0.15 (Marchant and Hynes, 1981)
17	Fox et al., 1948	organism dw/ww = .17 (Cammen, 1980); detritus dw/ww = 0.34 and faeces dw/ww = 0.41 (Ravera, 1955)
18	Ono, 1965	detritus dw/ww = 0.15 (Marchant and Hynes, 1981)
19	Zimmerman & Wissing, 1978	detritus dw/ww = 0.34 and faeces dw/ww = 0.41 (Ravera, 1955)
20	Klump et al., 1991	detritus dw/ww = 0.15 (Marchant and Hynes, 1981)
21	Klump et al., 1987	faeces dw/ww = 0.41 (Ravera, 1955)
22	Dermott, 1981	detritus dw/ww = 0.15 (Marchant and Hynes, 1981)
23	Gordon, 1966	faeces dw/ww = 0.41 (Ravera, 1955); organism dw from Hargrave (1972)
24	Murtaugh, 1984	copepod dw/ww = 0.111 (Herbes & Allen, 1983) length to dw relationship from Sell (1982)
25	Van Duyn-Henderson & Lasenby, 1986	estimated length; length to dw relationship from Sell (1982); faeces dw/ww = 0.41 (Ravera, 1955)
26	McCullough et al., 1979	detritus dw/ww = 0.15 (Marchant and Hynes, 1981)
27	Moore 1975	gammarus dw/ww = .301 (Herbes & Allan, 1983)
28	Landrum & Poore, 1988	detritus dw/ww = 0.15 (Marchant and Hynes, 1981) hexagenia dw/ww = 0.18
29	Hargrave, 1970	estimate of average dw from range of 0.0006 - 0.0008 g bacteria, diatoms and algae dw/ww = 0.1 (Great Lakes Monograph No. 4, Feb. 1993) detritus dw/ww = 0.15 (Marchant and Hynes, 1981) organism dw from (Hargrave, 1972)

Table 3 continued

Ref. #	Reference	Comments
30	Chang & Parsons, 1975	bacteria dw/ww = 0.1 estimated from (Great Lakes Monograph No. 4, Feb. 1993)
31	Trama, 1972	diatom dw/ww = 0.1 estimated from (Great Lakes Monograph No. 4, Feb. 1993)
32	Brown et al., 1989	crayfish dw/ww = 0.237 (Henson & Skukal, 1987 with <i>Astacus astacus</i>)
33	Saffran, 1993	crayfish dw/ww = 0.237 (Henson & Skukal, 1987 with <i>Astacus astacus</i>) macrophyte dw/ww = 0.15 (Hargrave, 1970 for chara)
34	Hessen & Skurdal, 1987	
35	Brown et al., 1990	macrophyte dw/ww = 0.15 (Hargrave, 1970 for chara) crayfish dw/ww = 0.237 (Henson & Skukal, 1987 with <i>Astacus astacus</i>)
36	Chambers et al., 1991	length - ww relationship from Brown & Konoval (1993) macrophyte dw/ww = 0.15 (Hargrave, 1970 for chara) crayfish dw/ww = 0.237 (Henson & Skukal, 1987 with <i>Astacus astacus</i>)
37	Brown et al., 1986	crayfish dw/ww = 0.237 (Henson & Skukal, 1987 with <i>Astacus astacus</i>)
38	Love & Savino, 1993	crayfish dw/ww = 0.237 (Henson & Skukal, 1987 with <i>Astacus astacus</i>)
39	Soderback et al., 1987	data extrapolated from graph leaf dw/ww = 0.30 (Marchant & Hynes, 1981)
40	Martin & Corkum, 1995	crayfish dw/ww = 0.237 (Henson & Skukal, 1987 with <i>Astacus astacus</i>) length to weight relationship from Saffran (1993) soft tissue wt to total weight of zebra mussels from Love & Savino (1993)
41	Moshiri & Goldman, 1969	stomach contents dw/ww = 0.22 (Saffran, 1993) macrophyte dw/ww = 0.15 (Hargrave, 1970 for chara)

Table 4: Gill ventilation rates for benthic invertebrates.

Ref.#	Organism	Genus species	Temp. (°C)	Dry weight (g)	GV (m ³ /d)
1 mayfly	Hexagenia limbata		18	0.000468	0.0000064
				0.001125	0.0000137
				0.000648	0.0000066
				0.000666	0.0000041
				0.002376	0.0000131
				0.003186	0.0000109
				0.005724	0.0000076
				0.009054	0.0000188
2 polychaete	Nereis virens		16	0.401	0.006
				0.032	0.0025
				0.022	0.0022
				0.027	0.0019
				0.026	0.0017
				0.028	0.0017
				0.026	0.0016
				0.02	0.0011
				0.018	0.0008
				0.0009	0.00031
				0.003	0.00023
				0.005	0.00026
				0.018	0.0016
				0.018	0.0018
Nereis succinea				0.019	0.0016
				0.021	0.0018
				0.025	0.002
				0.041	0.0049
				0.047	0.0042
				0.007	0.00041
				0.011	0.00073
				0.019	0.0017
				0.02	0.0017
				0.021	0.002
				0.022	0.0021
				0.024	0.0019
				0.028	0.0023
				0.028	0.0022
				0.034	0.0023
3 mayfly	Hexagenia limbata		10	0.018	0.00001
				0.018	0.00018
				0.018	0.000026
				0.018	0.000019
				0.018	0.000008
4 amphipod	Gammarus pulex		15	0.0012	0.000009
				0.0032	0.000021
				0.0051	0.000031
				0.0068	0.00004
				0.0086	0.000051

Table 4 continued

Ref.#	Organism	Genus species	Temp. (°C)	Dry weight (g)	GV (m ³ /d)	
4 con't			10	0.0107	0.000067	
				0.0012	0.000006	
				0.003	0.000014	
				0.0049	0.000007	
				0.0061	0.000008	
				0.0089	0.000035	
				0.0107	0.000038	
			5	0.001	0.0000022	
				0.0013	0.0000021	
				0.0048	0.0000075	
				0.0069	0.000011	
				0.0186	0.000013	
			2	0.0137	0.000019	
				0.0013	0.0000017	
				0.0028	0.0000034	
				0.0049	0.000005	
				0.0067	0.0000067	
				0.0092	0.000009	
			10	0.0108	0.0000089	
	5 amphipod	<i>Gammarus limnaeus</i>		0.0036	0.0073	
				0.0036	0.0069	
				0.0039	0.0049	
				0.0043	0.0054	
				0.0047	0.006	
				0.0054	0.0057	
				0.0054	0.0074	
				0.0057	0.0085	
				0.0060	0.0077	
				0.0060	0.0089	
				0.0060	0.0115	
				0.0063	0.01	
				0.0063	0.01	
				0.0063	0.0121	
				0.0066	0.007	
				0.0069	0.0058	
				0.0069	0.0073	
				0.0069	0.0073	
				0.0069	0.0131	
				0.0072	0.0061	
				0.0072	0.0099	
				0.0075	0.008	
				0.0075	0.0143	
				0.0075	0.0159	
				0.0075	0.0167	
				0.0075	0.0223	
				0.0075	0.0064	
				0.0077	0.0099	
				0.0077	0.0115	

Table 4 continued

Ref.#	Organism	Genus species	Temp. (°C)	Dry weight (g)	GV (m ³ /d)
5 con't				0.0077	0.0148
				0.0077	0.0156
				0.0080	0.0043
				0.0080	0.0094
				0.0084	0.0053
				0.0084	0.0107
				0.0084	0.016
				0.0084	0.0133
				0.0086	0.0129
				0.0086	0.0129
				0.0094	0.013
				0.0096	0.008
				0.0096	0.016
				0.0103	0.02
				0.0105	0.0067
				0.0105	0.0089
				0.0108	0.008
				0.0108	0.0115
				0.0111	0.0142
				0.0114	0.0085
				0.0114	0.0121
				0.0117	0.0075
				0.0117	0.0087
				0.0120	0.014
				0.0124	0.0079
				0.0124	0.0079
				0.0126	0.0081
				0.0126	0.0107
				0.0129	0.0055
				0.0129	0.0068
				0.0129	0.0096
				0.0133	0.0155
				0.0136	0.0159
				0.0144	0.0076
				0.0144	0.0153
				0.0147	0.0141
				0.0150	0.0143
				0.0150	0.0159
				0.0152	0.0081
				0.0156	0.0133
				0.0159	0.0152
				0.0162	0.0121
				0.0165	0.0088
				0.0176	0.0112
				0.0182	0.0097
				0.0182	0.0155
				0.0090	0.0077
				0.0090	0.0077

Table 4 continued

Ref.#	Organism	Genus species	Temp. (°C)	Dry weight (g)	GV (m3/d)
5 con't				0.0090	0.0086
				0.0090	0.0096
				0.0090	0.0096
6 polychaete	Clymenella torquata		28.5	0.0085	0.000089
	Clymenella zonalis			0.00425	0.000048
	Branchioasychis			0.1445	0.00051
	americana				
	Petaloproctus socialis			0.01105	0.000065
7 amphipod	Gammarus pulex		20	0.0005	0.0113
				0.0005	0.0411
				0.0006	0.0379
				0.0006	0.0443
				0.0006	0.0511
				0.00062	0.029
				0.0007	0.0564
				0.00072	0.0203
				0.00078	0.0474
				0.00078	0.0672
				0.00088	0.0717
				0.0009	0.0622
				0.0009	0.0653
				0.00094	0.059
				0.00099	0.0411
				0.00111	0.0495
				0.00114	0.0158
				0.00114	0.0717
				0.00114	0.0464
				0.00116	0.0026
				0.00116	0.0443
				0.00116	0.0635
				0.00116	0.0814
				0.00126	0.0353
				0.00126	0.039
				0.00128	0.0092
				0.00128	0.0485
				0.00128	0.0511
				0.00128	0.0535
				0.00128	0.059
				0.00128	0.0701
				0.00138	0.0474
				0.00138	0.0746
				0.00146	0.0495
				0.00146	0.0664
				0.0015	0.0643
				0.0015	0.069
				0.00152	0.0548
				0.00152	0.0582
				0.00156	0.0664
				0.00164	0.0516

Ref.#	Organism	Genus species	Temp. (°C)	Dry weight (g)	GV (m3/d)
7 con't				0.00164	0.0653
				0.00164	0.0495
				0.00164	0.0909
				0.00164	0.097
				0.0017	0.0516
				0.00172	0.0635
				0.00172	0.0672
				0.00172	0.0709
				0.0018	0.0311
				0.0018	0.0411
				0.0018	0.0495
				0.0018	0.0527
				0.0018	0.0601
				0.0018	0.0635
				0.0018	0.069
				0.0018	0.0717
				0.0018	0.0851
				0.002	0.0582
				0.002	0.0709
				0.003	0.0783
				0.003	0.0814
				0.00395	0.0909
				0.00395	0.1373
				0.00395	0.1431
				0.004	0.097
				0.00482	0.1739
				0.0064	0.097
				0.0067	0.1431
				0.0069	0.1739
				0.0069	0.2003
8 polychaete	Tubifex barbatus		15	0.0034	0.0033
	Ilyodrilus hammonicnisis			0.00068	0.0014
	Tubifex tubifex		11	0.0017	0.0022
			8	0.001	0.00075
	Lumbricillus rivalis		11	0.000765	0.0021
			8	0.000595	0.00095
insect larvae	Procladius sp.		15	0.0007	0.0021
	Chironomus anthracinus		14	0.0016	0.00387
				0.0016	0.00205
9 crayfish	Corethra flavicans		18	0.0001	0.0035
	Pacifastacus leniusculus		20	0.7993	0.00339
				0.7993	0.004148
				0.9564	0.00459
				0.9564	0.00531
				2.6983	0.00595
				2.6983	0.00688
				10.4026	0.0066
				10.4026	0.00753
				20.6209	0.0086
				20.6209	0.00913

Table 4 continued

Ref.#	Organism	Genus species	Temp. (°C)	Dry weight (g)	GV (m ³ /d)
10	crayfish	<i>Orconectes propinquus</i>	24	0.16	0.00012
				0.16	0.00125
				0.16	0.00133
				0.28	0.00119
				0.28	0.00186
				0.28	0.00203
				0.53	0.00109
				0.53	0.00186
				0.53	0.00222
				0.64	0.00312
				0.64	0.00543
				0.64	0.00667
				0.71	0.00254
				0.71	0.00299
				0.71	0.00449

Table 5: References and comments about gill ventilation tests.

Ref.#	Reference	Comments
1	Stehly et al., 1990	hexagenia dw/ww = 0.18 data extrapolated from graph
2	Kristensen, 1981	polychaete dw/ww = 0.17 data extrapolated from graph salt water species
3	Landrum & Poore, 1988	hexagenia dw estimated to be 0.018 g
4	Nilsson, 1974	data extrapolated from graph
5	Krog, 1954	gammarus dw/ww = 0.30 (Herbes & Allen, 1983), data extrapolated from graph
6	Mangum, 1964	polychaete dw/ww = 0.17 (Cammen, 1980)
7	Rumpus & Kennedy, 1974	data extrapolated from graph
8	Berg et al., 1962	polychaete dw/ww = 0.17 (Cammen, 1980) insect larvae dw/ww = 0.20
9	Moshiri & Goldman, 1969	
10	Spencer, 1984	crayfish dw/ww = 0.237 (Henson & Skukal, 1987 with <i>Astacus astacus</i>) data extrapolated from graph

REFERENCES

- Appleby, A.G. and R.O. Brinkhurst. 1970. Defecation rate of three tubificid oligochaetes found in the sediment of Toronto Harbour, Ontario. J. Fish. Res. Bd. Canada. 27:1971-1982.
- Benson, B.B., and D. Krause, Jr. 1980. The concentration and isotopic fractionation of gases dissolved in freshwater in equilibrium with the atmosphere. 1. Oxygen. Limnol. Oceanogr. 25:662-671.
- Berg, K., P.M. Jonasson and K.W. Ockelmann. 1962. The respiration of some animals from the profundal zone of a lake. Hydrobiol. 19:1-39.
- Cammen, L.M. 1980a. Ingestion rate: An empirical model for aquatic deposit feeders and detritivores. Oecologia. 44:303-310.
- Cammen, L.M. 1980b. A method for measuring ingestion rate of deposit feeders and its use with the polychaete Nereis succinea. Estuaries. 3:55-60.
- Chang, B.D. and T.R. Parsons. 1975. Metabolic studies on the amphipod Anisogammarus pugettensis in relation to its trophic position in the food web of young salmonids. J. Fish. Res. Board Can. 32:243-247.
- Dermott, R. 1981. Ingestion rate of the burrowing mayfly Hexagenia limbata as determined with ¹⁴C. Hydrobiol. 83:499-503.
- Fox, D.L., S.C. Crane and B.H. McConaughey. 1948. A biochemical study of the marine annelid worm, Thoracophelia Mucronata. J. Mar. Res. 7:567-585.
- Gordon, Jr. G.C. 1966. The effects of the deposit feeding polychaete Pectinaria gouldii on the intertidal sediments of Barnsdale Harbor. Limnol. Oceanogr. 11:327-332.
- Hargrave, B.T. 1970. The utilization of benthic microflora by Hyalella azteca (amphipoda). J. Anim. Ecol. 39:427-437.
- Hargrave, B.T. 1972. Prediction of egestion by the deposit-feeding amphipod Hyalella azteca. Oikos. 23:116-124.
- Herbes, S.E. and C.P. Allen. 1983. Lipid quantification of freshwater invertebrates: Method modification for microquantitation. Can. J. Fish. Aquat. Sci. 40:1315-1317.
- Hessen, D.O. and J. Skurdal. 1987. Food consumption, turnover rates and assimilation in the noble crayfish (Astacus astacus). Fresh. Cray. 7:309-317.
- Hobson, K.D. 1967. The feeding and ecology of two North Pacific Abarenicola species (Arenicolidae, polychaeta). Biol. Bull. 132:343-354.
- Hylleberg, J. 1975. The effect of salinity and temperature on egestion in mud snails (Gastropoda: Hydrobiidae). Oecologia. 21:279-289.
- Ivlev, V.S. 1939. Transformation of energy by aquatic animals. Coefficient of energy consumption by Tubifex tubifex (Oligochaeta). Int. Rev. Hydrobiol. 38:449-458.
- Jacobsen, V.H. 1967. The feeding of the lugworm, Arenicola marina (L.). Ophelia. 4:91-109.

- Klump, J.V., J.R. Krezski, M.E. Smith and J.L. Kaster. 1987. Dual tracer studies of the assimilation of an organic contaminant from sediments by deposit feeding oligochaetes. *Can. J. Fish. Aquat. Sci.* 44:1574-1583.
- Klump, J.V., J.L. Kaster and M.E. Sierszen. 1991. *Mysis relicta* assimilation of hexachlorobiphenyl from sediments. *Can. J. Fish. Aquat. Sci.* 48:284-289.
- Kristensen, E. 1981. Direct measurement of ventilation and oxygen uptake in three species of tubicolous polychaetes (*Nereis* spp.). *J. Comp. Physiol.* 145:45-50.
- Krog, J. 1954. The influence of seasonal environmental changes upon the metabolism, lethal temperature and rate of heart beat of *Gammarus limnaeus* (Smith) taken from an alaskan lake. *Biol. Bull.* 106:397-410.
- Landrum, P.F. and R. Poore. 1988. Toxicokinetics of selected xenobiotics in *Hexagenia limbata*. *J. Great Lakes Res.* 14:427-437.
- Mangum, C.P. 1964. Activity patterns in metabolism and ecology of polychaetes. *Comp. Biochem. Physiol.* 11:239-256.
- Marchant, R. and H.B.N. Hynes. 1981. Field estimates of feeding rate for *Gammarus pseudolimnaeus* (Crustacea: Amphipoda) in the Credit River, Ontario. *Freshwater Biol.* 11:27-36.
- McCullough, D.A. and G.W. Minshall. 1979. Bioenergetics of a stream "collector" organism, *Thicorythodes minutus* (Insecta: Ephemeroptera). *Limnol. Oceanogr.* 24:45-58.
- McDiffett, W.F. 1970. The transformation of energy by a stream detritivore, *Pteronarcys scotti* (Plecoptera). *Ecology.* 51:975-988.
- Moore, J.W. 1975. The role of algae in the diet of *Asellus aquaticus* L. and *Gammarus pulex* L. *J. of Anim. Ecol.* 44:719-730.
- Moshiri, G.A. and C.R. Goldman. 1969. Estimation of assimilation efficiency in the crayfish, *Pacifastacus leniusculus* (Dana) (Crustacea: Decapoda). *Arch. Hydrobiol.* 66:298-306.
- Murtaugh, P.A. 1984. Variable gut residence time: Problems in inferring feeding rate from stomach fullness of a mysid crustacean. *Can. J. Fish. Aquat. Sci.* 41:1287-1293.
- Nilsson, L.M. 1974. Energy budget of a laboratory population of *Gammarus pulex* (amphipoda). *Oikos.* 25:35-42.
- North, W.J. 1954. Size distribution, erosive activities, and gross metabolic efficiency of the marine intertidal snail, *Littorina planaxis* and *L. Scutulata*. *Biol. Bull.* 106:185-197.
- Ono, Y. 1965. On the distribution of ocypoid crabs in the estuary. *Mem. Fac. Sci. Kyushu. Univer., Ser. E. (Biol.).* 4:1-60.
- Ravera, O. 1955. Amount of mud displaced by some freshwater oligochaeta in relation to the depth. *Mem. Ist. Idrobiol. suppl.* 8:247-264.
- Reducing uncertainty in mass balance models of toxic in the Great Lakes - Lake Ontario case study. Donald W. Rennie Memorial Monograph Series. Great Lakes Monograph No. 4. February 1993. p.270.
- Rhoads, D.C. 1967. Biogenic reworking of intertidal and subtidal sediments in Barnstable Harbor and Buzzards Bay, Massachusetts. *J. Geol.* 75:461-476.

- Rumpus, A.E. and C.R. Kennedy. 1974. The effect of the acanthocephalan Pomphorhynchus laevis upon the respiration of its intermediate host, Gammarus pulex. Parasitol. 68:271-284.
- Sanders, H.L., E.M. Goudsmid, E.L. Mills and G.E. Hampson. 1962. A study of the intertidal fauna of Barnsdale Harbor, Massachusetts. Limnol. Oceanogr. 7:63-79.
- Sell, D.W. 1982. Size-frequency estimates of secondary production by Mysis relicta in Lakes Michigan and Huron. Hydrobiol. 93:69-78.
- Spencer, D.F. 1984. Oxygen consumption by the crayfish Orconectes propinquus (Girard) exposed to Aquashade. Bull. Environ. Contam. Toxicol. 33:373-378.
- Stehly, G.R., P.F. Landrum, M.G. Henry and C. Klemm. 1990. Toxicokinetics of PAHs in Hexagenia. Environ. Toxicol. Chem. 9:167-174.
- Van Duyn-Henderson, J.A. and D.C. Lasenby. 1986. Zinc and cadmium transport by the vertically migrating opossum shrimp, Mysis relicta. Can. J. Fish. Aquat. Sci. 43:1726-1732.
- Zimmerman, M.C. and T.E. Wissing. 1978. Effects of temperature on gut-loading and gut-clearing times of the burrowing mayfly, Hexagenia limbata. Freshwater Biol. 8:269-277.

