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DEEP CREEK VALIDATION STUDY: RESULTS OF DATA SEARCH FOR AQUATIC MODEL

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INTRODUCTION

Development of an aquatic model for the Desert Biome began in the spring of 1972 and within a relatively short period had made substantial progress. The need for an extensive data base, from which "parameterization" of the model could be done, soon became apparent and in July, 1972, funds were requested from the Desert Biome Executive Committee for the support of the required data-gathering activities. These activities began in May, 1973, and will extend through 1974, at which time the completion of an operational version of the model is anticipated.

Due to the limited financial support available, it was decided that the most efficient use of the funds would be to concentrate on the wealth of information already available in the literature and to enter into collection of original data only in those cases where the required values could be obtained in no other way. The primary goal was to provide reasonable "order of magnitude" values for initial exercising of the computer model. It was felt that once this was accomplished it would be possible to gain direction from the model itself for further refinement of the key factors through original research or additional examination of the literature.

This report summarizes the results of the Data Search activities during the first year. The work has proceeded along three lines: (1) "literature search," including examination of unpublished reports, (2) "on-site data collection," usually involving simple sets of measurements (e.g., light transmission under different sediment loads) from one or more of the aquatic validation sites, and (3) "short-term process studies" -- small scale research projects intended to answer specific questions or provide specific values (e.g., the determination of food preferences of invertebrates from Deep Creek and Locomotive Spring). The approach has proven to be a profitable one and will be continued in 1974.

Searching of the literature was done mainly in terms of parameters defined in the model (designated in the report by captions in FULL CAPITALS) but a few additional categories were examined (designated by Partial Capitals) to provide information for checking computer-derived values or to serve as the basis for modeling areas of anticipated interest. All of the pertinent references and the data obtained from them have been entered on 4 x 6 file cards. Author cards have been prepared in standard bibliographic format. The data cards are headed with the relevant parameter name and the author and page reference. Where appropriate, the published tables or figures have been photocopied and attached to the cards. A separate file is maintained for each of the major subroutines of the model.

In the preparation of this summary report each data set was examined to obtain one or a few "representative" values. Determination of representativeness was arbitrary but where possible was framed in terms of desert aquatic systems. In some cases it was necessary to convert the data into usable form but generally the data were left in their original state. The user can make his own interpretation as to their suitability. Only data that were directly applicable or readily converted were used; in most cases additional information is available in the data file but will require transformation or extrapolation.

The report is arranged in five sections:

1. Subroutines EXTERN, MEDIUM and PHYSIC
2. Subroutine VEGET
3. Subroutine ANIMAL -- Decomposer Parameters
4. Subroutine ANIMAL -- Animal Parameters
5. Bibliography

Within each section the categories are in alphabetical order. Parameters used in the model are listed first followed by supplemental categories, if used. A definition is given of each parameter reviewed along with a listing of the number of data cards available at the time (December, 1973) and the number of independent sources represented. Following the presentation of key or representative values, all of the references that were examined are cited. These are given in full in the Bibliography.

Data Search Guide

Parameters	No. of Data Cards	No. of References	Page No.
COAGUL	5	2	4
EVAP	0	0	4
FALL	14	5	4
AMORT	1	1	4
CONNI2	15	14	4
CONRAD	12	11	4
CONTE 2	8	6	5
CONTE 3	7	7	5
EXTINP	3	3	5
EXTINS	0	0	5
EXTINW	2	1	6
LEACH	22	6	6
LEAK	27	5	6
RESPD	11	7	6
RESPV	2	2	6
UPCON	21	15	6
UPCON1	18	15	7
UPCON2	11	9	7
Growth	14	13	7
Net Assimilation	14	10	7
CONS	101	39	8
CONT	21	15	9
PREFER	24	14	9
Constituents	8	5	10
Microbe Kinds	9	6	10
Microbe Populations	22	12	12
AMORTA	30	17	12
ASSIM	40	30	13
EGEST	16	9	14
PREF	63	32	15
RECONST	25	17	16
RESP	53	51	16
TAKE	45	27	16
TEMCON	5	5	18
XCRSOL	5	1	18

RESULTS OF DATA SEARCH

SUBROUTINES EXTERN, MEDIUM AND PHYSIC

COAGUL (5 data cards) -- Rate of coagulation of dissolved organic matter to a size sufficient to settle out (FALL)

Representative range of values:

0.005 mg C/l/day (plateaus after 5 days)
(Sheldon et al., 1967)

Literature sources:

Cummins et al., 1972
Sheldon et al., 1967

EVAP (0 data cards) -- Pan evaporation for the current day

Representative range of values:

Evaporation from Curlew Valley at Snowville, Utah in $g/m^2/day$ (= in/mo x 25 mm/in x 1 mo/30 day x 1000 $g/m^2/mm$)

J	1180	Jly	5980
F	1470	A	5420
M	2380	S	4000
A	3320	O	2980
M	4350	N	1910
Jn	5150	D	1300

FALL (14 data cards) -- Settling rate of various-sized organic and inorganic particles (detritus) and assorted kinds of algae

Representative range of values:

Particle	Settling rate (cm/sec)	Reference
gravel	1.0×10^2	(Todd, 1970)
coarse sand	6.0×10	(Todd, 1970)
fine sand	3.8×10^{-1}	(Todd, 1970)
silt	7.5×10^{-2}	(Todd, 1970)
calcite crystals	2.3×10^{-3}	(Brunskill, 1969)
diatoms	12.6×10^{-3}	(Hutchinson, 1967)
bacteria	1.5×10^{-4}	(Todd, 1970)
clay	1.5×10^{-6}	(Todd, 1970)
colloid particles	1.5×10^{-8}	(Todd, 1970)

Literature sources:

Brunskill, 1969
Hutchinson, 1967
Smayda, 1970
Smayda and Boleyn, 1965
Todd, 1970

SUBROUTINE VEGET

AMORT (1 data card) -- The proportional non-grazing mortality per time unit, of the I'th plant species group

Representative value:

3% lysing of cells

Literature sources:

Middlebrooks, Falkenborg and Maloney, 1973

CONNI 2 (15 data cards) -- Nutrient (C, N, P) concentration at which photosynthesis ceases

Representative range of values:

Organism	Minimum mg/l		Reference
marine algae	CO_2	0.4	(Strickland, 1960)
green algae	CO_2	0.4	(King, 1972)
blue green algae	CO_2	0.1	(King, 1972)
Cladophora	N	0.46	(Mason, 1965)
	P	0.01	
phytoplankton	N	0.1	(Chu, 1943)
	P	0.009	
diatoms	Si	0.05	(Schelske and Stoermer, 1972)

Literature sources:

Chu, 1943
Gerloff, 1969
Gerloff and Krombholz, 1966
Gerloff & Skoog, 1954
Jorgensen, 1957
King, 1972
Lund, 1950
Mason, 1965
Moss, 1962
Peltier & Welch, 1969 & 1970
Pitcairn & Hawkes, 1973
Pratt, 1965
Schelske & Stoermer, 1972
Strickland, 1960

CONRAD (12 data cards) -- Radiation intensity at which maximum photosynthesis occus for assorted plant groups, especially *Cladophora*, *Spirogyra*, benthic diatoms, *Potamogeton* (also, point of light inhibition)

Representative range of values:

Organism	$cal/cm^2/min$	Reference
Chlorella	2.6×10^{-1}	(Sorokin, 1971)
Chlorophyta	5.7×10^{-3}	(Di Toro et al., 1971)
diatoms	1.7×10^{-2}	(Di Toro et al., 1971)
Cladophora	4.3×10^{-2}	(Whitton, 1967)

Literature sources:

Biebl, 1962	Sorokin and Krauss, 1958
Di Toro et al., 1971	Stockner, 1968
Franck and Loomis, 1950	Wetzel, 1964
Manning et al., 1938	Whitton, 1967
McIntire et al., 1964	Zuraw, 1969
Sorokin, 1971	

CONTE 2 (8 data cards) -- Relation of photosynthesis to temperature

Representative range of values:

Organism	gC/g/hr	°C	Reference
Chlorella	13.4	20	(Sorokin, 1971)
	19.2	25	"
	26.8	30	"
	26.8	35	"
	14.7	39	"

Literature sources:

Bellis, 1968	Sorokin, 1971
Emerson, 1929	Strickland, 1960
Metzner, 1969	Zuraw, 1969

CONTE 3 (7 data cards) -- Temperature at which maximum photosynthesis occurs

Representative range of values:

Organism	°C	Reference
Cladophora	18	(Storr and Sweeny, 1971)
	25	(Zuraw, 1969)
Chlorella	33	(Sorokin, 1971)
diatoms	23	(Wang and Evans, 1969)

Maximum growth rates as a function of temperature (Di Toro et al., 1971, Table 1):

Ref.	Organism	Temperature	Saturated growth rate, K'($Base_e$, Day^{-1})
21	*Chlorella ellipsoidea*	25	3.14
	(green alga)	15	1.2
22	*Nannochloris atomus*	20	2.16
	(marine flagellate)	10	1.54
23	*Nitzschia closterium*	27	1.75
	(marine diatom)	19	1.55
		15.5	1.19
		10	0.67
5	Natural association	4	0.63
		2.6	0.51
24	*Chlorella pyrenoidosa*	25	1.96
24	*Scenedesmus quadricauda*	25	2.02
25	*Chlorella pyrenoidosa*	25	2.15
25	*Chlorella vulgaris*	25	1.8
25	*Scenedesmus obliquus*	25	1.52
25	*Chlamydomonas reinhardti*	25	2.64
26	*Chlorella pyrenoidosa*	10	0.2
	(synchronized culture)	15	1.1
	(high-temperature strain)	20	2.4
		25	3.9

Literature sources:

Bellis, 1968	Storr and Sweeny, 1971
Di Toro et al., 1971	Wang and Evans, 1969
Metzner, 1969	Whitton, 1967
Sorokin, 1971	Zuraw, 1969

EXTINP (3 data cards) -- Extinction coefficient for light intercepted by plant material (per g per m^2)

Representative value:

.23/gC/m^2 (Talling, 1969)

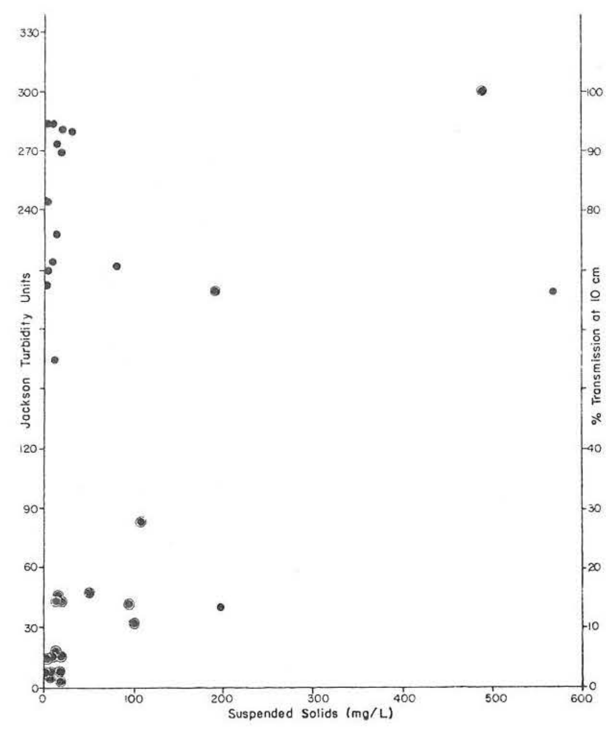
Literature sources:

Di Toro et al., 1971	Talling, 1969
Murphy, 1962	

EXTINS (0 data cards) -- Extinction coefficient for light intercepted by suspended inorganic material (per g per m^2)

Representative range of values:

Relationship of turbidity (ringed dots) and percent transmission (solid dots) to suspended solids as determined empirically for Deep Creek water:



EXTINW (2 data cards) -- Extinction coefficient for light passing through water (per m; distilled and various defined dissolved solids concentrations)

Representative value:

.210/m (Hutchinson, 1967)

Literature sources:

Hutchinson, 1967

LEACH (22 data cards) -- Rate of leaching of dissolved organic matter from fine and coarse detritus

Representative range of values:

Fallen leaves	% dry wt. lost/hr	Reference
Silver maple	0.77	(Cummins et al., 1972)
Maple	0.54	(Kaushik and Hynes, 1971)
Elm	0.42	(Kaushik and Hynes, 1971)
Hickory	0.26	(Cummins et al., 1972)
Oak	0.21	(Kaushik and Hynes, 1971)
Beech	0.21	(Kaushik and Hynes, 1971)
Alder	0.17	(Kaushik and Hynes, 1971)
Mean	0.37	

Literature sources:

Cummins et al., 1972
Gosz et al., 1973
Grill and Richards, 1964
Jewell, 1971
Kaushik and Hynes, 1971
Liston, 1972

LEAK (27 data cards) -- Rate of loss of dissolved constituents across cell membrane of living organism

Representative range of values:

Cyanophyceae *Calothrix*	N loss in % of total N- dependent on temperature and incubation time-- Range 34-94%; higher at higher temperature (40°C, 74-85%) (Jones and Stewart, 1969)
Phytoplankton	(Reservoirs) 0.2-5% extracellular, of total mg chlorophyll a or b/m³
Bacillariophyceae	C loss in % of total C assimilated-- Range 8.5-43% (Hellebust, 1965)

Literature sources:

Fogg and Watt, 1965
Hellebust, 1965
Hobbie and Wright, 1965
Jones and Stewart, 1969
Watt, 1966

RESPD (11 data cards) -- Relation of respiration to temperature (preferably as gC/hr) for assorted plant groups

Representative range of values:

Organism	gC/g/hr	°C	Reference
Chlorella	0.80	15	(Sorokin, 1971)
	0.91	20	"
	0.96	25	"
	1.13	30	"
	0.91	35	"
	0.75	39	"
	0.70	43	"
	0.70	45	"
Elodea and *Potamogeton*	210	9	(McDonnell and Weeter, N.D.)
	180	10	"
	130	11	"
	290	12	"
	390	15	"
	270	16	"
	490	19	"
	550	20	"

Literature sources:

Beyers, 1965
Di Toro et al., 1971
Gibbs, 1962
McCree, 1970
McDonnell and Weeter, N.D.
Owens and Maris, 1964
Sorokin, 1971

RESPV (2 data cards) -- Current respiration rate of the plant species group under consideration

Representative range of values:

Organism	Date	°C	mg/g/hr	Reference
Potamogeton crispus	Jan	5	0.53	(McDonnell and Weeter, N. D.)
	Mar-Apr	10	1.43	"
	June	15	1.88	"
Potamogeton perfoliatus		12	1.3	(Gessner and Pannier, 1958, cited by McDonnell and Weeter, N. D.)
Periphyton communities		7-10	1.0	(McIntire, 1966, cited by McDonnell and Weeter, N. D.)
		19	2.4	

Oxygen consumption decreased with decreasing oxygen in the water (and also decreasing current velocity)

Literature sources:

McCree, 1970
McDonnell and Weeter, N.D.

UPCON (21 data cards) -- Rate of uptake of a nutrient (C, N, P) by various plants (preferably per unit biomass C per time) per unit by which the internal ratio of the nutrient falls below that which would be in equilibrium with exterior

Representative range of values:

Nutrient	Rate of uptake	Reference
C	2×10^{-2} gC/g dry wt/hr	(Goering et al., 1966)
C	8.2×10^{-2} gC/g/hr	(Powers et al., 1972)
N	3×10^{-2} gN/g dry wt/hr	(Goering et al., 1966)
N	12.8 mgN/m²/hr	(Stockner, 1968)
P	5.5 mgN/m²/hr	(Stockner, 1968)
Michaelis constants		
N	0.010 mg/l	(Di Toro et al., 1971)
P	0.050 mg/l	

Literature sources:

Billand, 1966	Jorgensen, 1952 and 1953
Boyd, 1970a, b	Kilham, 1971
Di Toro et al., 1971	Lewin, 1957
Eppley and Thomas, 1969	MacIssac and Dugdale, 1969
Eppley et al., 1969	Powers et al., 1972
Fitzgerald, 1968	Stockner, 1968
Goering et al., 1966	Toetz et al., 1973

UPCON 1 (18 data cards) -- Maximum value for the ratio of the nutrient (N, P) to carbon

Representative range of values:

Organism	C : N : P	Reference
general mean	50: 8 : 1	
marine algae	42: 7 : 1	(Round, 1965)
Potamogeton	10: 1	(Gerloff, 1969)
freshwater algae	8: 1	(Milner, 1953)
diatoms	7: 1	(Strickland, 1960)
Chlorophyceae	43: 8 : 3	(Di Toro et al., 1971)
Cyanophyceae	50: 8 :0.1	(Hutchinson, 1973)
algae	100: 16: 1	(King, 1972)
Typha latifolia and *Scirpus americanus*	7 : 1	(Boyd, 1970a)

Literature sources:

Boyd, 1970a	Milner, 1953
DiToro et al., 1971	Peltier and Welch, 1970
Gerloff, 1969	Platt and Irwin, 1973
Gerloff and Krombholz, 1966	Round, 1965
	Ryther et al., 1958
Hutchinson, 1973	Strickland, 1960
King, 1972	Westlake, 1965
McDonnell and Weeter, N.D.	Whitton, 1970

UPCON 2 (11 data cards) -- Relation of internal to external concentration of a given nutrient

Representative range of values:

Nutrient	Ex:In	Reference
N	2:1	(Gerloff and Skoog, 1954)
P	2:1	(Gerloff and Skoog, 1954)
Si	$1:10^{-8}$	(Lewin, 1957)

Literature sources:

Billand, 1966	Kuhl, 1962
Gerloff & Krombholz, 1966	Lewin, 1957
	Lund, 1950
Gerloff & Skoog, 1954	McDonnell & Wheeter, N.D.
Gerloff & Skoog, 1957	
Jorgensen, 1955	

Growth (14 data cards)

Representative range of values:

Freshwater algae
1-3 cell divisions/day (exponential phase; favorable conditions) (Talling,1969)

Periphyton (filamentous blue-greens and *Spirogyra* plus diatoms, respectively) (Kevern et al., 1966)
instantaneous growth rate on plexiglass plates (lab. stream) 0.51 $gm^{-2}day^{-1}$
instantaneous growth rate on stream bottom (lab stream) 0.60 $gm^{-2}day^{-1}$
average rate of growth (single exposure period) 0.31 g/m^2/day

Diatoms, marine (Strickland, 1960)
0.02-0.15 generation/hr (probably optimum conditions)

No. of cell divisions/day of two diatom species vs. the no. of cells inoculated (Williams, 1965; Table 2):

Inoculum (number of cells)	*Cylindrotheca gerstenbergeri*	*Pleurosigma angulatum*
3	1.2	0.8
10	1.1	0.7
100	1.1	0.7
1,000	1.0	0.7
7,300	0.9	---
10,000	---	0.5

Most of the values are averages of two replicates.

Maximum number of divisions per day = 3.75 - 0.7 (log volume) = -0.01 + 1.64 $(\text{area/volume})^{1/2}$. Cell volume is in cubic microns and cell area in square microns

Cellular growth rate of *Cladophora* (Zuraw, 1969; Table 3):

Time (days)	Cell numbers/fragment 1	2	3	4	5
0	19	24	12	23	20
4	32	100	40	125	200
5	80	207	66	260	450
7	178	487	138	616	993
11	---	820	220	960	---

Culture conditions: One filament fragment per Petri dish; Medium C; 25 C; 200 ft-c; stagnant.

Literature sources:

Di Toro et al., 1971	Storr and Sweeny, 1971
Jitts et al., 1964	Strickland, 1960
Jorgensen, 1952	Talling, 1969
Kevern et al., 1966	Westlake, 1965
Lewin, 1957	Williams, 1965
Mason, 1965	Zuraw, 1969
Stockner, 1968	

Net Assimilation (14 data cards)

Representative range of values:

The annual net primary production of aquatic communities on fertile sites (Westlake, 1965):

Organism	m.t dry organic matter/ha
Marine phytoplankton	1 - 4.5
Lake phytoplankton	1 - 9
Freshwater submerged macrophytes (water weeds)	4 - 20
Marine submerged macrophytes (seaweeds)	25 - 40
Marine emergent macrophytes (salt marsh)	25 - 85?
Freshwater emergent macrophytes (reedswamp)	30 - 85

Literature sources:

Dwivedi, 1971	Ryther et al., 1958
Ichimura, 1968	Stockner, 1968
McIntire et al., 1964	Westlake, 1965
Odum, 1956	Wetzel, 1964
Owens and Edwards, 1961	Yentsch, 1962

SUBROUTINE ANIMAL

DECOMP Parameters

CONS (101 data cards) -- Rate or amount of substrate used by different groups of microbes, esp. relationships between decompostion or use of organic matter and different microbial types

Representative range of values:

Epiphytic bacteria showed the greatest metabolic activity (as O_2-uptake), benthic bacteria were least active and the water isolates were intermediate (Strzelczyk and Mielczarek, 1971)

Percent of substrate taken up per day (Banoub and Williams, 1972): amino acids, 1-27%; glucose, 1-44% (heterotrophic activity for the western Mediterranean)

Glucose-uptake activity. Glucose uptake by bacteria at low substrate concentrations (0 to *ca.* 500 μg glucose/1) follows Michaelis-Menten kinetics and is described by a modification of the Lineweaver-Burk equation (see Wright and Hobbie, 1966 for derivation):

$$Ct/c = (K_t + S_n)/V + A/V$$

where c is the radioactivity of the organisms retained on the filter (cpm); C the cpm from added ^{14}C-labeled glucose; t the incubation time in hours; K_t a transport constant; S_n the *in situ* concentration of glucose (mg/1); V the maximum velocity attained when all uptake sites are saturated with glucose; and A the concentration of added glucose (labeled and unlabeled, mg/1). By plotting Ct/c against A, the intercept on the negative abscissa is equal to $(K_t + S_n)$; the reciprocal of the slope is V. The ordinate intercept is equivalent to complete removal of the natural glucose by organisms. The $(K_t + S_n)$ approximates the *in situ* substrate concentration S_n, if K_t is very small

Values for $(K_t + S_n)$, V_p and T_t obtained with natural populations in sea-water samples (Takahashi and Ichimura, 1971; Table 2):

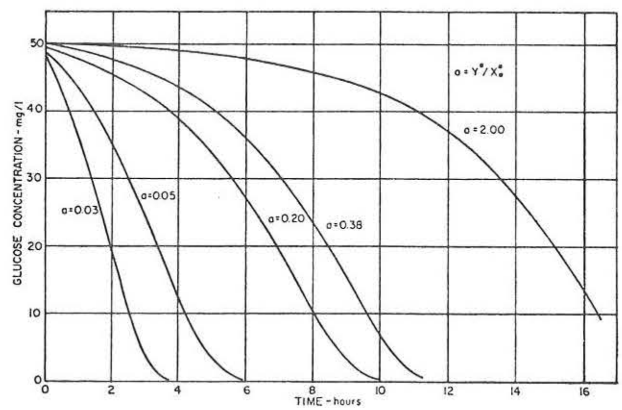
Depth (m)	Station 1 $(K_t+S_n)^a$	Station 1 V_p^b	Station 1 T_t^c	Station 2 $(K_t+S_n)^a$	Station 2 V_p^b	Station 2 T_t^c	Station 3 $(K_t+S_n)^a$	Station 3 V_p^b	Station 3 T_t^c
0	50.0	0.1540	320	23.0	0.0550	420	5.0	0.0185	270
10	50.0	0.0230	2200	23.0	0.0290	790	5.0	0.0276	180
30	57.0	0.0142	4000	19.0	0.0140	1400	6.5	0.0245	270
50	8.4	0.0053	1580	18.0	0.0170	1060	10.0	0.0028	3570
75	13.0	0.0146	890	28.0	0.0200	1400	11.0	0.0036	3000
100	19.8	0.0277	710	30.0	0.0180	1700			
125	27.5	0.0055	5000	60.0	0.0010	6000	31.5	0.0063	5000
150	36.5	0.0041	8900	44.0	0.0145	2800	41.5	0.0035	11900
300	41.5	0.0073	5700	23.0	0.0103	2200	157	0.0152	10300
500	108	0.0022	49000	38.0	0.1250	300	54.5	0.0024	22700
700	80.0	0.0147	5400	23.0	0.0169	1400			
1000	10.0	0.0220	450	40.0	0.0092	4300			
1500	60.0	0.0028	21400	9.5	0.0195	490			
Experimental temperature (°C)		25.0			22.0		24.0		

[a] μg glucose/1. [b] μg glucose/1/h. [c] hours.

Reaction activity constants (μ) of samples taken from each depth in temperature range 5 to 35 C (Takahashi and Ichimura, 1971; Table 1):

Depth (m)	μ Station 1	μ Station 2	μ Station 3
0	16400	21900	11900
30	11000	18000	?
75	13100	22500	13600
125	10100	25500	?
500	---	29400	7300
700	13100	15000	5800
1000	14500	22100	8800
1500	3600	20800	8800
Average	11700 ± 1600	21900 ± 1500	9400 ± 1200

The effect of initial organisms concentration on the utilization of glucose (Gates et al., 1969; Figure 8):



Literature sources:

Banoub & Williams, 1972	Hobbie, 1971
Borst-Pauwels, 1967	Hobbie & Crawford 1969
Burkholder & Bornside, 1957	Jannasch, 1967
Buswell et al., 1954	Johnson, 1936
Button et al., 1973	Kuznetsov, 1968
Caperon, 1967	Labaw et al., 1950
Cummins, 1973	Ljunger, 1968
Droop, 1968	Longbottom, 1970
Gates et al., 1969	McCarty, 1965
Hargrave, 1970 & 1972	Monod, 1949
	Rhee, 1973

Rodina, 1963
Romanenko, 1964a & b
Saunders, 1972
Sorokin & Paveljeva 1972
Strzelczyk & Mielczarek, 1971
Takahashi & Ichimura, 1971
Thornton, 1963 & 1965
Tsernoglou & Anthony, 1971
Volkman & Oppenheimer, 1962
Waksman & Renn, 1936
Watt, 1966
Wright & Hobbie, 1966
ZoBell, 1943
ZoBell & Grant, 1943
ZoBell & Stadler, 1940

CONT (21 data cards) -- Relationship between temperature and substrate utilization by different microbes

Representative range of values:

The growth constants of the organisms increased considerably with increasing temperature in the range from 8 to 23 C. The equation of the regression line fitted to the data for *Nitrosomonas* is $\log_{10} k_m = 0.0413T - 0.944$ (with k_m in day^{-1} and T in °C), the implication of which is that the growth-rate constant increased by about 9.5% of the existing value per °C increase in temperature. The corresponding equation for *Nitrobacter* is $\log_{10} k_b = 0.0255T - 0.492$ (with k_b in day^{-1} and T in °C), implying that the temperature coefficient for this organism was about 5.9%/deg (Knowles et al., 1965)

Temperature coefficients for oxygen consumption per milligram N, per two hours for eight species, with and without added glucose (Johnson, 1963; Table 3):

Species Number	Q_{10} (Endogenous)		Q_{10} (+ 1 mgm glucose)	
	5° to 15° C	15° to 25° C	5° to 15° C	15° to 25° C
AA17*	2.5	2.0	3.5	2.5
21*	2.5	1.7	3.3	2.1
23*	2.3	1.5	9.1	2.5
1	1.7	2.9	2.8	1.7
2	4.2	1.4	1.1	2.3
4	1.5	3.7	3.8	3.7
7	1.9	2.0	3.2	2.1
Average	2.3	2.18	3.8	2.4

*Average values obtained from 2 or 3 repeated experiments.

Specific growth rates of coliform and pseudomonad types isolated from waters (Baig & Hopton, 1969; Table 1):

Organism	NA[a]	Specific growth rate at						
		5C	10C	15C	20C	25C	30C	37C
C 1	+[b]	0.07	0.13	0.22	0.33	0.44	0.58	
C 2		*[b]	0.06	0.14	0.28	0.36	0.77	0.92
C 4	+	0.06	0.12	0.19	0.25	0.36	0.53	
C 7		*	0.07	0.17	0.32	0.50	0.58	
C 10		*	0.05	0.15	0.23	0.39	0.73	0.95
ML 30		*	0.04	0.10	0.23	0.38	0.59	0.77
EBT	+	0.06	0.13	0.22	0.36	0.44	0.50	
P 11	+	0.05	0.11	0.18	0.23	0.37	0.39	
P 14	+	0.09	0.14	0.21	0.35	0.48	0.73	
P 15		0.02	0.04	0.11	0.23	0.43	0.82	
P 22	+	0.06	0.08	0.20	0.28	0.41	0.69	
P 26	+	0.06	0.11	0.21	0.32	0.43	0.49	
P 27	+	0.03	0.09	0.20	0.32	0.51	0.69	
8602		*	0.03	0.09	0.21	0.37	0.50	0.58

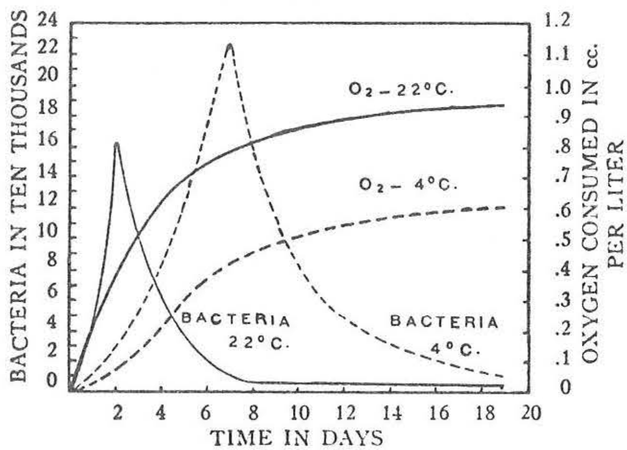
[a]Growth on nutrient agar after 7 days at 5 C.
[b]Symbols: +, visible growth; *, mean generation time was so long that pregrowth was impracticable.

Calculated μ values over 10 C ranges (Baig and Hopton, 1969; Table 2):

Organism	Temperature interval[a]			
	5-15 C	10-20 C	15-25 C	20-30 C
C 1	18.2	15.4	11.8	10.0
C 2	*[b]	25.4	16.1	17.8
C 4	18.3	12.1	10.9	13.3
C 7	*	25.0	18.4	10.5
C 10	*	25.2	16.3	14.0
ML 30	*	28.8	22.8	16.6
EBT	20.7	16.9	11.8	5.8
P 11	20.4	12.1	12.3	9.3
P 14	13.5	15.1	14.1	13.0
P 15	27.2	28.7	23.3	22.9
P 22	19.2	20.7	12.3	15.9
P 26	19.9	17.6	12.2	7.5
P 27	30.2	20.9	16.0	13.6
8602	*	32.1	24.1	15.3

[a]Values are expressed as kilocalories per mole
[b]Growth was so slow that determination of growth rate was impracticable.

Influence of temperature upon bacterial development and oxygen consumption in sea water (Waksman & Renn, 1936; Figure 1):



Literature sources:

Allen & Brock, 1968
Baig & Hopton, 1969
Boon & Laudelout, 1962
Brown et al., 1942
Chan & McManus, 1969
Delp, 1954
Dowben & Weidenmuller, 1968
Haines, 1931
Hobbie & Wright, 1965
Johnson, 1936
Knowles, Downing & Barrett, 1965
Takahashi & Ichimura, 1971
Vaccaro & Jannasch, 1966
Waksman & Renn, 1936
Wright & Hobbie, 1966

PREFER (24 data cards) -- Different food types used or decomposed by different groups of heterotrophic microorganisms (normally a qualitative value; for quantitative values, see CONS)

Representative range of values:

Results of the biochemical tests of bacteria isolated from a microcosm (Gorden et al., 1969; Table 1):

Isolates	Sugars G	L	S	A	Ga	M	Ma	MR	VP	H_2S	Lim	NR	Pathotec CO	U	PD	LD	5°C
L	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
O	d	-	d	d	d	-	d	-	-	-	-	-	-	-	-	-	-
G	d	-	-	-	-	-	-	-	-	-	d	-	-	-	-	-	-
T	A	-	A	A	-	A	A	-	-	-	-	-	-	-	-	-	-
C	a	a	A	A	A	a	a	-	-	-	-	-	+	-	-	-	-
BAC								+	+	-	A	+					
Y	A	A	A	A	A	A	A	-	-	-	pep	-	+	-	-	+	-
W	-	-	-	-	-	-	-	-	-	-	-	±	+	+	-	+	-
P	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-
B	d	-	d	-	-	-	-	-		pep	-	-	-	-	-	-	-

Sugars
G = glucose
L = lactose
S = sucrose
A = arabinose
Ga = galactose
M = mannose
Ma = maltose

Reaction in sugar
A = acid production
a = weak acid production
- = no reaction
d = doubtful acid production
+ = positive reaction
pep = peptonization

Biochemical tests
MR = methyl red
VP = Voges-Proskuer
H_2S = sulfate reduction
Lim = litmus milk
NR = nitrate reduction
5°C = growth at 5°C

Pathotec tests
CO = cytochrome oxidase
U = urease
PD = phenylalanine deaminase
LD = lysine decarboxylase

Characteristics of bacteria isolated from a microcosm (Gorden et al., 1969; Table 2):

Isolates	Probable genus	Gram-reaction	Morphology in hanging drop	Electron-micrograph flagella
L	*Xanthomonas*	negative	long, thin nonmotile rods	1 polar
O	*Flavobacterium*	negative	spiral-like motile chains	none
G	*Pseudomonas*	negative	straight rods and odd shapes	1 polar
T	*Pseudomonas*	negative	curved, paired thick rods	none
C	*Pseudomonas*	negative	very motile rods and short chains	1 or 2 polar
BAC	*Bacillus*	positive	motile cells and chains of cells	many peritrich
Y	*Flavobacterium*	negative	thin nonmotile chains of rods	no photo
W	*Pseudomonas*	negative	short motile rods	1 polar
P	*Pseudomonas*	negative	motile paired rods, refractile ends, rosettes	1 polar
B	*Flavobacterium*	negative	paired rods with squared ends	1 polar

Literature sources:

Bocock, 1964
Gorden et al., 1969
Haines, 1930
Jannasch, 1969
Kuznetsov, 1968
Ljunger, 1968
Machlis, 1953
MacLoed and Onofrey, 1956
MacLoed et al., 1954
Rodina, 1963
Romanenko, 1964a
Thornton, 1965
ZoBell, 1943
ZoBell and Grant, 1943

Constituents (8 data cards) -- Chemical composition, or percent composition of selected elements in different microbes, or in different substrates subjected to microbial action; e.g. detritus

Representative range of values:

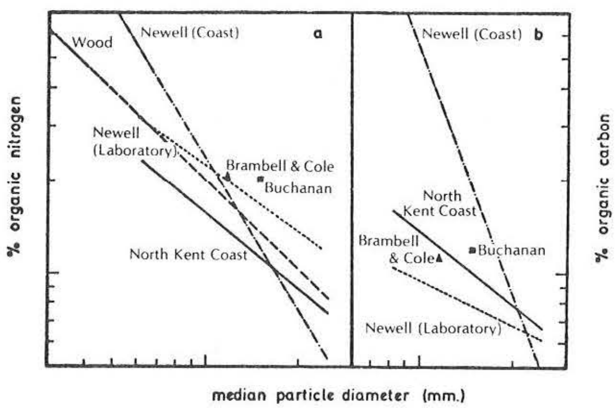
Elementary composition of *Escherichia coli* (Luria, 1960; Table 3):

Element	Per cent of dry weight
Carbon	50[a]
Nitrogen	15[a], 10.3
Phosphorus	3.2[a]
Sulfur	1.1[a]
Ash (total)	12.75%
Fixed salts (nonextractable by water after heat killing)	7.25
Free salts (extractable)	5.5

Element	Per cent of fixed salt fraction	Per cent of free salt fraction
Sodium	2.6	19.8
Potassium	12.9	9.9
Calcium (as CaO)	9.1	13.8
Magnesium (as MgO)	5.9	2.0
Phosphorus (as P_2O_5)	45.8	41.3
Sulfur (as $SO_4^{=}$)	1.8	4.4
Chlorine	0.0	7.4
Iron (as F_2SO_3)	3.4	tr
Manganese		(20 p.p.m.)
Copper		(80 p.p.m.)
Aluminum		(100 p.p.m.)

[a]Values from isotope analysis of growing cells (Roberts et al.[29]). The values on ash composition are from M. Guillemin and W. P. Larson, *J. Infectious Diseases* 31, 349 (1922). The values in parentheses are data for other aerobic bacteria (in parts of element per million parts of dry weight).

Comparison of the values (log scales) of organic nitrogen (a) and organic carbon (b) with median particle diameter (Longbottom, 1970; Figure 6):



C/N ratios for deposits with median particle diameters of 100 μ, 150 μ and 200 μ (Longbottom, 1970; Table 1):

	100μ	150μ	200μ
September, 1964	9	8.9	8.7
January, 1965	8	8.5	9
May, 1965	11	10.6	10
July, 1965	8.9	7.8	7
September, 1965	10	9.5	9
November, 1965	8.5	8.7	8.9

Literature sources:

Bocock, 1964
Burkholder & Bornside, 1957
Button et al., 1973
Longbottom, 1970
Luria, 1960

Microbe Kinds (9 data cards) -- Descriptions and characteristics of the different microbes found in fresh water, including generic names and characteristics of metabolism and distribution

Representative range of values:

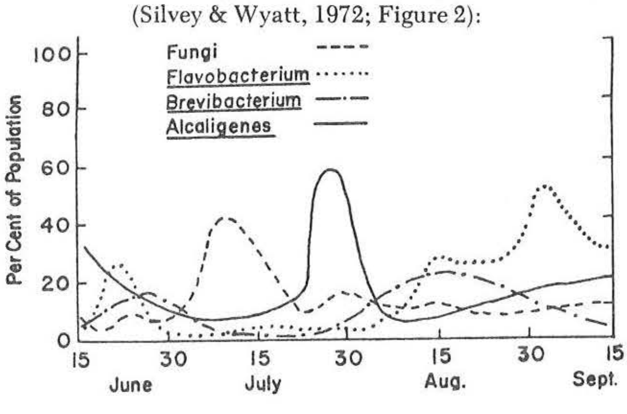
Occurrence of fungi at sampling stations, Lytle Creek (W = creek water; P = water and sediment in pools; R = water and sediment in riffles; S = bank soil) (Cooke, 1961; Table 7):

Fungus	Station 1.0	2.8	4.2	5.2	6.5	7.2	7.6	8.7	Sampling periods (of 12)
Aspergillus versicolor	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	10
Fusarium aquaeductuum	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	11
Margarinomyces heteromorphum	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	11
Penicillium funiculosum	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	12
Penicillium lilacinum	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	12
Penicillium ochro-chloron	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	12
Penicillium variabile	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	11
Pullularia pullulans	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	10
Rhodotorula glutinis ss.lat.	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	10
White Yeasts	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	WPRS	10
Phoma spp.	WPRS	WPRS	WPRS	PRS	WPRS	WPRS	WPRS	WPRS	10
Geotrichum candidum	WPRS	WPRS	WPRS	PRS	WPRS	WPRS	WPRS	WPRS	12
Cladosporium cladosporioides	WPRS	WPRS	WPRS	WPRS	PRS	WPRS	WPRS	WPRS	10
Trichoderma viride	WPRS	WPRS	WPRS	WPRS	WPRS	PRS	WPRS	WPRS	12
Penicillium spp.	WPRS	WPRS	WPRS	PRS	WPRS	PRS	WPRS	PRS	12
Moniliaceae spp.	WPRS	WPRS	WPRS	WPRS	W RS	PRS	PRS	WPRS	10
Dematiaceae spp.	WPRS	WPRS	WPRS	P S	W RS	P S	WPRS	WPRS	10
Penicillium chrysogenum	WPRS	WPRS	R	P S	W RS	WP	WP S	WPRS	3
Coniothyrium spp.	WPRS	WPRS	W RS	WPRS	PRS	S	RS	W S	10
Penicillium nigricans (+ nr.)	WPRS	WPRS	RS	PRS	S	S	S	PR	7
Fusarium oxysporum	W RS	RS	W RS	PR	PRS	W R	PRS	RS	3
Penicillium rugulosum	W S	WP	RS	S	S	S	W S	S	1
Aspergillus fumigatus	PRS	WPRS	WPRS	WPRS	WP S	WPRS	PRS	WPRS	12
Alternaria tenuis ss.lat.	PRS	WPRS	P S	P S	P S	WPRS	WPRS	S	10
Aspergillus ochraceous	PRS	RS	PRS	P S	PRS	P S	PRS	RS	10
Gilocladium roseum	PRS	WPRS	PRS	WPRS	P S	WPRS	PRS	P S	10
Myrothecium verrucaria	PRS	WPRS	WPRS	PR	RS	S	P S	S	10
Penicillium herquei	PRS	RS	PRS	S	P S	S	S	RS	8
Penicillium oxalicum	PRS	WPRS	WPRS	W RS	P S	WP S	PRS	PRS	11
Penicillium fellutanum	PR	R	P S	P	P S	S	P S	R	5
Aspergillus flavipes	RS	PRS	S	S	S	P S	P S	P S	9
Mucor fragilis	RS	PRS	PRS	WPRS	WPRS	WPRS	PRS	WP S	11
Penicillium janthinellum	RS	S	WPRS	WPRS	WP S	WPRS	WPRS	WPRS	9
Penicillium purpureogenum	RS	PRS	PRS	PRS	P S	RS	PRS	PRS	8
Mucor plumbeus	S	S	S	PRS	S	W S	P	W S	9
Aspergillus niger	WPRS	W RS	P S	WPRS		W S	RS	P S	12
Penicillium puberulum	WPR	PR	S		P S	P	RS	P	2
Aspergillus sydowii	WP S	W RS	PR		R	W R	P S	WPRS	4
Penicillium martensii	S	PR	P	S	P S	WP	P S		3
Penicillium velutinum	S	P	S	P S		R	S	P	1
Coniothyrium fuckelii	S	RS	P S	P		W S	RS	W S	3
Mucor hiemalis	S		P S	P S	S	S	S	S	3
Mucor racemosus	WP S		S	P S	P	W	W		3
Fusarium solani	W R	PR			PR	RS	RS	PRS	3
Aspergillus clavatus	PRS	S		P	P		PRS	PRS	7
Penicillium expansum	PR		RS		W	RS	P S	RS	3
Paecilomyces varioti	P S	W R		R	PRS		P	WPR	8
Aspergillus terreus	RS	RS	P S	RS			S	S	6
Penicillium lanosum	RS	RS	P S			RS	RS	RS	7
Penicillium charlesii (+nr.)	S	S	W S	P			S	S	2
Rhizopus arrhizus			S	P	S	S	P	S	5

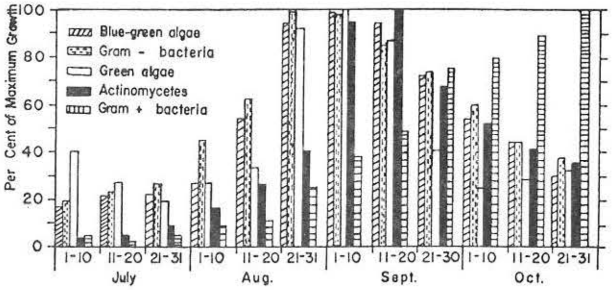
Table continued

Fungus	Station 1.0	2.8	4.2	5.2	6.5	7.2	7.6	8.7	Sampling periods (of 12)
Aspergillus flavus	PR			S		W S	W S	S	5
Penicillium javanicum (+ Ser.)	P S		WP	S			P	W	2
Epicoccum nigrum	R		P		P	S		R	3
Fusarium roseum	R	P S	P S	W	S				2
Stysanus stemonitis	S			R		R	P	PR	1
Zygorhynchus moelleri	S	R			S		S	S	3
Verticillium spp.		S	P S	S			W	W	3
Thielavia sp.		S	P		S		R	W	1
Aspergillus ustus	WPR	S			P			PR	4
Chaetomium funiculosum	P		S		P	S			2
Penicillium commune	RS	W R	S		S				3
Penicillium tardum	R	RS			P			S	2
Sphaeronema spp.			S	R		W	P		2
Penicillium brevi-compactum	WP	PRS		R					2
Penicillium casei (+ nr.)	W					W		W	1
Gliocladium penicillatum	P		P				P		3
Pestalotia dichaeta	P	P						PR	1
Fusidium viride	R					R	R		1
Monosporium olivaceum	R				W S			S	1
Penicillium cyaneo-fulvum	S	W		P					2
Penicillium raistrickii	S	P S	R						2
Mucor brunneus		P	S	S					1
Curvularia lunata		RS			S		S		2
Gliomastix convoluta		S		S			PR		2
Penicillium jenseni			S		S		P		1
Trichoderma alba			S				P	P	2
Humicola grisea				P			RS	P	2
Penicillium melinii				S	W		S		2
Penicillium parvum					R		S	P	1
Paecilomyces sp.	PRS						R		2
Penicillium simplicissimum	P S	P							1
Penicillium aurantio-virens	P		P						1
Torula herbarum	P	PRS							2
Memnoniella echinata	RS							R	3
Mucor corticolous	S							P	1
Penicillium palitans		R					S		1
Aspergillus candidus		S						S	2
Aspergillus carneus		S		P					2
Paecilomyces marquandii		S	WP						2
Penicillium piscarium		S						S	1
Penicillium pulvillorum		S			P S				1
Aspergillus ruber				P	R				2
Penicillium citreo-viride						S		RS	1

Dominant heterotrophs in Lake Hefner (summer, 1967) (Silvey & Wyatt, 1972; Figure 2):



Relative summer population of a typical southwestern reservoir (Silvey & Wyatt, 1972; Fig. 3):



Literature sources:

Chann & McManus, 1969
Cooke, 1961
Gorden et al., 1969
MacLoed et al., 1954
Silvey & Wyatt, 1972
Stokes & Redmond, 1966

Microbe Populations (22 data cards) -- Indications of the population size of different microbes in selected environments in fresh water

Representative range of values:

Density of bacteria on sediment particle surface compared with similar measurements of others on sediments, soils and pebbles (Tsernoglou & Anthony, 1971; Table 7):

Sources	Bacteria /µg dry weight	Surface in $mm^2/\mu g$ of sediment: Untreated	Treated	Bacteria/mm^2: Untreated	Treated
Present work					
Amherst Pond	3780	0.258	0.588	14700	6410
Copper Lake	2240	0.220	0.697	10200	3210
Grand Lake	1420	0.273	0.302	5180	4690
Jesse Lake	3730	0.412	0.450	9090	8260
Batoosingh (1964)					
Marine pebbles				16000	
Anderson and Meadows (1965)					
Marine sand				60000*	
Gray et al. (1968)					
Sand dune					
Horizon A_1	1850	0.722		2570	
Horizon C	2390	0.725		3300	

*Median of the published range of values.

Microbial populations of river and stream water (Stokes and Redmond, 1966; Table 2):

	Bacteria						Fungi			
	Psychrophiles		Mesophiles		Thermophiles		Psychrophiles		Mesophiles	
Source	No. per ml	Per cent	No. per ml	Per cent	No. per ml	Per cent	No. per ml	Per cent	No. per ml	Per cent
River water										
7A	410	29	1,000	70	16	1.1	<10		35	100
7B	1,200	27	3,300	73	10	0.2	<10		10	100
7C	690	16	3,600	84	6	0.1	0		5	100
7D	710	16	3,800	84	12	0.3	0		19	100
Stream water										
4A	8,700	27	24,000	73	22	0.1	<10		16	100
4B	700	16	3,600	83	30	0.7	<10		90	100
4C	3,100	42	4,300	58	25	0.3	5	8	60	92
4D	3,300	47	3,700	52	50	0.7	<10		95	100

Microbial populations of lake water and lake mud (Stokes and Redmond, 1966; Table 3):

	Bacteria						Fungi			
	Psychrophiles		Mesophiles		Thermophiles		Psychrophiles		Mesophiles	
Source	No.*	Per cent	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent
Lake water										
5A	500	67	250	33	<10		<10		<10	
5B	500	71	190	27	10	1.4	<10		<10	
5C	390	76	120	23	5	1.0	<10		<10	
5D	380	41	550	59	<10		<10		<10	
Lake mud										
6A	28,000	33	55,000	65	1,200	1.4	<100		<100	
6B	85,000	12	640,000	88	6,200	0.8	100	0.5	19,100	99
6C	68,000	11	530,000	88	5,600	0.9	<100		15,000	100
6D	18,000	16	92,000	83	810	0.7	<100		2,100	100

*Per milliliter of water or per gram of mud (dry weight).

In local streams and rivers the bacterial content ranged from 1 to 250 cells per ml (Fredeen, 1964)

The number of microbes in detritus (Rodina, 1963; Table 2):

Lake	Place of collection	Year	Total number of microbes X 10^{-9}/g*	Number of heterotrophic bacteria X 10^{-6}/g MPA≠
Otradnoye	Open lake	1960	10.21-27.17	1.223-14.500
		1961	18.09-47.57	4.900-19.120
	Reed overgrowth	1960	2.4 -14.57	0.224- 0.790
		1961	2.26-19.36	0.130- 1.784
Swetloye	Open lake	1960	6.95-32.23	0.89 - 5.23
		1961	38.67	6.04
	Reed overgrowth	1960	5.5 - 6.9	2.2 - 4.6
		1961	3.37-17.87	0.340- 4.6
Bezymjannoye	Open lake	1960	7.21-13.3	1.037-10.410
		1961	5.96-20.33	1.228- 5.018
Goossinoye	Border of overgrowth	1960	6.14-35.52	1.16 -13.290
		1961	15.9 -27.95	0.300- 0.735
Solovjevskoye	Open lake	1961	16.3 -18.1	0.270- 0.380
Naryadnoye	Reed overgrowth	1960	5.5 -14.9	0.353-12.631
Ti-Lampi	Open lake	1960	11.8 -47.5	0.011-80.900

*By direct count.
≠Meat-peptone agar.

Literature sources:

Burkholder & Bornside, 1957
Fredeen, 1964
Gorden et al., 1969
Haines, 1931
Monod, 1949
Potter and Baker, 1961
Rodina, 1963
Silvey and Wyatt, 1972
Sorokin & Paveljeva, 1972
Stokes and Redmond, 1966
Trentham, 1973
Tsernoglou & Anthony, 1971

SUBROUTINE ANIMAL

ANIMAL PARAMETERS

AMORTA (30 data cards) -- Proportion of individuals of the L'th animal cohort dying in a time unit

Representative range of values:

Hirudinea (leech)
Erpobdella

Year 1 90.7 - 93.1%
Year 2 50.0 - 73.5%

Year 3 50.0 - 92.5%
(Mann, 1953; Sawyer, 1970)

The exponential rate of mortality (+ small losses in drift) was not constant during the life cycle and was high in winter (age 2-7 months and 13-19 months), low in spring and summer (age 7-13 mo. and 19-23 mo.), and highest in the period which included and followed breeding (age 23-26 mo.). In each of these five periods, the relationship between the mean number of leeches/m² (Y_X) and time (X months) from the start of the period was defined by the regression equation:

$$\log_e Y_X = \log_e A + RX$$

where A and R are constants, and the sample regression coefficient R is also the constant relative rate of mortality (+ some losses in drift). Values of the constant A and exponent R were calculated for the five periods in the life cycle:

Values of the constant A and regression coefficient R (±95% confidence limits) for mortality (+ losses in drift) in each year-class (Elliott, 1973; Table 2):

Age		Year-class 1964	1965	1966	1967	1968
Mortality (months)						
2- 7	A		6095·4	2971·7	1224·6	2824·9
	R		-0·269±0·007	-0·288±0·020	-0·265±0·008	-0·288±0·026
7-13	A		926·8	399·9	195·9	
	R		-0·074±0·007	-0·074±0·013	-0·078±0·011	
13-19	A	542·0	597·0	254·1		
	R	-0·143±0·008	-0·145±0·006	-0·138±0·012		
19-23	A	222·8	255·	118·6		
	R	-0·071±0·026	-0·076±0·026	-0·094±0·010		
23-26	A	188·8	192·8	75·9		
	R	-1·870±0·468	-1·568±0·149	-1·506±0·128		

Odonata (Dragonfly)

Pyrrhosoma

Year	I	y = -0.0062 x +4.63	(Lawton, 1970)
	II	y = -0.0018 x +2.59	
	III	y = -0.0012 x +2.10	

where y = log (mean no. per m²)
x = days from 1 July in year of hatch
(= time from date of hatching)

Diptera (Flies and Midges)

Chironomus tetans	65%	(Hall et al., 1970)
Glyptotendipes	60%	(Kimerle and Anderson, 1971)

Literature sources:

Aston, 1970
Becker, 1973
Elliott, 1973
Grafius, 1973
Hall et al., 1970
Herrmann, 1970
John, 1964
Kimerle & Anderson, 1971
Kitchel (pers. comm.)
Lawton, 1970a
Mann, 1955 and 1957
Sawyer, 1970
Stalnacker (pers. comm.)
Teal, 1957
Tillman & Barnes, 1973
Van der Schalie & Berry, 1973

ASSIM (40 data cards) -- Proportion of the food ingested that is assimilated into the tissues by each animal species

Representative range of values:

For most invertebrates feeding on natural food at optimum concentrations, index of assimilation varies widely, but rarely exceeds 50%. The assimilability of plant food was 45-55% in the majority of investigated species and appears to be considerably higher when animal food is used (Monakov, 1972):

Organism	Food	% Assimilation	Reference
Mollusca			
Ancylus fluviatilis	*Navicula*	88.00	(Calow and Fletcher, 1972)
Planorbis contortus	Bact. D	96.54	"
	Bact. E	84.78	"
Annelida			
Tubifex tubifex	Detritus	50.0	(Ivlev, 1939, cited by Welch, 1968)
Crustacea			
Pacifastacus leniusculis	Plant	40.6-52.5	(Moshiri and Goldman, 1969)
	Animal	43.3-64.0	"
Hyalella azteca	Bacteria	60.0-82.5	(Hargrave, 1970)
	Navicula	75.0	"
	Bl.-gr. algae	5.5-15.0	"
	Gr. algae	45.0-55.0	"
	Chara and epiphytes	72.8	"
	Surface sediments	14.9	"
Insecta			
Trichoptera			
Banksiola crotchi	Plant	30.0	(Winterbourn, 1971)
	Animal	70.0	
Glossosoma nigrior		17.2-32.3 X = 23.7	(Cummins et al.,N.D.)
Ecclisomyia sp.	Dead leaves	8.93	(Grafius, 1973)
Heteroplectron californicum	Dead leaves	7.43	"
Lepidostoma sp.	Dead leaves	6.9-12.0	"
Odonata			
Lestes sponsa		20-40	(Fischer, 1966, 1967; cited by Lawton, 1970b)
Pyrrhosoma	Chironomids	84.0	(Lawton, 1970b)
	Cloeon	76.9	"
Fish			
Fundulus notatus		96.9	(Atmar and Stewart, 1972)
Gila atraria		85.6-94.4	(Cheng et al., 1972)

Changes in ASSIM and TAKE values with changes in the age of the animal

	ASSIM	TAKE
Fundulus notatus (Atmar and Stewart, 1972)		cal/g initial dry weight/day
17mm S.L. (sic)	96.9%	321 (15%)
17-47mm S.L.	96.9%	422 (12%)
48mm S.L.	96.8%	220 (23%)
Walleye (Kelso, 1972)	82.1-97.9%	

ASSIM decreased with size (slope of -0.0045)

Herpobdella (Monakov, 1972)	(Ration in % body "wet" weight)	
wt. (mg)	Oligochaeta	*Tendipes*
0.6	246.9	-----
1.2	215.0	177.4
2.5-3.0	168.9	134.7
40-45	26.0	20.2
55-60	21.0	13.1
65-70	32.0	9.2
95-100	19.9	11.2

Pulmonata (Monakov, 1972)	(Av. ration in % body dry weight)
Coretus corneus	
wt. (mg)	
0-50	167
51-100	118
101-300	40
301-500	24
Limnea stagnalis	
wt. (mg)	
0-50	349
51-100	331
101-200	227
201-500	134
Radix ovata	
wt. (mg)	
0-50	422
100-200	165
Galba truncata	
wt. (mg)	
0-100	242
101-200	220

Limpets (Burky, 1971)

Population assimilation efficiency seems to change with season

Crustacea

Calanus (Corner, 1973)

Stage	
CI	68.9%
CII	80.8-98.1%
NIII-NVI	94.8-98.1%

Hyalella azteca (Hargrave, 1970)	ASSIM (%)	(g/hr)	TAKE (g/g/day)
dry wt (g)			
580	86.0	96	3.97
620	89.1	96	3.72
710	89.2	129	4.36

Pacifastacus (Moshiri and Goldman, 1969)

$\bar{x}$ dry wt (g)	$\bar{x}$%
0.7993	64.0
0.9613	55.1
0.9514	52.2
2.4876	45.9
2.9090	40.2
10.2671	43.3
10.5381	41.6
20.6209	43.7

Insecta

Pteronarcys scotti (McDiffett, 1970)

mg dry wt	cal	(cal/cal/day)
3.7	411	0.233
7.1	594	0.263
21.9	1332	0.127
30.4	1627	0.168
47.0	5647	0.189
86.5	3756	0.137

Pyrrhosoma (Lawton, 1970b)

1.3mm	95%
4.0mm	92.9%
13-14 mm	84-86%

Decline in ASSIM with an increase in size. Author has graphs of percent ASSIM in terms of calories and dry weight (they are similar)

Pyrrhosoma (Lawton, 1971)

Life history stage	Mean field feeding rate (cal/cal larva/month)
Hatch	0.54
First winter	0.46
Second summer	8.32
Entry to final instar	18.96
Second winter	7.96
First larvae enter metamorphosis	23.35

Table continued

Hedriodiscus truquii (Stockner, 1971)	Instar	ASSIM / TAKE mg wet wt/mg wet wt/day)
Spring 6	2	0.425
	3	0.362
	4	0.166
Spring 4	2	0.350
	3	0.288
	4	0.123

Literature sources:

Anderson, 1973
Arnold, 1971
Atmar and Stewart, 1972
Burky, 1971
Calow & Fletcher, 1972
Cheng et al., 1972
Conover, 1966
Corner, 1973
Cummins et al., 1969 & N.D.
Grafius, 1973
Hargrave, 1970 & 1971
Hillbricht-Ilkowsha & Karabin, 1970
Izvekova, 1971
Kelso, 1972
Lawton, 1970b and 1971a
Mathias, 1971
McDiffett, 1970
Monakov, 1972
Moshiri & Goldman, 1969
Pandian & Raghuraman, 1972
Prus, 1974
Schindler, 1971
Solomon & Brafield, 1972
Stockner, 1971
Teal, 1957
Welch, 1968
Winterbourn, 1971

EGEST (16 data cards) -- Amount of material egested per day by each animal species, expressed as mg C dry feces/mg C animal dry wt/day. Also includes data on composition of the feces

Representative range of values:

	°C	mg dry feces/mg dry wt/day	
Annelida			
Tubifex tubifex	4	5.736	(Appleby and Brinkhurst, 1970)
	14	21.264	"
	22	63.000	"
Limnodrilus hoffmeisteri	4	2.124	"
	14	8.508	"
	22	44.460	"
Crustacea		mg dry feces/mg dry wt/day	
Hyalella azteca		1.0-3.2	(Hargrave, 1972)
Plecoptera			
Pteronorcys scotti		.14-.20	(McDiffett, 1970)
Trichoptera			
Ecclisomyia sp.		.33	(Grafius, 1973)
Lepidostoma sp.		.36	"
Heteroplectron californicum		.08	"

Literature sources:

Anderson, 1973
Appleby & Brinkhurst, 1970
Brinhurst et al., 1972
Corner, 1973
Grafius, 1973
Hargrave, 1971 & 1972
Malone and Nelson, 1969
McDiffett, 1970

PREF (63 data cards) -- Preference for consumption of each major food type, given equal accessibility to all types

Representative range of values:

Information from the literature is almost entirely on food habits

A. Herbivores

Results of summer (1973) food preference experiments with Deep Creek fauna. All values are expressed as percentages to indicate the percent of times the animal would choose that food, if all foods were equally available. Values are means of three runs, and individual values are presented, followed by the mean

Foods	*Tricorythodes minutus* sizes 3 and 4	*Baetis tricaudatus*	*Hydropsyche occidentalis*	*Hyalella azteca*	*Optioservus*[1] (A)	*Optioservus*[1] (L)[2]	*Simulium*[2]
Potamogeton filiformis	4.3,33,4 14%	9.5,14,25 16%	11,5.5,0 5%	5.9,24,7.3 12%	0,6.1,10 5%	9.1,0 4.5%	0, 11.6 5.8%
Potamogeton pectinatus	34, 13, 0 16%	13, 42, 15 23%	28, 36, 11 27%	33,9.3,12 18%	28, 25, 0 18%	0, 30 15%	7.1, 5.8 6.5%
Chara sp.	2.1,13,44 20%	7.9,11,20 13%	17,5,16 13%	59,37,12 36%	22, 25, 0 16%	18.2, 10 14%	0, 11.6 5.8%
Cladophora glomerata	23, 0, 0 8%	32,8.3,10 17%	17,36,44 32%	2,11,19 10%	46, 6.1,20 23%	27.3,10 18.6%	0, 34.8 17.4%
Detritus	8.5,27,0 12%	16.8.[illegible] 8%	5.5,17,24 15%	0,25,41 22%	2, 29, 10 14%	27.3, 20 23.7%	0, 11.6 5.8%
Spirogyra sp.	4.3,6.7,12 8%	7.9,2.8,0 4%	11,0,0 4%	0, 0, 0 0%	2, 0, 10 4%	0, 10 5%	7.1, 5.8 6.5%
Colonized plastic leaves	21,6.7,20 16%	5.3,2.8,15 8%	5.5,17,0 7%	0, 0, 0 0%	0,8.2, 30 13%	0, 10 5%	35.5, 5.8 20.7%
Uncolonized plastic leaves	0, 0, 4 1%	2.6,2.8,0 1.8%	0, 5.5, 0 2%	0, 0, 0 0%	0, 20, 2 7%	18.2, 0 9.1%	7.1, 5.8 6.5%
Diatoms	2.1, 0, 16 6%	5.3,8.3,15 10%	5.5, 0, 0 2%	0, 0, 2.5 0.8%	0, 0, 0 0%	0, 10 5%	21.3, 5.8 13.6%

[1] *Optioservus* (A) and *Optioservus* (L) are the adult and larval forms, respectively.

[2] Due to extensive experimental mortality, the data from the third runs with *Optioservus* (L) and *Simulium* have been discarded.

Larval Chironomidae were used once in a food preference experiment. However, it was found to be nearly impossible to locate the individuals after the termination of the experiment.

Due to the method of feeding (filter-feeders) the results of the trials with *Hydropsyche* and *Simulium* should be regarded as questionable. Their location at the termination of the experimental run may have simply reflected prevailing water currents or preferred substrates, rather than actual food preferences.

B. Carnivores

At the termination of the feeding run, the total number of organisms consumed was calculated. Then the percentage of the organisms falling into each of the experimental food species was determined. Thus, the values represent the actual findings, and the means of those findings, as a percent preference, assuming equal availability of all prey types

Carnivores table

Prey	Predator: *Ophiogomphus severus*	*Enallagma anna*	*Hydropsyche occidentalis*	*Rhinichthys osculus*
Hyalella azteca	20, 21, 4 15%	0, 0, 15 5%	27, 5, 22 18%	22, 28, 30 27%
Tricorythodes minutus	34, 24, 0 19%	11, 24, 31 22%	27, 71, 44 47%	20, 23, 0 14%
Optioservus (adults)	12, 10, 4 9%	0, 0, 5 2%	0, 0, 11 4%	7, 11, 0 6%
Baetis tricaudatus	34, 21, 26 27%	65, 50, 26 47%	47, 24, 22 31%	51, 39, 70 53%
Hydropsyche occidentalis	0, 24, 65 30%	24, 25, 23 24%	XXX,XXX,XXX XXX	0, 0, 0 0%

Literature sources:

Arnold, 1971
Atmar & Stewart, 1972
Coffman, Cummins & Wuycheck, 1971
Corefoot, 1970
Cummins, 1973
Fagade, 1971
Fredeen, 1964
Gibbons & Gee, 1972
Grafius & Anderson, 1973
Graham, 1961
Griffiths, 1970
Haage, 1971
Haram & Jones, 1971
Hargrave, 1970
Hargrave & Geen, 1970
Hellawell, 1972
Hoyt, 1970
Hunt & Jones, 1972
Izvekova, 1971
Izvekova & Lvova-Katchanova, 1972
Johnson & Jakniovich, 1970
Lawton, 1970b
Monakov, 1972
Moriarty, 1971
Pickavance, 1971a and b
Siefert, 1972
Sunaga, 1971
Tanaka, 1970
Tarter, 1970
Teal, 1957
Vanicek & Kramer, 1969

RCONST (25 data cards) -- The maximum rate of oviposition (proportion of adult biomass per time unit) for the M'th animal cohort

Representative range of values:

	eggs/indiv/time
Annelida	
Limnodrilus hoffmeisteri	.004/day at 5°C (Aston, 1970)
	.13 at 10°C
	.49 at 15°C
	1.15 at 20°C
	1.22 at 25°C
	.79 at 30°C
Tubifex tubifex	0.0 at 5 and 30°C
	.22-
	.28/day between 10 and 25°C
Erpobdella punctata	42.8/year Laboratory
	50.1/year field est. (Sawyer, 1970)
Helobdella stagnalis	17.4 1st brood (Tillman and Barnes, 1973)
	13.6 2nd brood
Insecta	
Ephemeroptera	
Tricorythodes minutus	4.5 mm 900/lifetime (Newell, 1973)
	5.0 mm 1300
Fish	
Rhinichthys osculus	45 mm 228/year (John, 1963)
	56 mm 376
	75 mm 482

Literature sources:

Aston, 1970
Becker, 1973
Buckland-Nicks et al., 1973
Elliott, 1973
Gee & Machniak, 1972
Grahame, 1973
Herrmann, 1970
John, 1963
Miller, 1951
Newell, 1973 (pers. comm.)
Pennak, 1956
Petersen, 1973 (pers. comm.)
Sawyer, 1970
Tarter, 1968
Tillman & Barnes, 1973
Traver, 1929
Van der Schalie & Berry, 1973

RESP (53 data cards) -- Amount of energy used, CO_2 expired, or C expelled by each animal species in a resting state; portion of the species' energy budget devoted to respiration

Representative range of values:

Organism	ml O_2 consumed/ dry g/hr	Temp. °C	Reference
Annelida			
Limnodrilus hoffmeisteri	180-480	5-20	(Brinkhurst et al., 1972)
Tubifex tubifex	240-510	5-20	
Mollusca: Gastropoda			
Bithynia tentaculata (with shell)	75	20	(Kamler, 1969)
Pelecypoda			
Pisidium casertanum	320	8	(Berg and Jonasson, 1965; cited by Johnson and Brinkhurst, 1971)
Crustacea: Amphipoda			
Gammarus pulex	993-1142	10	(Fox and Simmonds, 1933)
Decapoda			
Astacus torrentium	71-112	20	(Wolsky, 1934; cited by Fox et al., 1937)
Insecta: Diptera			
Chironomus riparius	843-3519	10-20	(Edwards, 1958; cited by Johnson and Brinkhurst, 1971)
Ephemeroptera			
Baetis scambus	1861	10	(Fox et al., 1937)
Odonata			
Argia vivida	1250	18	(Brass, 1971)
Enallagma anna	1540	18	(Brass, 1971)
Ophiogomphus severus	454	18	(Brass, 1971)
Trichoptera			
Hydropsyche occidentalis	1550	18	(Brass, 1971)
Limnophilus rhombicus	226-1046	3-24	(Collardeau, 1961)

Table continued

Organism	°C	O_2 consumption (µl O_2/dry g/hr) Active	Routine	Standard	Reference
Fish					
Rhinichthys osculus	4	815			(Atmar and Stewart, 1972)
	8	1276			
	12	1643	475		
	18	2365	888	835	
		O_2 consumption (µl O_2/wet g/hr) Active		Standard	
Gila atraria	6	126		39	
	9	177		49	
	12	250		63	
	18	491		102	
	22	543		141	

Note: At RQ = 1.0 (Herbivore) gC = µl RESP x (462×10^{-9})
RQ = 0.79 (Carnivore) gC = µl RESP x (419×10^{-9})
This gives an overall range for the above values (70-3519 µl O_2/hr) of roughly 0.00037 - 0.0184 gC/gC/day (using RQ = 1.0 and 1 g dry wt = 0.473 gC).

Literature sources:

Atmar & Stewart, 1972
Berg et al., 1962
Brass, 1971
Brinkhurst et al., 1972
Buck, 1965
Buinkema, 1972
Collardeau, 1961
Cummins et al., 1965
Cummins et al., 1969
Cummins et al., 1973a,b
Edwards, 1958
Edwards & Learner, 1960
Eriksen, 1963
Erman & Helm, 1970
Feldmeth, 1970
Fowler & Goodnight, 1965
Fox & Simmonds, 1933
Fox et al., 1935
Fox et al., 1937
Hargrave, 1971
Hillbricht-Ilkowska & Karabin, 1970
Johnson & Brinkhurst, 1971
Kamler, 1969
Kimerle & Anderson, 1971
Knight & Gaufin, 1966
Konstantinov, 1971
Kramer & Rajagopal, 1972
Lawton, 1971b
Lewis, 1971
Lumbye & Lumbye, 1965
Maloeuf, 1936
Mathias, 1971
McDiffett, 1970
Morgan & Grierson, 1932
Moshiri et al., 1968
Norris et al., 1964
Palmer, 1968
Richman, 1958
Rueger et al., 1969
Sessions, 1961
Solomon & Brafield, 1972
Spector, 1956
Teal, 1957
Tilly, 1968
Trama, 1957
Ulanoski & McDiffett, 1972
von Brand & Mehlman, 1953
Walshe-Maetz, 1953
Wiens & Armitage, 1961
Yoshida, 1970

TAKE (45 data cards) -- Maximum rate of ingestion of food (as gC/unit biomass C/unit time) by each animal species group under conditions of unlimited food supply

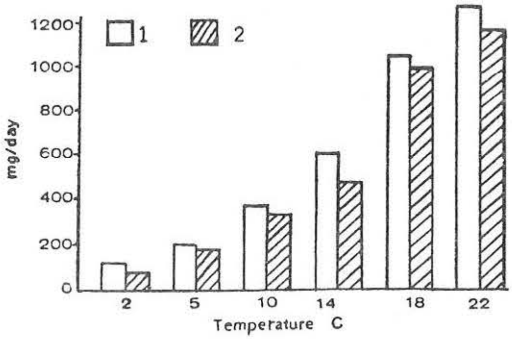
Representative range of values:

The main results obtained at the Borok Institute during the last decade are reviewed. Food and methods of feeding by various aquatic invertebrates, daily food consumption, and assimilation of food have been investigated. Most invertebrates are omnivores although some species live on only one type of food. Daily food consumption changes with food concentrations near optimum, mean daily rations of most invertebrates studied (Rotatoria, Oligochaeta, Mollusca, Cladocera, Copepoda, Chironomidae larvae) usually range from 25 to 100% of body weight. Only in pulmonary Gastropoda and silt-eating Tubificidae does it greatly exceed body weight In rare cases, at very high concentration of food unusual in nature, the so-called "extra feeding" may take place under experimental conditions (Monakov, 1972)

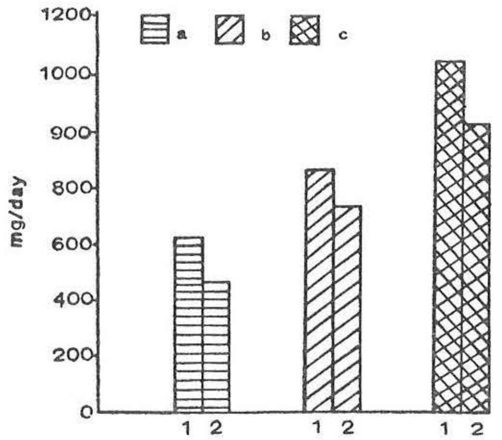
Intensity of feeding of Oligochaeta (18-20 C) (Monakov, 1972; Table 2):

Species	Kind of food	Ration consumption (C) % of body "wet" weight	(mg)
Limnodrilus hoffmeisteri	Silt	703	32.4
L. udekemianus	Silt	745	35.6
Chaetogaster diaphanus	*Bosmina*	27.8	0.7
	Eudiaptomus	23.5	0.6
	Naididae	25.0	0.6
	Chydoridae	22.7	0.5

Feeding rate of *Limnodrilus udekemianus* (1) and *Limnodrilus hoffmeisteri* (2) at different temperatures. Abscissa, temperature °C; ordinate, weight of excrement in mg per 24 hr (Monakov, 1972; Fig. 1):



Feeding rate of *Limnodrilus udekemianus* (1) and *Limnodrilus hoffmeisteri* (2) on different silt. a. grey silts; b. intermediary silts; c. peaty silts. Ordinate weight of excrement in mg per 24 hr (Monakov, 1972; Figure 2):



Feeding of *Herpobdella nigricollis* (18-22 C) (Monakov, 1972; Table 3):

Weight of *Herpobdella* (mg)	Ration in % of body "wet" weight: Oligochaeta	Tendipes
0.6	246.9	----
1.2	215.0	177 4
2.5-3.0	168.9	134.7
40-45	26.0	20.2
55-60	21.0	13.1
65-70	32.0	9.2
95-100	19.9	11.0

Feeding of Gastropoda (19-21 C) (Monakov, 1972; Table 4):

Species	Weight (mg)	Ration, % of body dry weight: Plant food	Animal food	Avg.
Prosobranchia				
Valvata piscinalis	0-50	117	153	135
Bithynia tentaculata	0-50	123	121	122
	0-100	63	48	55
Viviparus contectus	0-50	124	64	99
	51-100	81	58	70
	101-300	37	23	30
Pulmonata				
Coretus corneus	0-50	171	163	167
	51-100	113	124	118
	101-300	47	34	40
	301-500	25	23	24
Limnea stagnalis	0-50	350	347	349
	51-100	-	331	331
	101-200	-	227	227
	201-500	-	134	134
Radix [illegible]ata	0-50	400	445	422
	100-200	-	165	165
Galba truncata	0-100	-	242	242
	101-200	-	220	220
Physa fontinalis	0-50	424	395	410

Hyalella azteca

Epiphytic material from *Chara* (Hargrave, 1970). 0.456-3.967 μg/μg/day (219%-25%)

Trophic relations of aquatic insects. Comparison of ingestion data for selected aquatic insects (Cummins, 1973b; Table 2):

Taxon	Food	CI	CI as % body wt/day	Reference
Plecoptera				
Pteronarcys scotti	Conditioned leaves, mixed species	0.062	6.2	43
Ephemeroptera				
Stenonema pulchellum	Culture of *Navicula minima*	0.130-0.220	13-22	66
Stenonema spp.	Culture of *Ankistrodesmus*	0.082	8.2	Petersen, unpublished
	Culture of *Lunuiospora curvula*	0.020	2.0	
Stenonema spp. (Low density)	Conditioned hickory leaves	0.232	23.2	Cummins, Petersen, Howard, Wuycheck, unpublished
(High density)	Conditioned hickory leaves	0.040	4.0	
Trichoptera				
Neophylax concinus	Natural stream substrate	0.80-1.60	80-160	58
Diptera				
Tipula abdominalis	Conditioned leaves, mixed species	0.030-0.051	3.0-5.1	68
Tipula sp.	Well conditioned hickory leaves	0.173	17.3	
	Hickory leaves--short conditioning time	0.088	8.8	Cummins et al., unpublished
	Oak leaves--short conditioning time	0.030	3.0	

Consumption index = CI = dry weight of food ingested per dry weight of animal per day (69).

Literature sources:

Arnold, 1971
Conover, 1966
Cummins et al., 1969 & 1973b
Davis & Warren, 1965
Di Toro et al., 1971
Fredeen, 1964
Geckler, 1971
Gerking, 1972
Grafius, 1973
Haram & Jones, 1971
Hargrave, 1970, 1971
Hargrave & Geen, 1970
Izvekova, 1971
Kryutchkova & Sladeck, 1969
Lawton, 1971a
Malone & Nelson, 1969
McDiffett, 1970
McQueen, 1970
Monakov, 1972
Pandian & Raghuraman 1972
Pickavance, 1971a
Siefert, 1972
Stockner, 1971
Tarter, 1970
Vanicek & Kramer, 1969

TEMCON (also HATCOB, HATCON; 5 data cards) -- Coefficient for temperature dependence of transfer into the L'th animal cohort

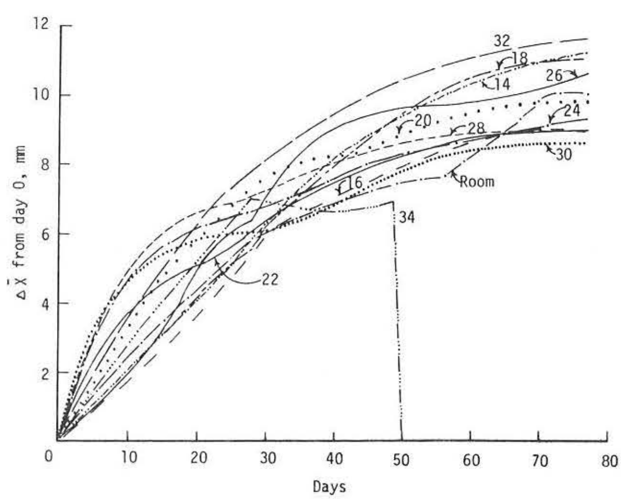
Representative range of values:

Simulium

Species: *S. venustum*; *S. verecundum*; and *S. vittatum* (Tarshis, 1968)

Temp. °C	Days to hatch	Days to pupate	Days to emerge
10	7-38	18-50	21
15	1- 8	7-62	1-26
20-25	1- 5	11-29	1- 5

Growth of *Physa gyrina* maintained in tanks with temperatures set at 2 C intervals between 14 and 34 C; room temperature (25 C) served as control. *P. gyrina*, in contrast to the lymnaeids and planorbids tested, can maintain itself in an unusually wide range of temperatures (Van der Schalie & Berry, 1973; Table 50):



Rhinichthys osculus (John, 1963)

Temp. °C	Days to hatch
18-19	6

Literature sources:

Buckland-Nicks et al., 1973
John, 1963
Sefton & Reynoldson, 1972
Tarshis, 1968
Van der Schalie & Berry, 1973

XCRSOL (5 data cards) -- The amount of the L'th animal cohorts excretion going into the water column as dissolved constituents

Representative range of values:

Comparison of measured rate of excretion of phosphorus by *Daphnia magna* and calculated rate of excretion by *Calanus finmarchicus* (Rigler, 1961; Table 5):

	D. magna	*C. finmarchicus*
Dry wt (mg)	0.25	0.3
Phosphorus content (μg/animal)	0.5	3.2
Phosphorus excreted (μg/hr/mg dry wt)	3.2×10^{-2}	4.8×10^{-2}
P excreted (%/hr)	1.6	0.45

Literature sources:

Rigler, 1961

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