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Data Search for Aquatic Model

J. Perry II

G. W. Minshall

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DATA SEARCH FOR AQUATIC MODEL

J. Perry II and G. W. Minshall (Project Leader)
Idaho State University

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INTRODUCTION

This report summarizes the results of the Data Search activities for 1974. This is a continuation of work begun in 1973. Reference should be made to the report of that work (Minshall et al. 1974) for a more detailed description of the selection and arrangement of information and to obtain additional data.

This summary has been completed in order to indicate the type of information available in the data card file and to provide a readily accessible compendium of relevant information for the Aquatic Modeling Group. All the data cards are in alphabetical order, by category, and within each category. Only the most pertinent information has been transferred from the cards to the summary. However, the majority of the information available on the cards has at least been mentioned.

There are now 293 author cards in the DECOMP parameter category. Twenty-four are marked "1974," and about 25 more were completed between December 12, 1973, and the date in June when dating of the cards began. Thus, there are 220 cards for 1973 and 49 for 1974. The cards completed in 1974 comprised 18.2% of the total.

The ANIMAL parameter category now contains 396 author cards; 110 are dated 1974 and about 50 more were really from 1974. Thus we have 236 for 1973 and 160 for 1974; 40.4% being completed in 1974.

The VEGET subroutine now contains 272 cards; 72 of them marked 1974 and about 30 more actually from 1974. Thus we have 170 for 1973 and 102 for 1974; 37.5% being completed in 1974.

The MEDIUM-PHYSIC group now contains 92 author cards. Seventy are dated 1974 and about seven more are actually from 1974. Thus we have 15 cards from 1973 and 77 for 1974; 83.7% being completed in 1974.

In all, we now have 1053 author cards with 388 of them being completed in 1974. That approximates 39% completion for 1974.

The following is a categorized summary of the data search.

DATA SEARCH GUIDE

Category	Date	Data cards	Authors	Page No.
DECOMP	12/12/73	182	91	35
	8/15/74	205	104	
	Additions	23	13	
ANIMAL	12/12/73	328	180	36
	8/15/74	658	305	
	Additions	330	125	
VEGET	12/12/73	196	126	43
	8/15/74	326	183	
	Additions	130	57	
MEDIUM-PHYSIC	12/12/73	82	51	46
	8/15/74	182	131	
	Additions	100	80	

RESULTS OF DATA SEARCH

Subroutine ANIMAL

DECOMP Parameters

CONS: The rate of substrate utilization by microorganisms.

	Cards	Authors
12/12/73	95	38
8/15/74	97	39

Good list of different decay coefficients from Petersen and Cummins (1974).

Constituents: Microbes, litter, etc.

	Cards	Authors
12/12/73	0	0
8/15/74	2	2

The mean calorific value for all litter entering the Thames was 4.5 kcal/g dry weight (Mathews and Kowalczeski 1969). The nitrogen content of willow litter was 1.79%.

For *Escherichia coli*, the following constituents were measured (Luria 1960):

	% Dry weight
Carbon	50
Nitrogen	15
Phosphorus	3.2
Ash	12.75

CONT: The relation between temperature and substrate utilization for different microbial groups.

	Cards	Authors
12/12/73	21	15
8/15/74	21	15

No new information for 1974.

Decomposition Rates:

	Cards	Authors
12/12/73	8	4
8/15/74	28	12

(Refer to information under **CONS.**)

Decomposition follows the following function (Jewell 1971):

$$M = (M_o - fM_o)e^{-k't} + fM_o$$

where

M = total organic mass in the system at any time t
M_o = organic material present at the start of decay
k' = first order decay rate coefficient*
f = refractory fraction of initial mass

Nutrient regeneration averaged 18 x 10^{-4} mg released per day per mg ISS (ignitable suspended solids). For nitrogen that was 4.9% of the original concentration. For phosphorus it was 5.4 x 10^{-4} mg released per day per mg ISS; 5.8% of the original concentration. The refractory portion averaged 24% of the initial organic matter. When plants are killed, or die, at 18 C, they are consumed at about 9% per day. Plants in good initial condition use about 1.0 mg oxygen/mg ISS on death.

Aquatic weeds decay more than twice as fast as phytoplankton and use 20% more oxygen than do algae during aerobic stabilization.

Long-term, aerobic decay of algae, in the dark, was 0.0016 mg algae per mg algae per day, with the algae measured in ash-free dry weight (Porcella, pers. comm.).

Microbial Kinds:

	Cards	Authors
12/12/73	9	5
8/15/74	8	5

(Note: This category seems to be of limited value, because there is so much available in the literature on bacterial populations of different aquatic environments. If more information on this subject is needed, we have a great deal in the Comprehensive Bibliography on Detritus in Aquatic Ecosystems; in prep., Perry.)

Microbial Miscellaneous:

	Cards	Authors
12/12/73	1	1
8/15/74	5	3

No way to summarize this type of data.

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* k', the decay rate coefficient, was obtained by plotting the log (number or mass) of the remaining biodegradable organisms against time. The slope of the straight line of the best fit was k'. The measurable values ranged from 0.052 per day to 0.19 per day, with an average of 0.086 per day (Jewell 1971).

Microbial Populations:

	Cards	Authors
12/12/73	24	14
8/15/74	22	14

(Note: This category seems to be of limited value because there is so much available in the literature on bacterial populations of different aquatic environments. If more information on this subject is needed, we have a great deal in the Comprehensive Bibliography on Detritus in Aquatic Ecosystems; in prep., Perry.)

PREFER: The type of substrate used by different bacterial groups.

	Cards	Authors
12/12/73	24	14
8/15/74	24	14

(Note: As for the above categories, information on the type of substrate used by different microbial groups seems to be available but we have not searched it out. A lot of references in the above-mentioned Detritus Bibliography deal with this subject but these have not been closely investigated.)

ANIMAL Parameters

AMORTA: The proportion of the individuals of the J'th animal cohort dying in a unit time.

	Cards	Authors
12/12/73	30	13
8/15/74	26	13

Can't seem to find any new data for 1974!

ASSIM: The proportion of the food taken that is assimilated by the L'th animal cohort.

	Cards	Authors
12/12/73	41	27
8/15/74	49	29

Zooplankton, in a natural environment, with food at or near optimum, assimilate 10 to 28% as calculated by Harvey (1950), Deevey (1952) and Conover (1961) [all reported in Ketchum 1961].

Calanus finmarchicus had food digestion and assimilation of more than 90% of the ingested, readily utilizable phytoplankton species (Marshall and Orr 1955a, 1955b). However, Ketchum (1961) casts doubt on the possibility of such an efficiency being realistic.

Asellus aquaticus, fed on alder leaves, ingested an average of 0.2674 cal per mg per 24 hr, and assimilated an average of 0.1075 cal per mg per 24 hr of that (40.2%). The number of individuals in the culture vessel had a significant effect on assimilation efficiency as follows:

No. of individuals	Assimilation (%)
1/12.6 cm^2	30.28
5/33.6 cm^2	35.24
10/33.6 cm^2	40.20
20/33.6 cm^2	40.20

This seems to be because consumption is constant at all densities but feces production varies (see Egestion; Prus 1971).

Constituents:

	Cards	Authors
12/12/73	30	19
8/15/74	30	19

No new data for 1974.

CURVE: The factor relating food intake in the L'th animal cohort to the available food supply.

	Cards	Authors
12/12/73	0	0
8/15/74	1	1

(Note: We may have acceptable literature values for this category, but they are probably filed under **TAKE.**)

Rate of Development:

	Cards	Authors
12/12/73	3	3
8/15/74	3	3

All new data for 1974 would be filed in the Growth and Temperature effects categories, or possibly under **TEMCON**, Emergence, or such categories

Dispersal: As a function of density (also see Drift).

	Cards	Authors
12/12/73	0	0
8/15/74	3	1

Snails, *Campeloma decisum*, showed a consistent movement upstream; upon meeting an obstacle, they stopped and ended up aggregating.

Gammarus, in populations of 10, 30 and 100 showed rapid dispersal that was **not** density related.

Hyalella azteca in populations of 10, 30 and 100, in a "very small chute," showed an **inverse** relation of density to dispersal (Bovbjerg 1952).

Drift: And factors affecting it.

	Cards	Authors
12/12/73	0	0
8/15/74	13	4

Drift rate is density related, and directly related to production rate, but only where organisms of similar longevity are compared. Animals from the drift to be compared should be the common species in the drift like *Gammarus limnaeus*, free-swimming Ephemeroptera and Simuliidae (Waters 1961).

Drift functions to regulate population density, especially with organisms like *Gammarus* (see Dispersal about *Gammarus*; Müller 1954, as cited by Waters 1961).

Drift has been measured and described in mathematical terms by Elliott (1971). He has functions for calculating distance traveled by invertebrates, total catch from all points upstream, and the number of invertebrates entering the drift from a given area. He estimated that 4.3% of the *Baetis* population of a specific area left in one night. Drift was shown to be a linear function of water velocity as:

$$\overline{X} = aV^b$$

where

$\overline{X}$ = the mean number of animals in the drift
V = current velocity
a & b = constants

Egestion: The rate of egestion, or feces production, by the animals in the ecosystem.

	Cards	Authors
12/12/73	16	8
8/15/74	22	12

Asellus aquaticus had an average egestion rate of 0.1599 cal per mg per 24 hr when their consumption rate was an average of 0.2674. Feces production varied with density as follows (Prus 1971):

Density	Feces (cal per indiv. per 24 hr -- mean wt = 10.8 mg)
$1/12.6\ cm^2$	1.4752
$5/33.6\ cm^2$	1.0870
$10/33.6\ cm^2$	1.1117
$20/33.6\ cm^2$	1.1103

Pteronarcys exhibits a feces production which is related to temperature by the following function (McDiffett 1970):

$$Y = aX^b$$

where

Y = mg feces per nymph per day
X = dry weight

and for

	5 C	10 C	15 C
a =	0.40	0.24	0.22
b =	0.65	0.89	0.90

Trama (1957) reported that for *Stenonema pulchellum*, 46.9% of the food consumed per day was egested. In percentage of dry body weight per day, he reported:

5 C	10 C	15 C
11.3%	15.8%	14.8%

(as mean values corrected for the effect of weight).

Cummins (1969) reported an egestion rate for *Glossosoma nigrior* of 21.0 cal/day, when ingestion was 22.4 cal/day. Thus egestion was 87.8% of ingestion.

Emergence:

	Cards	Authors
12/12/73	0	0
8/15/74	31	4

The duration of the subimago stage of *Baetis alpinus* depends only on temperature, not photoperiod or such (Humpesch 1971).

Nebeker (1971) elevated water temperatures in the laboratory and recorded early emergence as follows:

Species	Approx. normal dates	Dates at elevated temperatures
Baetis sp.	5/15 to 6/25	1/10 to 2/5
Hydropsyche betteni	6/2 to 7/5	1/5 to 2/20
Simulium sp.	4/20 to 7/25	1/15 to 2/20

The following notes about the emergence of adult insects from a marsh are paraphrased from Judd (1953). Much more information is available on the cards.

Species	Emergence period	Day-degrees
Enallagma ebrium (males)	6/3 to 6/29	972
E. ebrium (females)	6/1 to 7/5	972
Ischnura verticalis	7/29 to 8/27	(6 indiv.)
Sympetrum vicinum	7/19 to 8/6	1887

Chironomidae — Emerged April 14 through October 29, depending on the species. Day-degrees varied from 189 to 3489 depending on species.

Judd (1953) found that "the seasonal variation in the emergence of numbers of species was correlated directly with changes in the temperature of the water, the day of emergence of maximum numbers of species being preceded by the day on which maximum temperatures were recorded at all cages." (p. 819)

Energy Budgets:

	Cards	Authors
12/12/73	0	0
8/15/74	13	10

(Note: See component parts of the budgets for the species under consideration. Very few of the energy parameters are filed here.)

Have recorded as follows:

Tubificidae: Brinkhurst et al. 1972, R, E, A (calc.), G (poor); Palmer 1968.

Hyalella azteca: Hargrave 1970, 1971; Mathias 1971.

Pyrrhosoma nymphula: Lawton 1970, 1971a, R, A (calc. G + R + Exuv), I + E.

Pteronarcys: McDiffett 1970.

Banksiola crotchi: Winterbourn 1971, I, E, A, wt. achieved, molting loss, metabolism. (Values are given for all these facets of the budget on the card.)

Asellus aquaticus: Prus 1971, 1972; Klekowski et al. 1970.

Lestes sponsa: Klekowski et al. 1970.

Dipletus cygnus: Klekowski et al. 1970.

Tribolium castaneum: Klekowski et al. 1970.

Simocephalus vetulus: Klekowski et al. 1970.

Growth Production:

	Cards	Authors
12/12/73	0	0
8/15/74	80	28

(Note: Some data relative to Growth and Production may be under Energy Budgets, and not be filed here.)

Some data on body length/weight relationships, and size increases after molting have been collected and plotted by Abrahamsson (1971), for the following species: *Pacifastacus leniusculus* and *Astacus astacus*.

Odonata growth has been documented as follows (Benke 1970):

Tetragoneuria cynosura: growth curves.

Ladona deplanta and *Libellula incesta*: instar number vs. time.

Ladona deplanta: instar definition histograms using head width and mesothoracic wing pad length.

Growth rate of *Ladona* and *Libellula* in two ponds (the rate of growth was significantly different for *Ladona*, but not for *Libellula*).

Species	Pond A	Pond B
Ladona	$Y = 3.21 - 2.31 \log X$	$Y = 7.83 - 4.10 \log X$
Libellula	$Y = 18.60 - 7.20 \log X$	$Y = 11.00 - 4.17 \log X$
Tetragoneuria	--	$Y = 6.47 - 2.88 \log X$

where Y = instar number, X = time in days, with July 1 arbitrarily chosen as day 1.

Growth curves for embryos and juveniles of *Littorina* have been calculated. The young are 575 μ at hatching, grow to 1 cm in the first year, then to a maximum of 2.5 cm in the second year (Buckland-Nicks et al. 1973).

Temperate, freshwater pulmonate snails grow rapidly after emergence (May-June), cease to grow during winter, resume growth during spring and continue growing through oviposition up to death (June-July).

This has been calculated for *P. cornutus* here (Calow 1973). That pattern of growth is reported to be typical for temperate, freshwater pulmonates (Hunter 1961).

The effects of food supply and temperature on the rate of growth of *P. cornutus* were investigated by Calow (1973) and curves were plotted.

Growth curves of *Nannothemis bella* and *Anax junius* have been plotted. Growth factors, or percentage increase, from various odonates, plus detailed information on odonate growth from individuals reared in cages are available on the cards also (Calvert 1929).

Glossosoma nigrior is reported to invest 0.3 cal/day into growth (Cummins 1969).

Physa showed two "periods" of growth in a pond. The first group hatched in June, grew rapidly and reached breeding condition in 6-7 wk. The second group hatched in August, grew rapidly and by September were an average of 7.1 mm shell length. They were quiescent during the winter and showed increased activity in the spring as they approached the summer breeding season (Duncan 1959).

Hydrophilus triangularis has data available on the cal/day invested in growth (Hallmark and Ward 1972).

Production is documented for four populations of Chironomids, Oligocheates, Crustaceans and Sphaerids for two 1-yr periods by Johnson and Brinkhurst (1971). Production varied from 50.6 to 274.9 (g or kcal/m^2; units not specified), depending on locality, but was quite constant within a locality for the 2-yr period.

Production estimates for five species are listed below:

Species	Production (kcal/m^2)
Chironomus anthracinus	75.3
Chaoborus flavicans	14.4
Procladius pectinatus	2.9
Ilyodrilus hammoniensis	12.0
Pisidium casertanum	1.5

Production for *Glyptotendipes barbipes* was estimated in primary and secondary waste stabilization ponds by Kimerle and Anderson (1971).

Data on growth of *Daphnia pulex* are available from Kryutchkova and Sladeck (1969).

Langford (1971) measured the growth of the following species (cards filed under **TEMCON** or Temperature Effects):

Taeniopteryx nebulosa
Ephemerella ignita
Heptagenia sulphurea
Baetis pumilus
B. rhodani
B. vernus
B. buceratus
an unidentified species of *Baetis*

McCraw (1961) has a growth summary for *Lymnaea humilus*.

Larval growth rates of *Ischnura elegans* and *Coenagrion puella* have been calculated and plotted by Parr (1970).

The growth of *Ancylus fluviatilis* has been measured and summarized by Hunter (1953).

The growth of several species of Swedish stoneflies has been measured and summarized by Svensson (1966).

Growth of *Hyalella* adults has been plotted by Strong (1972). Growth rate was constant for different sizes of *Hyalella* and three curves for different populations, at two temperatures, showed the same slope ($P < 0.1$) but different intercepts ($P < 0.001$) [ed. note: the alpha level was set after he ran the tests]. Growth was measured as increase in head capsule width. Growth rate was 0.3-4.3 mm x 10^{-3} per day at 22 C and 0.7-5.2 mm x 10^{-3} per day at 25 C (two extreme points at 25 C; 7.3 and 7.6 x 10^{-3} mm per day).

Stenonema invests 14.5% of the food consumed into growth (Trama 1957).

Growth of *Physa gyrina* at 14 C did not seem to be affected by temperature fluctuations (14 to 26 C) or dissolved oxygen fluctuations (10 to 15 ppm) during a 77-day observation period. Growth was a curvilinear function during that time (Van Der Schalie and Berry 1973).

Early development and growth of *Lymnaea stagnalis* has been documented by Vaughn (1953).

Oxytrema silicula had a maximum specific growth rate of about 2 mg·g^{-1}·day^{-1} (Warren and Davis 1971; Earnest 1967, as reported by McIntire 1973).

Turnover ratio (production:mean density) has been measured for the following organisms by Waters (1966).

Species	Ratio
Baetis vagans	9.7
Chironomidae (Littoral)	8-9
Chironomidae (Profundal)	2-3
Tanytarsus jucundus	3.4
Calospectra dives	3.5

(list continued on page 40)

list, continued from page 39

Species	Ratio
Anatopynia dyari	2.7
Corixa germari	2.5
Asellus	14
Planktonic Crustacea (enriched lake)	10.0
Planktonic Crustacea ("normal" lake)	4.8

Growth and production of *Ephemerella subvaria* have been calculated by several methods by Waters and Crawford (1973). Total production was 26.71 to 28.90 g/m^2. A growth curve has also been plotted.

The larval stage of *Simulium ornatum*, for one generation, showed a production about eight times the maximum biomass (Westlake et al. 1972).

LEAK (An):

	Cards	Authors
12/12/73	0	0
8/15/74	11	4

Daphnia released 30 μg P per g dry wt per day at 10 C but that rate increased to 125 μg P per g dry wt per day at 20 C (Edmonson 1961).

Zooplankton excretion was measured and reported by Ganf and Blažka (1974). The following data are taken from their graphs:

Temperature °C	Approx. excretion $\mu g NH_3 \cdot N/mg N \cdot hr$	Approx. excretion $\mu g PO_4 \cdot P/mg N \cdot hr$
22	13	3.8
24	15	4.6
26	18	5.4
28	22	6.2
30	25	7.3
32	30	8.7
34	34	10.0

Phosphorus excretion is described by the function:

$$\log_{10} P = 0.0304t - 0.450$$

where P is the excretion rate in $\mu g PO_4 \cdot P/mg N \cdot hr$, and t is time.

Ammonia-temperature and phosphate temperature curves are "generally" similar.

Nitrogen excretion in Long Island Sound was reported as follows (Ketchum 1961):

	μg-at. N/cm^2 1952-53	1953-54
Zooplankton	0.404	0.218
Bottom organisms	0.050	0.050

Zooplankton excreted 0.285 μg-at. N/liter on a volumetric measurement.

On a weight basis it was:

	μg-at. P (as PO_4)$\cdot mg^{-1} \cdot day^{-1}$
Zooplankton	0.37
Bottom organisms	0.0044

	μg-at. N (as NH_4)$\cdot$mg dry $wt^{-1} \cdot day^{-1}$
Zooplankton	2.6
Bottom organisms	0.054

Molting Loss:

	Cards	Authors
12/12/73	0	0
8/15/74	3	3

Ten percent per molt is lost in terms of the final larval weight. For *Anatopynia dyari* it was 9 to 11.5% with an average of 10% (Teal 1957). Ten percent of the energy equivalent of the calculated growth is lost in molting (McDiffett 1970).

Upstream Movement:

	Cards	Authors
12/12/73	0	0
8/15/74	4	2

Gammarus (Kocor 1973):

Movement	Current velocity
0.152 cm/sec	9 cm/sec
0.100 cm/sec	15 cm/sec

Campeloma decisum (snail) showed a positive upstream movement in a natural situation (Bovbjerg 1964).

Miscellaneous:

	Cards	Authors
12/12/73	14	7
8/15/74	35	17

There is no way to summarize these data.

Oviposition:

	Cards	Authors
12/12/73	0	0
8/15/74	13	6

(Note: See more information under Growth and Emergence.)

PREF:

	Cards	Authors
12/12/73	63	30
8/15/74	74	35

Ancylus feeds directly on algae growing on stones while *Physa* feeds on a variety of detritus as well as algae (Duncan 1959).

Limpets browse indiscriminately on the algal felt on the rocks; they show no preference (Geldiay 1956).

Sialis ate chironomids, *Chydorus*, *Diffulgia*, *Cypria* and *Sphagnum* in unknown percentages. Chironomidae ate 36% *Sphagnum*, 10% *Tabellaria*, 3% *Clostertium* and 51% detritus. *Pisidium* fed exclusively on detritus (Griffiths 1973).

Nematoda feed on bacteria (Teal 1957).

Garter snakes take many *Rhinichthys* (White and Kolb 1974).

RCONST: The maximum rate of oviposition for the M'th animal cohort (or any other reproduction information not included elsewhere).

	Cards	Authors
12/12/73	25	15
8/15/74	38	24

Copulating pairs of *Physa* were found in the field only in April. Oviposition was retarded by low temperatures (stopped at 4-5 C) and reinstated by a rise in temperatures (20-23 C). Eggs per mass varied from a few (3-5) to a maximum of 118 (DeWitt 1954).

Physa had a main reproductive period in the spring (April) and a smaller one in August (Duncan 1959). Duncan implied 23-24 C was too warm to keep *Physa fontinalis* in the lab. DeWitt (1954) had *P. gyrina* breeding at 30 C. Duncan also found that the change in the environmental factor, not the level of the factor, induced breeding. The majority of the egg capsules were laid between 12:00 midnight and 8:00 a.m., and that was not dependent on photoperiod.

Erpobdella otoculata exhibited a mean fecundity of 31.9 $\pm$ 3.3; 33.6 $\pm$ 3.3; and 34.3 $\pm$ 3.4 eggs per leech in 1966, 1967 and 1968, respectively (Elliott 1973).

Rhinichthys spawns from late June to July, the mean gonad weight being recorded as follows (Gee and Machniak 1972):

July 2	10.5 $\pm$ 3.23
July 15	11.0 $\pm$ 4.84
July 23	6.5 $\pm$ 1.84

Leeches breed and deposit cocoons in May and August; *Macrobdella* takes two to three years to mature. Certain other Hirudidae may require four to five years (Pennak 1956).

Crayfish females carry 10 to 800 eggs which have an incubation period of 2-20 weeks. The young leave the burrow of the mother at 8-20 mm (Pennak 1956).

Nigriona females weigh 90-120 mg (probably dry wt). A 120-mg female declines 25% to 90 mg after depositing her first egg mass and 75% more to 30 mg after depositing the second egg mass (R. C. Petersen, pers. comm.).

Hyalella carry more eggs per individual as they grow larger. Strong (1972) has plotted head length of females in millimeters vs. marsupial clutch size, head length of females vs. free-swimming clutch size, and head length of female vs. reproductive output per molt in mm^3. The curves are on the cards for reference.

RESP:

	Cards	Authors
12/12/73	53	27
8/15/74	65	35

Tubifex tubifex (Brinkhurst et al. 1972):

°C	ml $O_2 \cdot$mg dry wt$^{-1} \cdot$hr^{-1}
5	0.24
10	0.21
15	0.40
20	0.51

Limnodrilus hoffmeisteri:

°C	ml O_2·mg dry wt^{-1}·hr^{-1}
5	0.18
10	0.21
15	0.31
20	0.48

Zooplankton respiration at different temperatures has been documented by Ganf and Blažka (1974).

Isoperla buresi (Kamler 1969):

282.8 ± 10.77 μl O_2·g dry wt^{-1}·hr^{-1} in flowing water at 8 C

$Q = 1750\ t^{-0.377}$, where t = time in hr

Cloeon dipterum (Kamler 1969):

2655 ± 87.9 μl O_2·g dry wt^{-1}·hr^{-1} in flowing water at 20 C

$Q = 7500\ t^{-0.366}$, where t = time in hr

Bithynia tentaculata (Kamler 1969):

74.7 ± 2.62 μl O_2·g dry wt^{-1}·hr^{-1} in flowing water at 20 C (dry wt measured with shell)

$Q = 185\ t^{-0.459}$, where t = time in hr

Klekowski et al. (1970) give R:W values for eight different aquatic species.

Gila atratia: (1-5 g fish; Kramer, pers. comm.)

°C	mg C consumed·g C^{-1}·day^{-1}
2	9
12	18
22	36

Roux and Roux (1967) have documented the oxygen consumption (in mm^3 of O_2·g dry wt^{-1}·hr^{-1}) for three species of *Gammarus* at temperatures ranging from 5-27 C.

Widdows (1973) reported the respiratory rate of *Mytilus edulis* at 10, 15, 20 and 25 C.

TAKE: The rate at which an animal cohort would use its food resources if an overabundance of those resources were available.

	Cards	Authors
12/12/73	45	27
8/15/74	48	30

The new values are for *Tricorythodes* (Newell, unpubl.); *Pyrrhosoma nymphula* from Lawton (1971b); and *Pteronarcys scotti* from McDiffett (1970). The data are extensive and are available on the cards.

TEMCON: The coefficient for temperature dependence of transfer into the L'th animal cohort. (This category overlaps broadly with "Temperature Effects." Therefore, all material has been filed under the latter category and needs sorting.)

	Cards	Authors
12/12/73	3	3
8/15/74	3	3

Temperature Effects: See note under **TEMCON.**

	Cards	Authors
12/12/73	0	0
8/15/74	88	21

There is a great deal of material here, relative to a large number of groups. When one is looking for specific data about the effects of temperature on an organism, this is a reasonable place to search. Also see **RESP** for temperature effects there, **GROWTH**, especially for snails, and **TEMCON.**

THRESH: The lower threshold value of temperature, or accumulated temperature, for transfer into the L'th animal cohort.

	Cards	Authors
12/12/73	0	0
8/15/74	0	0

See Temperature Effects category for any data on this topic. Nothing has been found which is specifically relevant to the lower threshold for temperature.

XCRSOL: The amount of the L'th animal cohort's excretion going into the water as dissolved consitituents.

See **LEAK (An)** for probable values; otherwise, no new data for 1974.

	Cards	Authors
12/12/73	5	1
8/15/74	5	1

SUBROUTINE VEGET

Absorb: The location of mineral absorption in submerged aquatic plants.

	Cards	Authors
12/12/73	0	0
8/15/74	20	14

The view that plants absorb their mineral nutrition from the surrounding water, into the stems and leaves, was supported by Sutcliffe (1962).

The view that the plants get their minerals from the roots, and the surrounding substrate, has been supported by, among others: Bristow and Whitcombe (1971) working with P^{32}; DeMarte and Hartman (1974) working with P, Fe and Ca; Foehrenbach (1969**) working with phosphorus; Funderburk and Lawrence (1963**) working with phosphorus; Frantz and Cordone (1967); Lundegardh (1966*); McRoy and Barsdate (1970*, **); McRoy et al. (1972**); Reimold (1972); Sculthorpe (1967); and Toetz (1974) working with NH_4.

Commenting on the same subject, Denny (1972) claimed that the location of nutrient absorption was dependent on the following: amount and depth of submergence; substrate; complexity of anatomy; root:shoot ratio on poor substrate; and extent of vascular differentiation. He presented graphs depicting which way each influence would push the location of absorption, the implication being that absorption takes place in both locations in most situations.

Rates of absorption were experimentally determined by McRoy and Barsdate (1970). Their results are as follows:

	Uptake in μg P·g plant^{-1}·(day^{-1}?)	
	Light	Dark
Water to leaves and stems	6.4×10^{-6}	1.3×10^{-6}
Water to roots and rhizomes	0.13×10^{-6}	1.1×10^{-6}

AMORTV: The proportional, nongrazing mortality, per time unit, of the I'th plant species group.

	Cards	Authors
12/12/73	1	1
8/15/74	1	1

No additions for 1974.

*As cited by Toetz 1974.
**As cited by DeMarte and Hartman 1974.

CONNI2: The nutrient (C, N, P) concentration at which photosynthesis ceases.

	Cards	Authors
12/12/73	16	11
8/15/74	37	19

The limiting concentration for phosphorus, for diatoms, is 0.25 — 0.55 μg-at./liter (Thomas and Dodson 1968).

The limiting concentration and related information for *Selanastrum capricornutum* is as follows (Torrien and Huang 1973):

Maximum specific growth rate (μ) = 1.85/day (no units)
Half saturation constant (k_s) = 5 μg P/liter
Phosphorus yield coefficient (Y_p) = 805 mg cells produced/mg P utilized

CONRAD: The radiation intensity which yields maximum photosynthesis.

	Cards	Authors
12/12/73	8	12
8/15/74	16	23

Photosynthesis was climbing on a graph of photosynthesis vs. radiation intensity when the Y axis reached 800 ly/day, and still climbing at the edge of the figure (no author cited).

Constituents (Veg): The chemical composition of selected aquatic plants.

	Cards	Authors
12/12/73	6	6
8/15/74	34	16

The following are from Boyd and Lawrence (1967):

	In % dry weight			
Species	Ash	C	N	P
Cladophora	23.38%	35.27%	2.30%	0.56%
Chara	44 % (June)	28 % (June)		
	32 % (Oct)		2.0 % (July)	
		37 % (Sept)	3.0 % (Oct)	
Chara (mean)	43.41± 4.70%	29.28± 1.64%	2.46± 0.26%	0.25± 0.03%
Spirogyra	13.33± 2.15%	41.84± 1.11%	2.70± 0.32%	0.21± 0.04%

They conclude that the "most usual" composition of non-planktonic algae (on a dry weight basis) is:

Constituent	%
Ash	12-20
C	38-42
N	2-3
P	0.2-0.3

Phytoplankton (Platt and Irwin 1973):

The caloric value of the material, in relation to the percent C in dry tissue (pp. 308-309): cal/mg dry wt = 0.632 + 0.086 (% C), standard error = 0.181 cal/mg; cal/mg dry wt = —0.555 + 0.113 (% C) + 0.054 (C:N), standard error = 0.154 cal/mg.

Phytoplankton conversions (Jewell 1971):

1 mg C = 11.40 cal (p. 309).

Species	N (% ignitable solids)	Ash (% dry wt)	P (% ignitable solids)
Potamogeton	1.340	20.3	3.19
Chara	0.404	51.5	1.58

CONTE2: The relation of photosynthesis to temperature.

	Cards	Authors
12/12/73	8	5
8/15/74	15	8

Cladophora: The optimal temperature for photosynthesis is 25 C (Zuraw 1969).

CONTE3: The temperature for maximum photosynthesis.

	Cards	Authors
12/12/73	7	7
8/15/74	7	7

No new data for 1974.

Growth:

	Cards	Authors
12/12/73	14	8
8/15/74	14	8

No new data for 1974.

LEACH: The rate of leaching of dissolved organic matter from dead plant material.

	Cards	Authors
12/12/73	23	7
8/15/74	26	8

LEAK: Rate of loss of constituents from living plant material.

	Cards	Authors
12/12/73	27	8
8/15/74	43	12

There is a lot of material on the release of extracellular products by zooxanthellae from Trench (1971).

Saunders (1972) found that "detritus" released 23-29 $\mu g \cdot liter^{-1} \cdot day^{-1}$. He says that the release of organic matter from detritus is 2-6 times the amount released by phytoplankton, and the detrital reservoir is an order of magnitude more concentrated.

The excreted material in the sea (in $\mu g\ C \cdot liter^{-1} \cdot day^{-1}$) varied from 2.4 at 5 m to 11.0 at 1 m as follows (Hobbie 1972):

Depth (m)	μg C
0	7.8
1	11.0
3	2.5
5	2.4
7	3.2

Miscellaneous Vegetation:

	Cards	Authors
12/12/73	5	2
8/15/74	7	4

No way to summarize data.

Michaelis-Menton Kinetics:

	Cards	Authors
12/12/73	3	1
8/15/74	20+	6

Algae have a k_t of 1 μg-at. N/liter for NH_4 (Dugdale 1969).

M-M kinetics are plotted as the nitrate uptake rate (V) in μ-M $10^6 \cdot cell^{-1} \cdot hr^{-1}$ on the ordinate, over V/S, where S is the initial substrate concentration in μ-M NO_3. The negative slope of that regression line is the half saturation constant, k.

As such, k values varied from 0.1 μ-M NO_3 to over 1.5 μ-M NO_3, depending on external nutrient concentration (Carpenter and Guillard 1970).

We also have two very complete papers on soil urease Michaelis-Menton kinetics. They are not related enough to worry about now, but their data are on the cards if needed.

Net Assimilation:

	Cards	Authors
12/12/73	15	9
8/15/74	17	11

Phytoplankton gross, mean, annual production was 260 g $C \cdot m^{-2} \cdot yr^{-1}$. The range was 170-330 g $C \cdot m^{-2} \cdot yr^{-1}$. Net production (75 % of gross) was 195 g $C \cdot m^{-2} \cdot yr^{-1}$.

RESPD: The relation of plant respiration to temperature.

	Cards	Authors
12/12/73	11	10
8/15/74	12	10

No new data for 1974.

RESPV: The current respiration per day of the plant group under consideration.

	Cards	Authors
12/12/73	1	1
8/15/74	4	2

Potamogeton: Weeter 1968; Table 2.

10 C, $R = 0.323 + 0.019\,C$
20 C, $R = 0.658 + 0.069\,C$

R = uptake of O_2 in $mg \cdot g^{-1} \cdot hr^{-1}$
C = external O_2 concentration

Potamogeton: Weeter 1968; Table 3.

LINEAR

°C	$mg \cdot g^{-1} \cdot hr^{-1}$	r^2
	Clean	
10	$R = 1.048 + 0.050\,C$	0.792
15	$R = 0.746 + 0.068\,C$	0.848
	Polluted	
10	$R = 0.998 + 0.064\,C$	0.823
15	$R = 0.666 + 0.098\,C$	0.502

LOG

S.E.	$mg \cdot g^{-1} \cdot hr^{-1}$	r^2
	Clean	
0.190	$R = 1.079\,C^{0.157}$	0.622
0.214	$R = 0.670\,C^{0.330}$	0.795
	Polluted	
0.199	$R = 0.041\,C^{0.183}$	0.757
0.616	$R = 0.623\,C^{0.393}$	0.474

R = uptake of O_2 in $mg \cdot g^{-1} \cdot hr^{-1}$
C = external O_2 concentration

UPCON: The rate of uptake of a particular nutrient by various plants.

	Cards	Authors
12/12/73	20	14
8/15/74	20	14

No new data for 1974 except what may be under **ABSORB**.

UPCON1: The maximum value of the ratio of X nutrient (N, P) to carbon.

	Cards	Authors
12/12/73	19	12
8/15/74	21	13

UPCON2: The relation of nutrient X (N, P) to the external concentration of that nutrient.

	Cards	Authors
12/12/73	12	7
8/15/74	12	7

No new data for 1974.

Subroutines MEDIUM and PHYSIC

C, N, P, etc.:

	Cards	Authors
12/12/73	0	0
8/15/74	9	4

We have CO_2, nitrogen and phosphorus information filed here, but most information is filed under the various Constituents categories.

Conversion Factors:

	Cards	Authors
12/12/73	17	12
8/15/74	22	17

For phytoplankton, 1 mg carbon = 11.40 cal (Platt and Irwin 1973).

Caloric Values:

	Cards	Authors
12/12/73	29	23
8/15/74	35	27

Many more values are under the Constituents categories.

COAGUL: The rate of coagulation of dissolved organic matter to a size large enough to settle out.

	Cards	Authors
12/12/73	5	2
8/15/74	5	2

No new data for 1974.

EVAP: The rate of evaporation of water from water surfaces, especially streams and flowing surfaces.

	Cards	Authors
12/12/73	1	1
8/15/74	2	4

FALL: The settling rate of particles.

	Cards	Authors
12/12/73	14	4
8/15/74	17	5

Flow Reduction: Effects of flow reduction on the stream ecosystem.

	Cards	Authors
12/12/73	0	0
8/15/74	54	54

Abstracts are on the author cards which are filed in the subject box.

Physic Miscellaneous:

	Cards	Authors
12/12/73	12	7
8/15/74	22	13

Suspended Load:

	Cards	Authors
12/12/73	4	2
8/15/74	4	2

Temperature:

	Cards	Authors
12/12/73	0	0
8/15/74	12	3

Maximum stream temperatures are nearly always below 20 C. Winter temperatures range from 0 to 8 C, with a mean at 4 C (Crisp and LeCren 1970).

Daily fluctuations in temperatures in streams reach 6 C. Temperature is at a minimum at 6:00 a.m. and a maximum at about 6:00 p.m.

The average water temperature is close to the average air temperature (Macan 1958).

LITERATURE CITED

Introduction

Minshall, G. W., J. Perry II, S. Walrath, C. Nimz, M. McSorley, and J. Brock. 1974. Deep Creek validation study: results of data search for aquatic model. US/IBP Desert Biome Res. Memo. 74-67. Utah State Univ., Logan. 29 pp.

Subroutine ANIMAL Decomposition Parameters

Jewell, W. I. 1971. Aquatic weed decay: dissolved oxygen utilization and nitrogen and phosphorus regeneration. J. Water Pollut. Contr. Fed. 43:1457-1467.

Luria, S. E. 1960. The bacterial protoplasm: composition and organization. Pages 1-34 *in* I. C. Gunsalus and R. Y. Stanier, eds. The bacteria. Vol. I. Structure. Academic Press, N. Y.

Mathews, C. P., and A. Kowalczewski. 1969. The disappearance of leaf litter and its contribution to production in the River Thames. J. Ecol. 57:543-552.

Petersen, R. C., and K. W. Cummins. 1974. Leaf processing in a woodland stream. Freshwater Biol. 4:343-368.

Subroutine ANIMAL Animal Parameters

Abrahamsson, S. A. A. 1971. Density, growth and reproduction in populations of *Astacus astacus* and *Pacifastacus leniusculus* in an isolated pond. Oikos 22:373-380.

Benke, A. C. 1970. A method for comparing individual growth rates of aquatic insects with special reference to the Odonata. Ecology 51:328-331.

Bovbjerg, R. V. 1952. Ecological aspects of the dispersal of the snail *Campeloma decisum*. Ecology 33:169-176.

Bovbjerg, R. V. 1964. Dispersal of aquatic animals relative to density. Verh. Internat. Verein. Limnol. 15:879-884.

Brinkhurst, R. O., K. E. Chua, and N. K. Kaushik. 1972. Interspecific interaction and selective feeding by tubificid oligochaetes. Limnol. Oceanogr. 17:122-133.

Buckland-Nicks, J., F. S. Chia, and S. Behrens. 1973. Oviposition and development of two intertidal snails, *Littorina sitkana* and *Littorina scutulata*. Can. J. Zool. 51:359-365.

Calow, P. 1973. On the regulatory nature of individual growth: some observations from freshwater snails. J. Zool. 170:415-428.

Calvert, P. P. 1929. Different rates of growth among animals with special reference to the Odonata. Proc. Amer. Phil. Soc. 68:227-274.

Conover, R. J. 1961. The turnover of phosphorus by *Calanus finmarchicus*. Addendum to S. M. Marshall and A. P. Orr. 1961. On the biology of *Calanus finmarchicus*. XII. J. Mar. Biol. Assoc. U.K. 41:463-488.

Cummins, K. W. 1969. Energy budgets. Pages 31-37 *in* AAAS Symposium: The Stream Ecosystem. Inst. Water Res., Mich. State Univ., East Lansing.

Deevey, G. B. 1952. Quantity and composition of the zooplankton of Block Island Sound, 1949. Bull. Bingham Oceanogr. Inst. 13:120-164.

DeWitt, R. M. 1954. Reproduction, embryonic development, and growth in the pond snail, *Physa gyrina* Say. Trans. Amer. Microscop. Soc. 73:124-137.

Duncan, C. J. 1959. The life cycle and ecology of the freshwater snail *Physa fontinalis* (L.). J. Anim. Ecol. 28:97-117.

Earnest, R. D. 1967. Production of the snail *Oxytrema silicula* (Gould) in an experimental stream. M.S. Thesis, Oregon State Univ., Corvallis. 51 pp.

Edmonson, W. T. 1961. Secondary production and decomposition. Verh. Internat. Verein. Limnol. 14:316-339.

Elliott, J. M. 1971. The distances traveled by drifting invertebrates in a Lake District stream. Oecologia 6:350-379.

Elliott, J. M. 1973. The life cycle and production of the leech *Erpobdella octoculata* (L.) (Hirudinea:Erpobdellidae) in a Lake District stream. J. Anim. Ecol. 42:435-447.

Ganf, G. G., and P. Blažka. 1974. Oxygen uptake, ammonia and phosphate excretion by zooplankton of a shallow equatorial lake (Lake George, Uganda). Limnol. Oceanogr. 19:313-325.

Gee, J. H., and K. Machniak. 1972. Ecological notes on a lake-dwelling population of longnose dace (*Rhinichthys cataractae*). J. Fish. Res. Bd. Can. 29:330-332.

Geldiay, R. 1956. Studies on local populations of the freshwater limpet *Ancylus fluviatilis* Müller. J. Anim. Ecol. 25:389-402.

Griffiths, D. 1973. The structure of an acid moorland pond community. J. Anim. Ecol. 42:263-284.

Hallmark, M. D., and C. R. Ward. 1972. The life history and life process studies of the water scavenger beetle, *Hydrophilus triangularis* Say. US/IBP Desert Biome Res. Memo. 72-49. Utah State Univ., Logan. 24 pp.

HARGRAVE, B. T. 1970. The utilization of benthic microflora by *Hyalella azteca* (Amphipoda). J. Anim. Ecol. 39:427-437.

HARGRAVE, B. T. 1971. An energy budget for a detritus feeding amphipod. Limnol. Oceanogr. 16:99-103.

HARVEY, H. W. 1950. On the production of living organic matter in the sea off Plymouth. J. Mar. Biol. Assoc. U.K. 29:97-137.

HUMPESCH, U. 1971. Zur faktorenanalyse des schlüpfrhythmus der flugstadien von *Baetis alpinus* Pict. (Baetidae:Ephemeroptera). Oecologia (Berl.) 7:328-341.

HUNTER, W. R. 1953. On the growth of the fresh water limpet, *Ancylus fluviatilis* Müller. Proc. Zool. Soc. Lond. 123:623-636.

HUNTER, W. R. 1961. Annual variations in growth and density in natural populations of freshwater snails in the west of Scotland. Proc. Zool. Soc. Lond. 136:219-253.

JOHNSON, M. G., and R. O. BRINKHURST. 1971. Production of benthic macroinvertebrates of Bay of Quinte and Lake Ontario. J. Fish. Res. Bd. Can. 28:1699-1714.

JUDD, W. W. 1953. A study of the population of insects emerging as adults from the Dundes Marsh, Hamilton, Ontario during 1948. Amer. Midl. Natur. 49:801-824.

KAMLER, E. 1969. A comparison of the closed-bottle and flowing-water methods for measurement of respiration in aquatic invertebrates. Pol. Arch. Hydrobiol. 16:31-49.

KETCHUM, B. H. 1961. Regeneration of nutrients by zooplankton. Rapp. Cons. Perm. Int. Explor. Mer. 153:142-147.

KIMERLE, R. A., and N. H. ANDERSON. 1971. Production and bioenergetic role of the midge *Glyptotendipes barbipes* (Staeger) in a waste stabilization lagoon. Limnol. Oceanogr. 16:646-659.

KLEKOWSKI, R. Z., E. FISCHER, Z. FISCHER, M. B. IVANOVA, T. PRUS, E. A. SHUSKINA, T. STACHURSKA, Z. STEPEIN, H. ZYROMSKA-RUDZKA. 1970. Energy budget and energy transformation efficiency of several animals having different feeding types. IBP-UNESCO Symposium: Productivity problems in fresh water. 14 pp.

KOCOR, R. 1973. Alteration of upstream movement of *Gammarus fasciatus* by organophosphorus pesticides, abate and chlorpyrifos. M.S. Thesis, Northeastern Univ., Boston, Mass.

KRYUTCHKOVA, N. M., and V. SLADECK. 1969. Quantitative relation of the feeding and growth of *Daphnia pulex obtusa* (Kurz.) Scourfield. Hydrobiologia 33:47-64.

LANGFORD, T. E. 1971. The distribution, abundance, and life histories of stoneflies (Plecoptera) and mayflies (Ephemeroptera) in a British river, warmed by cooling water from a power station. Hydrobiologia 38:339-376.

LAWTON, J. H. 1970. Feeding and food energy assimilation in larvae of the damselfly *Pyrrhosoma nymphula* (Sulz.) (Odonata:Zygoptera). J. Anim. Ecol. 39:669-691.

LAWTON, J. H. 1971a. Ecological energetics studies on larvae of the damselfly *Pyrrhosoma nymphula* (Sulzer) (Odonata:Zygoptera). J. Anim. Ecol. 40:385-423.

LAWTON, J. H. 1971b. Maximum and actual feeding rates in larvae of the damselfly *Pyrrhosoma nymphula* (Sulzer) (Odonata:Zygoptera). Freshwater Biol. 1:99-111.

MARSHALL, S. M., and A. P. ORR. 1955a. On the biology of *Calanus finmarchicus*. VIII. Food uptake, assimilation, and excretion in adult and Stage V *Calanus*. J. Mar. Biol. Assoc. U.K. 34:495-529.

MARSHALL, S. M., and A. P. ORR. 1955b. Experimental feeding of the copepod *Calanus finmarchicus* (Gunner) on phytoplankton cultures labeled with radioactive carbon (14C). Deep Sea Res. 3:110-114.

MATHIAS, J. A. 1971. Energy flow and secondary production of *Hyalella azteca* and *Crangonyx richmondensis occidentalis* (Amphipoda) in Marion Lake, B. C. J. Fish. Res. Bd. Can. 28:711-726.

McCRAW, B. M. 1961. Life history and growth of the snail, *Lymnaea humilis* Say. Trans. Amer. Microscop. Soc. 80:16-27.

McDIFFETT, W. F. 1970. The transformation of energy by a stream detritivore, *Pteronarcys scotti* (Plecoptera). Ecology 51:975-988.

McINTIRE, C. D. 1973. Periphyton dynamics in laboratory streams: a simulation model and its implications. Ecol. Monogr. 43:399-420.

MÜLLER, K. 1954. Investigations on the organic drift in north Swedish streams. Rep. Inst. Freshwater Res. Drottningholm 35:133-148.

NEBEKER, A. V. 1971. Effect of high winter water temperatures on adult emergence of aquatic insects. Water Res. 5:777-783.

PALMER, M. F. 1968. Aspects of the respiratory physiology of *Tubifex tubifex* in relation to its ecology. J. Zool. (London) 154:463-473.

PARR, M. J. 1970. The life histories of *Ischnura elegans* (van der Linden) and *Coenagrion puella* (L.) (Odonata) in south Lancashire. Proc. Roy. Entomol. Soc. Lond. (A) 45:172-181.

PENNAK, R. W. 1956. Fresh-water invertebrates of the United States. Ronald Press Co., N. Y. 769 pp.

PRUS, T. 1971. The assimilation efficiency of *Asellus aquaticus* L. (Crustacea, Isopoda). Freshwater Biol. 1:287-306.

PRUS, T. 1972. Energy requirement, expenditure, and transformation efficiency during development of *Asellus aquaticus* L. (Crustacea, Isopoda). Pol. Arch. Hydrobiol. 19:97-112.

ROUX, C., and A. L. ROUX. 1967. Temperature et metabolisme respiratoire d'especes sympatriques de *Gammarus* du groupe *pulex*. Ann. Limnol. 3:3-16.

STRONG, D. R., JR. 1972. Life history variations among populations of an amphipod (*Hyalella azteca*). Ecology 53:1103-1112.

SVENSSON, P. 1966. Growth of nymphs of stream living stoneflies (Plecoptera) in northern Sweden. Oikos 17:197-206.

TEAL, J. M. 1957. Community metabolism in a temperate cold spring. Ecol. Monogr. 27:283-302.

TRAMA, F. B. 1957. The transformation of energy by an aquatic herbivore *Stenonema pulchellum* (Ephemeroptera). Ph.D. Diss., Univ. Mich., Ann Arbor. 80 pp.

VAN DER SCHALIE, H., and E. G. BERRY. 1973. The effects of temperature on growth and reproduction of aquatic snails. Sterkiana 50:1-92.

VAUGHN, C. M. 1953. Effects of temperature on hatching and growth of *Lymnaea stagnalis appressa* Say. Amer. Midl. Natur. 49:214-228.

WARREN, C. E., and G. E. DAVIS. 1971. Laboratory stream research: objectives, possibilities, and constraints. Annu. Rev. Ecol. Syst. 2:111-144.

WATERS, T. F. 1961. Standing crop and drift of stream bottom organisms. Ecology 42:532-537.

WATERS, T. F. 1966. Production rate, population density, and drift of a stream invertebrate. Ecology 47:595-604.

WATERS, T. F., and G. W. CRAWFORD. 1973. Annual production of a stream mayfly population: a comparison of methods. Limnol. Oceanogr. 18:286-296.

WESTLAKE, D. F., H. CASEY, H. DAWSON, M. LADLE, R. H. K. MANN, and A. F. H. MARKER. 1972. The chalk-stream ecosystem. Pages 615-635 *in* Z. Kajak and A. Hillbricht-Ilkowska, eds. Productivity Problems of Freshwaters. Proc. IBP-UNESCO Symposium. Warsaw, Poland. 918 pp.

WHITE, M., and J. A. KOLB. 1974. A preliminary study of *Thamnophis* near Sagehen Creek, California. Copeia 1974:126-136.

WIDDOWS, J. 1973. Effect of temperature and food on the heart beat, ventilation rate, and oxygen uptake of *Mytilus edulis*. Mar. Biol. 20:269-276.

WINTERBOURN, M. J. 1971. An ecological study of *Banksiola crotchi* Banks (Trichoptera, Phryganeidae) in Marion Lake, British Columbia. Can. J. Zool. 49:637-645.

SUBROUTINES VEGET, MEDIUM, PHYSIC

BOYD, C. E., and J. M. LAWRENCE. 1967. The mineral composition of several freshwater algae. Pages 413-424 *in* Proc. Twentieth Annu. Conf. Southeast. Assoc. Game and Fish Comm. Oct. 24-26, 1966.

BRISTOW, J. M., and M. WHITCOMBE. 1971. The role of roots in the nutrition of aquatic vascular plants. Amer. J. Bot. 58:8-13.

CARPENTER, E. J., and R. R. L. GUILLARD. 1970. Intraspecific differences in nitrate half saturation constants for three species of marine phytoplankton. Ecology 52:183-185.

CRISP, D. T., and E. D. LECREN. 1970. The temperature of three different small streams in north-west England. Hydrobiologia 35:305-323.

DEMARTE, J. A., and R. T. HARTMAN. 1974. Studies on absorption of ^{32}P, ^{59}Fe, and ^{45}Ca, by water-milfoil (*Myriophyllum exalbescens* Fernald). Ecology 55:188-194.

DENNY, P. 1972. Sites of nutrient absorption in aquatic macrophytes. J. Ecol. 60:819-829.

DUGDALE, R. C. 1969. The nitrogen cycle in the sea. Pages 16-18 *in* Biology and ecology of nitrogen. Proc. of a Conference. Univ. Calif., Davis.

FOEHRENBACH, J. 1969. Pollution and eutrophication problems of Great South Bay, Long Island, New York. J. Water Pollut. Contr. Fed. 41:1456-1466.

FRANTZ, T. C., and A. J. CORDONE. 1967. Final introductions of the Bonneville cisco (*Prosopium gemmiferum* Snyder) into Lake Tahoe, California and Nevada. Calif. Fish and Game 53:209-210.

FUNDERBURK, H. H., JR., and J. M. LAWRENCE. 1963. Absorption and translocation of radioactive herbicides in submersed and emersed aquatic weeds. Weed Res. 3:304-311.

HOBBIE, J. E. 1972. Carbon flux through a tundra pond ecosystem at Barrow, Alaska. Pages 206-208 *in* Proc. 1972 Tundra Biome Symposium, Univ. Wash., Seattle.

JEWELL, W. J. 1971. Aquatic weed decay: dissolved oxygen utilization and nitrogen and phosphorus regeneration. J. Water Pollut. Contr. Fed. 43:1457-1467.

LUNDEGARDH, H. 1966. Plant physiology [Transl. F. M. Irvine]. American Elsevier, N. Y. 241 pp.

MACAN, T. T. 1958. The temperature of a small stony stream. Hydrobiologia 12:89-106.

MCROY, C. P., and R. J. BARSDATE. 1970. Phosphate absorption in eelgrass. Limnol. Oceanogr. 15:6-13.

MCROY, C. P., R. J. BARSDATE, and M. NEBERT. 1972. Phosphorus cycling in an eelgrass (*Zostera marina* L.) ecosystem. Limnol. Oceanogr. 17:58-67.

PLATT, T., and B. IRWIN. 1973. Caloric content of phytoplankton. Limnol. Oceanogr. 18:306-310.

REIMOLD, R. J. 1972. The movement of phosphorus through the salt marsh cord grass, *Spartina alterniflora* Loisel. Limnol. Oceanogr. 17:606-611.

SAUNDERS, G. W. 1972. The transformation of artificial detritus in lake water. Mem. Ist. Ital. Idrobiol. 29(Suppl.):261-288.

SCULTHORPE, C. D. 1967. The biology of aquatic vascular plants. St. Martin's Press, N. Y. 610 pp.

SUTCLIFFE, J. F. 1962. Mineral salts absorption in plants. Permagon Press, Oxford, London, N.Y., Paris. 311 pp.

THOMAS, W. H., and A. N. DODSON. 1968. Effects of phosphate concentration on cell division rates and yield of a tropical oceanic diatom. Biol. Bull. 134:199-208.

TOETZ, D. W. 1974. Uptake and translocation of ammonia by freshwater hydrophytes. Ecology 55:199-201.

TORRIEN, D. F., and C. H. HUANG. 1973. Algal growth prediction using growth kinetic constants. Water Res. 7:1673-1681.

TRENCH, R. K. 1971. The physiology and biochemistry of zooxanthellae symbiotic with marine coelenterates. II. Liberation of C^{14} by zooxanthellae *in vitro*. Proc. Roy. Soc. Lond. (B) 177:237-250.

WEETER, D. W. 1968. The effect of environmental factors on the respiration of aquatic macrophytes. M.S. Thesis, Penn. State Univ., University Park.

ZURAW, E. W. 1969. Culture and physiological requirements of bacterialized *Cladophora glomerata* (L.) Kutz. from Lake Michigan. J. Phycol. 5:83-85.