The Lowland Stream Ecosystem of Amchitka Island, Alaska

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Introduction

Preliminary to the simulation of energy flow in an ecosystem, data must be collected to establish a basic description of that system. This description must account in quantitative detail for (1) diversity; (2) biomass; (3) rate processes between predators and prey; (4) behavioral patterns of organisms in the system; and (5) physical factors affecting biomass, processes, and behavior. The study of the stream ecosystem on Amchitka was designed to gain a conceptual understanding of these parameters as they might relate to a functional model of that system.

A reconnaissance survey, initiated in August 1967, established that the streams on the Island could be categorized as highland streams or lowland streams. The highland streams are characterized by hard substrates, high gradients, benthic periphyton growth, and invertebrate populations dominated by mayflies, caddisflies, and simulids. In contrast, lowland streams are characterized by low gradients, benthic periphyton, vascular aquatic plants, and invertebrate populations dominated by chironomids. This report describes the lowland streams, as represented by Bridge Creek.

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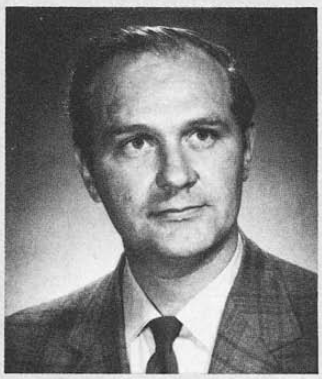
Description of the Study Area

Bridge Creek has a drainage area of 1939 ha and a mean annual flow rate of 0.1 m^3/sec. The watershed is predominantly maritime tundra. The stream flows off the north shed of the Island to the Bering Sea. The stream bottom is a high-organic-content silt with *Fontinalis neomexicana* Sull. and Lesq., *Ranunculus trichophyllus* var. *trichophyllus* Hult., and *Hippuris vulgaris* L. predominating (Shacklette et al., 1969). The predominant alga present in the stream was of the genus *Cladophora*. The section of stream under intensive study was a 2478 m stretch from its mouth to a point just below a waterfall, a natural obstruction to fish movement. The mean width of the study section was 1.9 m and mean depth was 0.75 m. The predominant invertebrates were chironomids, oligochaetes were next, followed distantly by caddisflies, mayflies, clams, isopods, and amphipods. The predominant fish species was the Dolly Varden, *Salvelinus malma* (Walbaum). Coho salmon, *Oncorhynchus kisutch* (Walbaum), and pink salmon, *Oncorhynchus gorbuscha* (Walbaum), constituted an insignificant portion of the total biomass. Traps were set upstream and downstream from both the mouth of the stream and the upper end of the study section to provide integrity to fish population data.

Methods

Physical Parameters

Sampling proceeded throughout 1968, but the sampling intensity varied during the year because of limited winter access. However, in May through November 1968, we sampled for invertebrates, fish, and primary production on a monthly basis, as was sampling for temperature and dissolved organic concentrations. Flow rates were measured on a continuous-recording water-stage recorder by the USGS. Dissolved organic concentration and detritus concentra-



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After receiving his Ph.D. in Fishery Biology from Utah State University in 1959, Dr. Neuhold pursued postdoctoral radioecological research at the Oak Ridge Institute of Nuclear Studies. In addition to various appointments at Utah State University, he has served on several environmental committees and has acted as a consultant with the National Science Foundation.

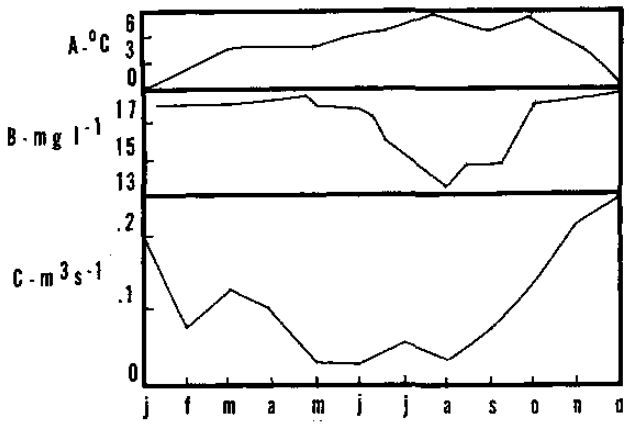

Fig. 1. Physical parameters measured on Bridge Creek during 1968. A. Stream temperature. B. Dissolved organic concentration. C. Flow rate.

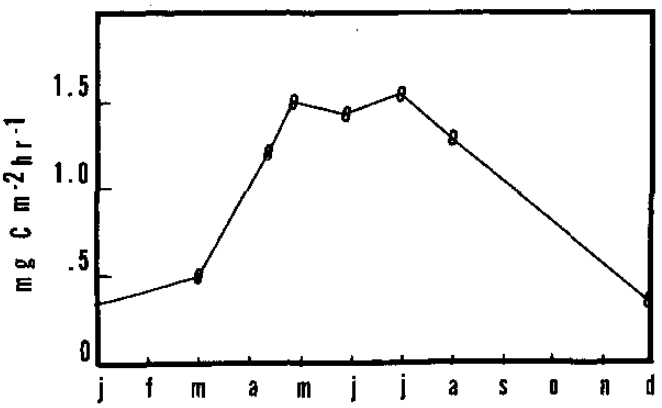

Fig. 2. Rates of gross primary production on Bridge Creek during 1968.

tion of the water were established by randomly sampling throughout the study section 1-liter aliquots of water. The concentration of the dissolved organic in the filtrate, following filtering through a Millipore filter, was established by wet ashing techniques (Amer. Publ. Health Assoc., 1960). Sampling for dissolved organic concentration did not always include a measure of the detritus concentration. Rather the ratio of total dissolved-organic concentration to detritus concentration was established for 24-hour periods several times during the year. The ratio was consistently 0.25 (coefficient of variation = 10%).

Primary Production

Primary production was determined from chlorophyll extracts of artificial substrates randomly placed in the stream throughout the study section. Sealed polyethylene bags full of sand were left in the stream for extended periods and sampled periodically. The surface portions of the bags were soaked in acetone to extract chlorophyll. Ryther's (1956) method of converting chlorophyll concentrations to the rate of gross primary production was employed for the measure of gross primary production. In addition, chlorophyll was extracted from areal samples of stream bottoms.

Invertebrates

Invertebrate samples were collected with a Surber stream-bottom sampler at random locations throughout the study section. At least nine samples were taken for each sampling period. Invertebrates were picked from the samples and preserved in 10% formalin for later enumeration and measurement. Invertebrate drift nets were also set up on the stream at various times throughout the year. However, invertebrate drift proved to be essentially nonexistent.

Fish

Fish, collected with an electrofishing apparatus, were weighed, measured, marked, and released, and subsequently recaptured for population estimates and biomass-growth measurements. Population size was estimated employing the Schnabel and Schummacher technique as described by Ricker (1958). Fish movement was studied by trapping fish both upstream and downstream at both the mouth of the stream and 2478 m above the mouth. The traps were visited daily; fish caught were weighed, measured, marked, and released. Throughout the year, fish were also collected for determination of length-weight relationships, age-growth data, and food habits. Fish were aged from otoliths.

Results

Physical

Stream flow varied throughout the year from a high of 0.24 m^3/sec in December to a low of 0.02 m^3/sec in May and June. In general, stream flow reached a low level May through August; the flow rate increased from August through December and decreased from December to May. The organic concentrations in the stream waters appeared to be related to the rate of flow, with a low concentration of 13 mg/liter in August and high concentrations in excess of 19 mg/liter in December and April. Both dissolved organic carbon concentrations and stream flow were inversely related to temperature,

TABLE 1. Annual standing crop and production in Bridge Creek during 1968

	Standing Crop $g/m^2/yr$	Production $g/m^2/yr$
Gross Primary Production[a]	—	3.9
Net Detritus Input	—	870.0
Invertebrates	5.3	41.7
Chironomids	1.5	29.0
Oligochaetes	2.4	6.1
Caddisflies	0.6	3.4
Clams	0.6	3.0
Mayflies	0.2	0.2
Dolly Varden[b]	200.0	10.6

[a] Biased toward benthic periphyton.

[b] Based on production of first four age classes.

which reached a low of 0 C during December and January and a high during July and August of 10 C (Fig. 1). Combination of the dissolved organic concentration with the flow rates integrated over the year and multiplied by the proportion of detritus to dissolved organic concentration and by the settling rate resulted in an estimate of the detritus input into the study section (Table 1).

Primary Production

Rates of primary production reached high levels during May, June, and July, and low levels during December and March. Primary production varied from a high of 1.5 mg/m^2/hr to a low of 0.3 mg/m^2/hr (Fig. 2). Crude integration of the curve thus outlined resulted in an estimate of the annual gross production (Table 1). Since the method used for primary production estimates was biased toward benthic periphyton production, it did not account for production of vascular plants in the system. However, the pattern of gross productivity displayed throughout the year is considered similar to that expected if vascular plant production were included, although it might be as much as an order of magnitude greater.

Invertebrates

Invertebrate populations as determined from the bottom samples were low in diversity. Chironomids were the most abundant, followed in order by oligochaetes, caddisflies, clams, and mayflies. Mayflies constituted less than 1% of the total invertebrate biomass (Table 1). The food-habits study conducted by Palmisano (1970) reinforced the bottom-sample findings but there was greater invertebrate diversity in fish stomachs indicating that the fish were better samplers than the biologists. The important food items in terms of biomass appeared in the bottom collections. Chironomids were the most important food item, with caddisfly larvae constituting somewhat less than 5% of the volume ingested. Since the chironomids constituted the most significant bulk of both food ingested and production in Bridge Creek, only their distribution is presented here.

The standing crop of chironomids appeared to remain consistently <0.2 g/m^2 during the entire winter and spring. It increased during July and

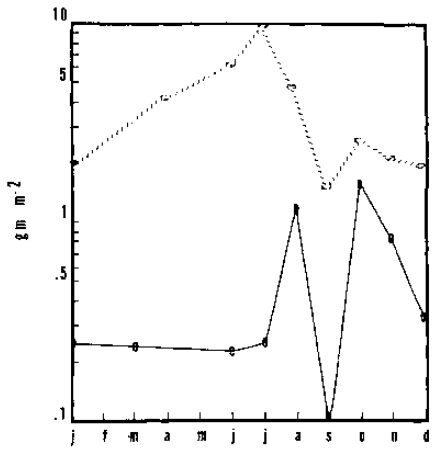

Fig. 3. Chironomid production (hatched) and standing crop (solid) in Bridge Creek during 1968.

August, decreased drastically during September to a low of 0.1 g/m^2 and increased to a high of 1.58 g/m^2 in October. Production estimates showed a consistent increase from January through June, with a sharp decline during July and August. Maximum production was estimated at 10.5 g/m^2 in July and minimum production (1.5 g/m^2) in September (Fig. 3). The sharp decline in both standing crop and production during July and August is coincidental with observed chironomid pupation and emergence and with the appearance of pupae and adults in fish stomachs (Palmisano, 1970).

Fish

Fish standing crops, predominantly Dolly Varden, reached their highest levels during November through January when they amounted to 330 g/m^2. Standing crops declined slowly through May and sharply from May until August

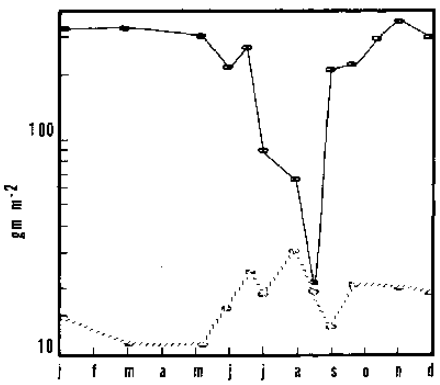

Fig. 4. Dolly Varden total standing crop (solid) and 0-4-year-old fish standing crop (hatched) in Bridge Creek during 1968.

to a low of 20 g/m^2, and then sharply increased again to a high in November (Fig. 4). Fish movement in and out of the study area, as determined by trapping, was consistent with the decline and increase of fish biomass. The fish movements (both in and out) were correlated with increased stream flow. An analysis of fish movement by age class revealed no significant movement from the study area by the first four age classes. Only fish of age class four and older moved.

Discussion

A comparison of the production estimates presented in Table 1 suggests that the flow of energy in the Bridge Creek system is based on detritus. The estimate for detritus input into the system and the fact that the predominant invertebrates are detritus feeders reinforces this suggestion. Comparing the production levels in Table 1 with Dolly Varden standing crop (Fig. 4) shows that the detritus-invertebrate base alone is not adequate to produce the Dolly Varden found in the stream. Since fish 4 years old and older start leaving the stream in May and do not return until September, it is concluded that the additional production must occur while the fish are in the sea. Only the first four age classes rely wholly on the production base in the stream. Migrant fish feed on invertebrate production during the winter months when temperatures are low and presumably fish-feeding activity is also low. That the feeding activity of fish in the winter months is low is borne out by the high proportion of fish with low stomach contents (Palmisano, 1970). As temperatures increase (Fig. 1), fish begin to leave the stream, thereby canceling out any increase in activity.

Fish activity affects the standing crop of the chironomid population (Fig. 3), standing crops of which increase when the fish are leaving the system. The decline in both production and standing crop during August and September reflects the emergence period. Undoubtedly, if the fish did not leave during this period of higher temperatures, their use of chironomids could be sufficiently severe to "crash" the system.

Stream-flow rates are depressed during the summer months (Fig. 1) making it difficult for fish to cross the intertidal gravel bars across the mouth of the

stream. Fish movement during this period is dependent on brief increases in flow following rainstorms. Should a drought occur during this period, access would be denied and the system would be in danger of a crash. Obviously, flow rate and temperature must play an important part in the construction of a functional model of the system. Detritus input is a function of the streamflow rate. Flow rate in addition serves as a "trigger" mechanism for fish movement. Fish activity and growth rate are both functions of temperature.

The system thus described is a simple system based on detritus with the principle route of energy flow to the fish through a single group of invertebrates, the chironomids. As such, it is an extremely tenuous system probably susceptible to a "crash" from any of the variety of perturbations that could result from natural catastrophes, pollution produced by construction activities, and other causes.

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Mathematical Simulation of Sea Otter Population Dynamics Amchitka Island, Alaska

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Introduction

An accurate, dependable model of sea otter population dynamics could be used to evaluate the potential effects of (1) removing individuals from the sea otter population; (2) removing a fraction of the food supply from the sea otter's habitat; (3) destroying food-production capability; and (4) various proposed management practices such as harvesting for fur. Such a model could also be useful in distinguishing between natural mortality and mortality due to shock effects.

Unfortunately, the biological and ecological data required for a comprehensive model are not available nor will they become available in the near future. The factors controlling birth rate, death rate, population growth rate, carrying capacity, fecundity, mating, longevity, interactions with food supply, interactions with potential competitors, and many other parameters that may be important with respect to population dynamics have not been studied adequately. However, it was still possible to develop population models on the basis of simple but plausible assumptions. A preliminary model was developed on the basis of a simple food-sea otter relationship in order to demonstrate the feasibility of modeling population dynamics of sea otters. This model was expanded by grouping otters in four categories: nonpregnant adult females, pregnant females, pups, and adult males; and food in four categories: echinoderms, mollusks, crustaceans, and fish. Also, an analytical study of the short-term recovery process was performed in order to investigate the effects of disproportionately severe casualties among pregnant females and pups. This analytical study considered the time periods required for reproductive processes.

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Preliminary Simulation Model

The information presently available indicates that the sea otter is not subjected to predation pressure, serious diseases, or parasitism, and that competition with other marine mammals is not significant. Ignoring other factors, such as possible human interference, this leads to the simplifying assumption that the only two important variables controlling sea otter population dynamics are the amount of food available and the number of sea otters present.

If it is assumed that the sea otter food is generated at a constant rate fixed by the habitat while the rate of food loss is proportional to both its supply and the number of otters present, then the food equation is

$$\frac{dF}{dt} = B - \lambda_F F - \lambda_e N, \qquad (1)$$

where F is the amount of "otter food" present in the environment around Amchitka Island, t is time, B is the food-generating capacity of the habitat, λ_F is