

Energy ingestion and conversion rate in pollock (*Theragra chalcogramma*) fed different prey types

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Paul, A. J., Paul, J. M., and Smith, R. L. 1990. Energy ingestion and conversion rate in pollock (*Theragra chalcogramma*) fed different prey types. – J. Cons. int. Explor. Mer. 46: 232–234.

Juvenile pollock were held at 5.5°C and fed a variety of whole crustaceans and fish tissues for which the energy content had been determined. Growth in body weight was measured relative to energy consumption. This relationship was described by the equation: $\text{growth (\%bw d}^{-1}\text{)} = 0.044 \text{ consumption (cal g}^{-1}\text{d}^{-1}\text{)} - 0.343$; $r^2 = 0.95$. Pollock converted the energy content of crustacean and fish tissues with similar efficiency. Therefore, if prey types are converted to caloric values, the relationship between energy consumption and growth can be expressed mathematically with confidence for a range of prey taxa.

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Introduction

The pollock, *Theragra chalcogramma*, supports a commercial harvest in the Gulf of Alaska and the Bering Sea, and serves as prey to a variety of fishes, birds, and marine mammals. Recently there has been considerable interest in quantifying the flow of energy from prey species into pollock (Yoshida and Sakurai, 1984; Harris *et al.*, 1986; Paul, 1986; Smith *et al.*, 1986, 1988). Two reports of the bioenergetic requirements of pollock have described growth as a function of energy consumption (Smith *et al.*, 1986, 1988). Both of these studies are based on laboratory experiments in which weight gain was measured for fish fed known amounts of tissue for which the energy content had been determined. The tissues used as food were fillets of Pacific herring (*Clupea harengus pallasii*) and pandalid shrimp tail from which the carapace had been removed. Pollock may occasionally prey upon herring but it is not their major prey species and crustacean prey would naturally be enclosed by the organism's carapace. Pollock feed on copepods, euphausiids, other crustaceans, and pollock (Clausen, 1983). One criticism of the existing bioenergetic studies is a lack of evidence demonstrating that the energy intake-growth relationship described for pollock fed herring or peeled shrimp tail has general applicability to the whole spectrum of natural prey organisms. The objective of the research described in this report was to

examine the rate of growth relative to energy consumption by pollock fed a variety of prey species.

Materials and methods

Pollock of 30–60 g were captured in Resurrection Bay, Alaska, returned to the laboratory at Seward Marine Center and held in 800 l aquaria at 5.5°C (± 0.5). Fish were held for a minimum of one month prior to experiments to ensure that they were used to captive conditions and were feeding regularly.

Aerated sea water was added slowly to aquaria so oxygen concentrations were maintained ($3\text{--}5 \text{ ml l}^{-1}$). At higher oxygen concentrations gas pockets formed behind the fishes eye lenses and buoyancy problems developed. The fish were held in groups of two to five, with individuals in a group weighing within 10 g of each other. This approach was used because pollock are schooling fish, and when held alone they do not feed well. Previous experience in holding pollock demonstrated that many skin infections resulted from repeated handling. Thus, measurements were restricted to initial weights and final weights. During measurements, fish were anaesthetized with MS-222 and handled carefully. After weighing to the nearest g, fish fasted for 24 h, were fed for 30 days, then not fed for two days. Weights

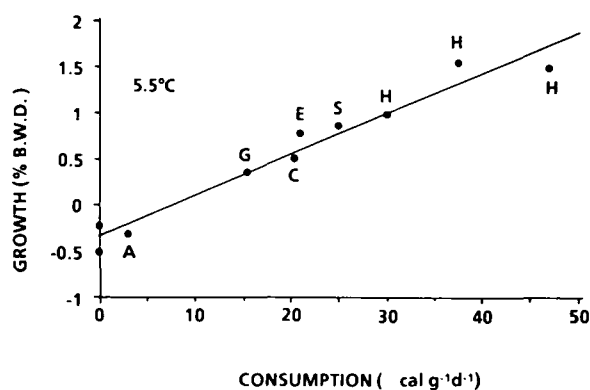


Figure 1. Growth (%bw d⁻¹) of juvenile pollock held at 5.5°C as a function of energy consumption (cal g⁻¹ d⁻¹ fish weight). Food types of the different groups of fish were amphipods (A), glass shrimp (G), euphausiids (E), cod fillet (C), salmon fillet (S), and herring fillet (H).

were measured again on day 32. Their schooling behaviour, similar size, and activity levels precluded individual identification by colour pattern. Experiments with various tags and dyes invariably resulted in skin infection or death. Because fish were held in groups, growth had to be expressed as the mean change in weight; individual consumption could not be determined.

The food types used were Pacific herring fillets (*Clupea harengus pallasii* Valenciennes); Pacific cod fillets (*Gadus macrocephalus* Tilesius); pink salmon fillet (*Oncorhynchus gorbuscha* Walbaum); whole amphipods (*Anisogammarus pugettensis* (Dana)); whole glass shrimp (*Pasiphaea pacifica* Rathbun); and whole euphausiids (*Thysanoessa raschii* (Sars)). There was a single group of fish for each of the prey types.

Fish were fed once per day to satiation with pre-weighed amounts of food; the uneaten portion was removed from the tanks after 10 min and weighed to determine the weight ingested. While fish were offered food each day not every fish fed. Thus, the results are indicative of average growth for the group. Two groups of fish were starved for 30 days to provide data on growth at a zero caloric consumption rate.

Samples of each food type were weighed wet to the nearest 0.001 g, then dried for 24 h in a freeze drier, thereafter dried to a constant weight in a convection oven at 60°C. This drying method was used both to obtain sample wet weight–dry weight ratios and dried tissue for calorimetry and ashing. Dried tissue samples were placed in pre-weighed porcelain crucibles with loose-fitting tops and weighed again to 0.00001 g. Next they were heated gradually over 3 h to 600°C and then maintained at this temperature for 12 h. Crucibles were allowed to cool to room temperature prior to reweighing to obtain the ash weight of the tissue. Bomb calorimetry was performed in triplicate on dried subsamples of each food type to calculate the caloric value (not adjusted for nitrogen formation in bomb calorimetry) of the food ingested (Table 1).

Results

Figure 1 shows the linear relationship between consumption and growth: growth (%bw d⁻¹) = 0.044 consumption (cal g⁻¹ d⁻¹) – 0.343; $r^2 = 0.95$ (Fig. 1). The poorest growth was shown by fish fed amphipods, the prey with the lowest energy content. The best growth was obtained by groups fed herring fillet, which had the highest energy content per unit weight. The results demonstrate that pollock convert the energy of crustacean and fish tissues with similar efficiency.

Discussion

Previously published relationships between consumption and growth for juvenile pollock are given in Table 2. The maintenance ration for juvenile (30 to 60 g) feeding pollock at 5.5°C is 7.8 cal g⁻¹ d⁻¹ (Fig. 1); that for adults (313–540 g) at 5.0°C is 4.8 cal g⁻¹ d⁻¹ (calculated from the growth equation in Table 2). At 3°C juveniles have maintenance requirements of 5.5 cal g⁻¹ d⁻¹ (Table 2). These maintenance requirements compare with estimates of 4.1 and 6.2 cal g⁻¹ d⁻¹ for 70 g unfed fish based on the indirect calorimetry of oxygen consumption at 3 and 5.5°C (Paul, 1986).

Table 1. Caloric values, wet-dry weight conversion factor, and ash content for pollock and food species.

Species	Caloric value (cal g ⁻¹ dry wt)	% Moisture (dry wt/wet wt)	% Ash (ash wt/dry wt)
Juvenile pollock	5800	24.9	10.9
Herring	6186	32.2	4.5
Cod	4709	18.0	10.9
Salmon	5574	23.5	10.4
Amphipod	2994	19.6	59.8
Glass shrimp	4370	15.6	14.3
Euphausiid	4742	12.9	13.5

Table 2. Functional relationships relating growth and food consumption for pollock held in captivity.

Y	X	T°C	Equation	r ²	Source
Juvenile pollock					
Growth (%bw d ⁻¹) = Consumption (cal g ⁻¹ d ⁻¹)		3.0	Y = 0.048X - 0.267	0.93	2
Growth (%bw d ⁻¹) = Consumption (cal g ⁻¹ d ⁻¹)		5.5	Y = 0.044X - 0.343	0.95	1
Growth (%bw d ⁻¹) = Consumption (cal g ⁻¹ d ⁻¹)		7.5	Y = 0.030X - 0.115	0.93	2
Adult pollock					
Growth (%bw d ⁻¹) = Consumption (cal g ⁻¹ d ⁻¹)		5.0	Y = 0.036X - 0.174	0.86	3

Sources: (1) This report; (2) Smith *et al.*, 1986; (3) Smith *et al.*, 1988.

In previous laboratory studies of pollock maintenance rations for adults held at 7.2°C were 0.8% bw d⁻¹ (Yoshida and Sakurai, 1984) and 0.26% bw d⁻¹ at 5°C (Smith *et al.*, 1988). In the latter case pollock were fed herring fillet (6.2 Kcal g⁻¹), while in the former pollock fillet (4.3 Kcal g⁻¹ (Smith *et al.*, 1988)) was fed. The thermal regime probably accounts for some of the difference in maintenance ration based on weight of food consumed. Variations in energy content of the food can explain much of the large difference in these estimates of weight-based maintenance ration. The maintenance ration for adult pollock based on energy intake is about 4.8 cal g⁻¹ d⁻¹ at 5°C (Smith *et al.*, 1988). With a moisture content of 80%, pollock fillet has an energy content of around 0.86 Kcal g⁻¹ (Smith *et al.*, 1988). A 650 g pollock consuming 4.8 cal g⁻¹ d⁻¹ would then eat 3.1 Kcal, 3.6 g, or 0.6% bw d⁻¹, a much higher consumption rate than the 0.26% bw d⁻¹ for fish fed on herring (Smith *et al.*, 1988). If those fish ate euphausiids (0.6 Kcal g⁻¹ wet wt.; Table 1) consumption would be 5.2 g or 0.8% bw d⁻¹. Thus, maintenance rations are best expressed in energy units rather than as a percentage of body weight.

The carapace of crustacean prey is low in energy (Paul and Fuji, 1989). By taking up room in the stomach one would expect the carapace to negatively affect energy intake for groups fed whole crustaceans. The negative effect of carapace consumption on growth appears to be accounted for when prey are converted to calories (Fig. 1).

The results of this study demonstrate that the previously existing models of conversion rates of pollock relative to energy consumption (Smith *et al.*, 1986, 1988), along with this report, can be used to make preliminary estimates of energy consumption of pollock feeding on a variety of prey species.

Acknowledgements

This study was sponsored by the Alaska Sea Grant College Program, cooperatively supported by NOAA, Office of Sea Grant and Extramural Programs, Department of Commerce, under grant no. NA86AA-D-SGO41, project no. R/06-23, and the University of Alaska with funds appropriated by the state. Facilities were provided by the University of Alaska's Institute of Marine Science, Seward Marine Center. This paper is contribution no. 749, Institute of Marine Science, University of Alaska at Fairbanks.

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