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ABSTRACT

Age I winter flounder, *Pseudopleuronectes americanus*, weighing 40–100 g were fed chopped bivalve siphons (*Mya arenaria*) *ad libitum*. Sixteen fish were held at 4 temperatures (12, 16, 20 and 24 C) and two salinities (20 and 30‰), with two fish per regime. Only 4 fish held at 12 C and 16 C in 20‰ salinity had a normal growth rate, and the conversion efficiency for these fish ranged from 13.9–19.0%.

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The winter flounder, *Pseudopleuronectes americanus*, inhabits coastal waters from Newfoundland to Chesapeake Bay and is considered an omnivorous sight feeder, preying primarily on crustaceans, polychaetes and bivalves (Linton, 1921; Richards, 1963). It is an important marine fish in New England where in 1969 commercial landings totaled 21 million pounds worth an estimated 2.6 million dollars to fishermen.

In this study I measured the food intake and growth and determined the conversion efficiency for 1-year-old winter flounder held under different temperatures and salinities. Conversion efficiency is the ratio of the increase in weight of an animal to the weight of food ingested for a given time period, usually expressed as a percentage. This ratio is termed gross efficiency and is identified by the symbol K_1. Knowledge of the conversion efficiency of different fishes fed different diets has broad application in the fields of ecology, physiology and mariculture.

MATERIALS AND METHODS

Although units of dry weight are considered a better measure of both food and growth, units of wet weight have been used by many researchers. Objections to the use of wet weights, based on changes in water and fat content that occur during feeding experiments, have been raised by Gerking (1952) and Pandian (1957). Conversion efficiencies calculated from wet weights tend to be lower than efficiencies based on dry weights and lower still than efficiencies expressed in calories.

One can circumvent some of the problems associated with the efficiency calculations by converting wet weights of animals, measured at regular intervals during the experiment, to dry weights and assigning standard caloric values, calculated by Kleiber (1961), to the weights of protein (5.7 Kcal/g), fat (9.5 Kcal/g) and carbohydrate (4.0 Kcal/g). In this experiment I calculated the dry weight of eight fish prior to the beginning of feeding and determined the quantity of water, protein, fat and carbohydrate. I weighed the fish during the experiment and calculated the dry weight and the quantity of water, protein, fat

TABLE 1.—*Rations and growth of winter flounder fed bivalve siphons at three temperatures and two salinities*

Fish no.	Duration days	Temperature (°C) / Salinity (‰)	Fish weight (g) initial	final	avg.[a]	Total food eaten (g)	Daily ration (mg)	Ration ÷ body wt. (%)	Daily growth (mg)	Growth ÷ body wt. (%)	(K_1) Daily growth ÷ daily ration % by wet wt.	(K_1) Daily growth ÷ daily ration % dry wt. converted to calories[b]
1	27	20/20	42.9	40.8	43.4	6.772	251	0.58	–78	–0.18	-31.1	
2	27	20/20	41.0	40.9	40.1	26.262	973	2.43	–4	–0.01	–0.4	
3	34	20/30	46.0	36.7	40.9	6.550	193	0.47	–247	–0.67	-142.0	
4	17	20/30	40.6	40.2	41.4	11.689	688	1.66	–24	–0.06	–3.5	
5	17	16/30	45.3	52.6	48.2	26.566	1,563	3.24	429	0.89	27.4	36.8
6	34	16/20	55.6	60.9	59.4	38.016	1,118	1.88	156	0.26	13.9	18.7
7	34	16/20	69.1	75.6	73.9	62.441	1,837	2.49	191	0.26	10.4	13.9
8	34	12/20	95.4	104.5	99.9	70.911	2,088	2.09	268	0.27	12.8	17.2
9	27	12/20	70.8	76.3	75.7	38.840	1,439	1.90	204	0.27	14.2	19.0

[a] The average weight does not always fall in the range because the fish gained weight and lost weight during the weekly weighing periods.
[b] The caloric conversion was done by changing the food and fish tissue to their respective dry weights. These values were then converted to calories based on the findings presented in Table 2.

and carbohydrate of the remaining nine fish at the end of the experiment.

Since clam siphons were known to be a preferred food of winter flounder (Frame, 1972), I decided to feed the experimental animals on chopped siphons of the soft clam, *Mya arenaria.* The quantity of water, protein, fat, and carbohydrate in siphon tissue was determined prior to the feeding experiment so that arithmetic adjustments could be made for dry weight and caloric value. During the experiment all fish were fed continuously throughout each day. At the end of each day I weighed the unconsumed food and attributed to fish consumption the difference in weight between the provided and uneaten food.

On the basis of my earlier findings of seasonal conditions in the Weweantic estuary, Wareham, Massachusetts and laboratory experiments on respiration rates of young flounder that resided in the estuary, I elected to keep the fish under estuarine-like conditions during the experiment (Frame, 1973). The experiment (Frame, 1972) was designed to test 16 fish in separate 5-liter aquaria at four temperatures (12, 16, 20 and 24 C) and two salinities (20 and 30‰)-two fish per regime. Fish were permitted to adjust to the temperature at the rate of 2 C per day and at salinities of 20 and 30‰. I can report the results for only nine fish since seven died early in the experiment.

I performed the experiments at the National Marine Fisheries Service Laboratory in Woods Hole, Massachusetts, during April and May, 1971. Age I fish weighing 40–100 g captured in the Weweantic estuary were confined in large wooden tanks supplied with a constant flow of sea water at ambient temperature and salinity (5 C and 32‰). They were allowed to adjust to the temperature and salinity for 1 week without food.

ANALYSIS AND CONCLUSIONS

Conversion efficiencies (K_1) based on dry weight of food and fish tissue converted to calories, ranged from 13.9% to 36.8% and averaged 21.1% (Table 1). Excluding fish number 5 which had a disproportionately high efficiency, K_1 averaged 17.2%. Efficiency values compared favorably with those of *Limanda yokohamae*—15.8% to 21.8% (Hatanaka, Kosaka, and Sato, 1956) but were considerably lower than those of *Pleuronectes platessa*—21% to 37% (Edwards, Finlayson, and Steele, 1969) and *Limanda limanda*—about 25% to 45% (Pandian, 1970).

All four fish held at 20 C lost weight (Table 1). The average daily consumption rates ranged from 193 to 973 mg/day and weight losses ranged from 4 to 247 mg/day. There was close correlation (r = 0.82) between weight loss and food consumption (adjusted by the initial weight). Temperature rather than salinity appears to have caused stress conditions, although metabolic factors such as lipid synthesis and protein loss may have masked the effects of salinity. Temperatures that are elevated beyond the seasonal limits, in this case 16 C (Frame, 1972), without allow-

TABLE 2.—*Mean and range of chemical constituents in siphons of the soft shell clam and young winter flounder*

Tissue	Dry weight (g)	Water (%)	Dry weight (%) Protein	Fat	Carbohydrate	Ash	Kcal/g dry weight
Clam siphons 3 samples (8 bivalves each)		80.0 79.6–80.8	59.0 57.4–60.4	1.7 1.6–1.8	0.20 0.20	39.2 37.6–40.8	3.533 3.4–3.6
8 fish prior to feeding	4.5–12.5	79.0 78.7–79.8	69.0 66.0–71.1	4.2 2.6–7.2	0.18 0.1–0.3	26.7 23.3–31.0	4.339 4.1–4.6
5 fish following feeding (nos. 5–9)	11.9–23.6	77.7 77.4–78.2	69.5 67.6–71.8	2.9 1.6–3.6	0.46 0.4–0.6	27.2 26.0–28.8	4.255 4.1–4.4

ing time for compensation create metabolic disturbances (Precht, 1958). Roberts (1964) found that an increase in temperature at the rate of 2.5 C/3 days was too rapid to permit acclimation, and that an increase in temperature at the rate of 2.5 C/2 weeks was necessary for complete acclimation.

The five fish held at 12 C and 16 C gained weight (Table 1). Excluding one fish held in 30‰ salinity, they had an average growth rate of 6.1 g/month which is in close agreement with flounder taken from the Weweantic estuary during April and May (Frame, 1972). Although the single specimen that survived the 30‰ salinity appeared to grow twice as fast as the other fish, the increase in weight actually resulted from intestinal fill following a 1-week starvation period in the holding tank. This fish survived only 17 days. Fish held up to 5 weeks required about 3 weeks for growth to stabilize.

During the experiment, the relative amounts of proteins, fats, and carbohydrates in the tissues of fish that gained weight changed (Table 2). The percentage of fat decreased by 1.3%, while carbohydrate and protein increased by 0.28% and 0.5%, respectively. These changes resulted in an average decrease of 84 cal/dry weight, most of which was caused by the decrease in fat content. Fat is variable in winter flounder (Brooke, Ravesi, and Steinberg, 1962) and since it has a high caloric value (9.5 Kcal/g dry weight) small changes have a major effect on the animal's energy content.

Imposing an unseasonal temperature-salinity regime on Age I flounder may be fatal. All four fish held at 24 C, one at 16 C and 30‰ salinity, and two at 12 C and 30‰ salinity, died. With the exception of one fish that survived at 20 C and 30‰ salinity, but which consumed the least food and lost the most weight, all fish held at 30‰ died during the experiment (Table 1). The fish held in 20‰ salinity at 12, 16, and 20 C survived. In the Weweantic estuary, where I captured the fish, the temperature increased from 5 C in late March to 12 C in late April and salinities ranged from 10 to 25‰. In late May, the temperature was 16 C and the salinities ranged from 15 to 25‰. Although young flounder were found throughout the estuary in April and May, they appeared to be concentrated at the mouth in July and August when temperatures averaged 25 C and salinity 28–31‰. During these summer months inside the estuary the salinity ranged from 16 to 28‰ and temperatures approached 29.5 C. Even though lower salinity decreases their metabolic rate by as much as 50% (Frame, 1973), flounder survival is apparently controlled by their ability to move gradually into favorable temperature-salinity environments.

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