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# INFLUENCE OF DIET AND TEMPERATURE ON FOOD CONSUMPTION AND GROWTH BY YELLOW PERCH, WITH SUPPLEMENTAL OBSERVATIONS ON THE BLUEGILL [1]

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## ABSTRACT

A series of 16 experiments were performed in aquaria on the feeding habits and growth of juvenile yellow perch in relation to size of ration (no food, to excess food), type of food (fish, mayfly nymphs, redworms) and temperature (11.0 to 27.8 C). Two additional experiments were conducted with juvenile bluegills. Growth was regressed against ration to determine the amount of food required for maintenance of body tissues (growth = 0).

I found that maintenance ration, appetite and growth of perch varied with temperature, being somewhat optimal at about 23 C. At this temperature, perch ate more food and grew more rapidly than did bluegills. However, perch required a fish meal of 2.0% of their body weight per day for maintenance, whereas the bluegill needed only 1.3%. Perch grew best on a diet of fish and poorest on a diet of redworms.

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## Introduction

Since 1964, extensive field studies have been conducted on natural and experimental populations of yellow perch (*Perca flavescens*) in Michigan (Schneider, 1971, 1972 1973a, 1973b; Laarman and Schneider, 1972). During these studies it was noted that the food habits of perch were diverse, that perch appeared to occupy most of the available niches, and that perch predation was depleting the benthic macroinvertebrates. Yet the standing crops of perch in experimental populations where they were the only fish present seemed relatively low compared to single-species bluegill populations or to fish populations with many species. For example, Jewett Lake supported 100 pounds per acre of bluegills (*Lepomis macrochirus*), yellow perch, pumpkinseed (*Lepomis gibbosus*), largemouth bass (*Micropterus salmoides*) and other fish; 93 pounds per acre of bluegills alone; but only 62 pounds per acre of yellow perch alone (Schneider, 1973c, and unpublished data of M. Patriarche).

Although it has long been recognized that no two species occupy identical niches, the discrepancy in standing crops was larger than anticipated. One possible explanation is that yellow perch may require more food for the maintenance of body tissues than do bluegills or other warmwater fish. Consequently, in lakes with a limited supply of fish food, the yellow perch would expend more food for maintenance, use less food for growth, and the total biomass of perch would be lower than of other fish.

Moore (1941) reported that the basal food requirement of yellow perch was much higher than that of bluegill or green sunfish (*Lepomis cyanellus*). His data are of limited value, however, because the species differed in size, and an unnatural food--beef muscle--was used. In studies summarized by Winberg (1956), the routine metabolic rate of the European perch (*Perca fluviatilis*) was similar to that of other fish. Since the European and yellow perches are so closely related, I judge that the metabolic rate of the yellow perch does not differ from that of other fish. The bluegill was not included in that comparison by Winberg, however, and Moss and Scott (1961) reported that the metabolic rate of bluegill was lower than either largemouth bass or channel catfish (*Ictalurus punctatus*).

A series of laboratory experiments were conducted to obtain more information on the feeding and growth of yellow perch. The objectives were to: (1) compare the growth of perch on different foods, (2) relate growth of perch to temperature, and (3) compare the amount of food required for maintenance by bluegill and yellow perch.

## Methods

Sixteen experiments (numbered I-XVII, excluding V) were conducted with yellow perch and two with bluegill (numbered I and II) between September 9, 1969 and August 22, 1971 (Table 1). Perch ranged from 5.2 to 23.7 g in weight; bluegills from 8.1 to 21.6 g. Temperature was regulated within the range of 9.4 to 30.6 C.

Illumination was provided by fluorescent fixtures which operated in phase with natural lighting.

Perch and bluegills were seined periodically from Sugarloaf Lake, Washtenaw County, with the exception of one group of slow-growing perch from Cassidy Lake, Washtenaw County. In experiment II, the feeding and growth of the "stunted" perch from Cassidy Lake were compared with the feeding and growth of "normal" perch from Sugarloaf Lake. No difference was found between these two stocks of perch, so the data have been pooled.

Perch and bluegills were held in large tanks or aquaria and fed various live foods while being acclimated to laboratory conditions. The greatest difficulty encountered in this study was in overcoming the fright of the perch so they would begin to feed. Also, during the summer months, mortality was often high during both the acclimation and experimental phases of the study. When enough fish (7-24) had begun to feed, usually after a period of two or more weeks, an experiment was begun. Each fish was blotted dry, wrapped in aluminum foil, weighed on a balance sensitive to ten-thousandths of a gram, then placed in a 10-gallon aquarium filled with aged Ann Arbor tap water. For 28 days some fish were starved, others received all they wanted to eat (excess food present at all times), and third and fourth groups were fed at intermediate rates based on a percentage of their body weight. Fish were fed daily, but not on weekends; they were supplied with extra food on Friday and Monday. Food which was not eaten after a day or two, or by the end of the experiment, was subtracted from the amount of food given.

All fish were reweighed at the end of the experiment to determine the amount of growth. Some of the perch, and all of the bluegills, were sacrificed for an analysis of their mosture content. Growth and ration of perch have been expressed in terms of wet weight. Growth and ration of bluegill have been expressed in terms of both wet and dry weight. The average water content was 77.6% for perch and 78.0% for bluegills. Generally, starved fish contained more water than did well-fed fish.

Specific growth (percentage change in weight per day) and specific ration (percentage of body weight per day) were calculated for each experimental fish from the equations:

$$\text{Specific growth} = \frac{\log_e W_2 - \log_e W_1 \times 100}{\text{Days}}$$

$$\text{Specific ration} = \frac{\text{Food}}{\overline{W} \times \text{days}} \times 100$$

Where: $W_1$ = initial weight of fish in grams

$W_2$ = final weight of fish in grams

$\overline{W}$ = geometric mean weight of fish in grams*

$\Sigma$food = total food eaten in grams

days = 28 in most experiments

For analysis of the results, specific growth was regressed against ration by the method of least squares. The maintenance ration was defined as the amount of food needed to maintain body weight (growth = 0).

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* The geometric mean, rather than the arithmetic mean was used, since growth rate is exponential.

Perch were fed redworms (Helodrilus foetidus) in experiments I and II and nymphs of the mayfly Hexagenia in experiment IV. Fathead minnows (Pimephales promelas) and occasionally, small green sunfish (Lepomis cyanellus) were the food organisms in the 13 other experiments with perch and in the two experiments with bluegills. The moisture content of redworms, mayflies, and prey fish averaged 82.5%, 86.4%, and 84.8%, respectively.

Ideally, these experiments would have been performed concurrently, so that seasonal changes in growth hormones and problems of acclimatizing the experimental fish could have been factored out easily. Because of limited facilities, however, the experiments had to be conducted sequentially; consequently, the task of interpreting the results becomes more difficult.

## Results

The effect of food type (experiments I-IV) on growth of perch may be seen in Figure 1. Note that the perch which were starved, in experiment I (Fig. IA), lost an unusually large amount of weight, and that their points were excluded when the regression line was fit. Clearly, fish were superior to mayflies or worms as food. The amount of food required for maintenance of body tissue was 2.0% per day on a diet of fish, 3.1% per day on mayflies, and 5.0% per day on worms. These differences were statistically significant at the 95% confidence level. Perch which were fed excess amounts of worms consumed an average of 6.6% of their body weight per day, but grew very little (specific growth = 0.25). Perch which were fed excess amounts of fish ate only slightly more food, 7.6% per day, yet grew much more (specific growth = 1.95). Perch were not offered all the mayflies they wanted to eat; however, they readily ate a ration of 6.2% and grew at an intermediate rate (specific growth = 0.80). Food conversion rates (grams gained per gram of food) on the highest rations were 4% for worms, 12% for mayflies, and 26% for fish.

The next aspect of perch feeding to be studied was the effect of temperature. Since experiments were conducted at various times of the year, the possibility of seasonal effects must be considered at the same time. These data are illustrated in figures 1C, 2-4 and are summarized in Table 2.

Seasonal effects were not clear-cut. The results of experiments IX, XII, XIII, and XVII were similar, even though these tests were performed over three seasons (late July through late February, Fig. 3A). Also, the results of experiment VII (spring) and experiment XI (early winter) fell on the same line (Fig. 2B), although perch in the spring experiment had a better appetite. On the other hand, for a group of experiments at room temperatures (19.9-22.9 C) there was considerable variation in the results, largely unexplained, which may be linked to season but was probably due to abnormal behavior by the perch (Figs. 1C, 4A, 4B). The fall experiment (III) gave results consistent with experiments at other temperatures and is considered to be the best. In the summer experiments (VIII, XV, XVI) maintenance ration appeared to be slightly higher (2.4% compared to 2.0%), and the appetite of perch on excess diets was relatively poor (4.9% compared to 7.3%). Perch required an extremely large amount of food (3.9%) for maintenance in the late winter experiment (XIV), but they had a good appetite (excess ration of 7.7%). While conducting the experiments in summer and late winter, which produced the unusual results, I observed that the perch were nervous and behaved strangely in other respects. Mortality was a problem also. Apparently these perch had a higher rate of metabolism than perch in the other experiments and, therefore, they required more food for maintenance. Consequently the results of experiments VIII, XV, XIV and XVI will be excluded from further discussion.

The maintenance ration of perch was lowest (1.2%) at the lowest temperature studied (10.0 C), and highest (3.0%) at the highest temperature studied (26.8 C). Over the broad range in between (15.6 to 25.0 C), maintenance ration was about 2%. The efficiency with which perch on excess diets converted fish into growth was not related to temperature. The highest conversion rate, 26%, occurred at 22.9 C (experiment III); in all other experiments food conversion rates varied from 13 to 18%. Perch had the best appetite (7-8%) at temperatures of 21-25 C. These data suggest that temperature of approximately 23 C may be optimal for the feeding and growth of perch.

Results of winter and summer experiments with bluegills have been pooled because they were similar (Fig. 5). The relationship between ration and growth of bluegill was curvilinear, rather than linear as was true for perch. Wet rations of 4-5% produced the maximum growth rate of 0.8% per day. On a dry weight basis, rations of 3.0-3.5% produced a growth rate of 1% per day. Food conversion rate was 20% on the basis of wet weight, and 29% on the basis of dry weight.

Compared to the yellow perch (experiment III), the bluegill had a lower maintenance ration (1.3% per day compared to 2.0% per day), a smaller appetite on excess diets (rations of 4.3% per day compared to 7.3% per day), and grew less (maximum of 0.8% per day compared to 1.8% per day). Food conversion coefficients were similar--26% for the perch and 20% for the bluegill. The major difference of ecological importance between the two species was the bluegill's ability to expend less energy on maintenance and channel more energy into growth when food is in limited supply. On a diet of 2% per day, yellow perch would not grow (and in some experiments even lost weight), while bluegill would grow at 0.35% per day.

## Discussion

Only three other studies, each conducted at about 20 C, have been made on the feeding and growth of yellow perch. Moore (1941) fed raw, lean, beef to small (2-4 g) perch. He estimated their basal food requirement at 3.3% per day and their food conversion rate at 25%--similar to the highest levels I observed. Keast and Welsh (1968) estimated the amount of food eaten by perch in a lake at 2% per day, from diurnal changes in the amount of food present in stomachs. Their study was made in early summer when the perch were presumed to be feeding extensively and growing rapidly; however, my laboratory data, for perch of the same size, indicate that no growth would occur on a 2% ration. Possibly the estimate of Keast and Welsh was not typical of wild perch at that time of year because it was based on only two 24-hour collections. Pearse and Achtenberg (1921) reported that perch in natural waters consume about 7% of their weight per day--a figure which corresponds to the rations selected by perch in my aquaria.

The European perch appears to be more efficient in food conversion than the yellow perch. For fish of similar size, Ivanova (1968) reported an annual conversion efficiency of 28% for European perch. Ivanova did not fully describe his methodology, but apparently this figure is a weighted average based on a series of laboratory experiments which simulated the thermal changes in Rybinski Reservoir during the course of a year. A comparable average for the yellow perch would be about 15-20% based on my laboratory data. For adult European perch, Ivanova estimated that 13% of their food (probably fish) was converted into new tissue. This figure is comparable, on a wet weight basis, to the figure of 15% (on a diet of earthworms) which I calculated from the data of Birkett (1969). Birkett's perch (adult) selected a small ration of 1.8% per day and used only about 0.5% of this for maintenance.

The yellow perch appears to be less efficient than several other species of warmwater fish. Ivanova (1968) found that juvenile European pike-perch (L. lucioperca) converted 71%, and adults 20%, of their food into growth. Juvenile northern pike (Esox lucius) incorporated 40%, and adult pike 10%, of their food. Johnson (1966) obtained a similar conversion rate for small pike, 44%, and estimated maintenance to be relatively low, 0.65% per day at 12 C. Lagler and Latta (1954), Lagler and Kruse (1953), and Williams (1959) reported efficiencies of 22-28% for rock bass (Ambloplites rupestris), large-mouth bass, and smallmouth bass (Micropterus dolomieui) when fed fish. The highest conversion rate which I found for yellow perch falls in this range. Thompson's (1941) estimate for largemouth bass was higher, 40%. Prather (1950), working at warmer temperatures (27-32 C), obtained conversion rates of 41% for largemouth bass smaller than 56 g, and 25% for bass of 56-170 g.

Several studies have been made on the feeding and growth of bluegill. Anderson (1959) fed a terrestrial organism, the mealworm (Tenebrio), and a natural food organism, the midge (Tendipes), to bluegills under laboratory conditions similar to mine. He also fed mealworms to bluegills in cages suspended in a lake. At room temperatures (21-25 C), conversion efficiencies averaged 39% for mealworms and 12% for midges. In my experiments, minnows were converted at a 20% rate. On a dry weight basis, conversion rates were about 29% for all three food types. Unlike my results, the growth of Anderson's bluegills, and also Gerking's (1971), did not level off at high rations. In other studies, Gerking (1971) reported protein conversion rates as high as 39% for 13.9-g bluegills fed mealworms (similar to Anderson's estimate of 33%), Ricker (1949) estimated the wet conversion efficiency of bluegills fed earthworms at about 15%, and Moore (1941) reported conversion rates at 38% on liver and 18% on beef.

Several estimates have been made of the quantity of food which bluegills need at room temperature. The amount of earthworms required for maintenance by bluegills was 1.7-2.5% per day (Ricker, 1949). Their maintenance ration on beef or liver was 1.1% (Moore, 1941), and on a diet of mealworms, about 0.7% (Anderson, 1959). Since mealworms contain less water than minnows (73.4% compared to 84.8%), Anderson's estimate was similar to my figure of 1.3%. Savitz (1969), using the endogenous nitrogen excretion technique, estimated the maintenance ration of small bluegills to be 0.12 mg N per day per gram of bluegill. Gerking (1971) obtained a higher figure--5.1 mg N per day for a 13.9-g bluegill, or 0.36 mg N per day per gram of bluegill--from a feeding experiment with mealworms. For a food organism with a nitrogen to protein ratio of 1:6.25 and a water content of 84.8%, Savitz's estimate of maintenance is equivalent to a wet ration of 0.5% per day and Gerking's to 1.5% per day. Savitz points out that his value is conservative compared to estimates obtained from feeding experiments.

The amount of food which bluegills consumed daily was 4-8% on a diet of worms (Ricker, 1949; and Maloney, 1949, as cited by Anderson, 1959), 4-5% on minnows (this experiment), and 4-8% on mealworms (Anderson, 1959). Midges were eaten at the rate of 20% per day in one of Anderson's experiments. Keast and Welsh (1968) estimated the daily ration of bluegills in a lake at 2.5% from periodic samples of the amount of food in their stomachs.

This review of the relatively sparse, and sometimes conflicting, literature on the feeding and growth of warmwater fishes points up the need for additional study of selected species and also the need for more comparative studies. The available data suggest that the yellow perch may not convert food into flesh as efficiently as other warmwater fish and that the basal food requirement of the yellow perch is higher than that of the bluegill, a species which appears to have a low metabolic rate and requires small amounts of food for maintenance. These observations, when coupled with the relatively low position of the bluegill on the food chain, explain why the bluegill is typically more abundant than yellow perch or other warmwater "sport" fish in suitable natural habitats. For the fisheries manager, the implication of these observations is that the bluegill is the most efficient species at converting the productivity of natural waters into usable production.

This review also reveals that type of food can have a pronounced effect on growth of fish. Generally, earthworms were not utilized so efficiently as other types of foods. Popchenko (1971) states that most aquatic worms are high in nutrients but low in minerals and vitamins, and that a prolonged diet of worms results in a decline in the mineral and hemoglobin content of fish. Among the terrestrial earthworms, the redworm or stinkworm (*Helodrilus foetidus*) is especially poor as a fish food. Some fish refuse to eat this species, and the chemical substance it emits appears to interfere with digestion (Ball and Curry, 1956). In my experiments perch were reluctant to eat redworms, and these worms were not utilized efficiently when consumed.

In two respects the results of my experiments with perch were not as anticipated. First, an optimal temperature for perch was not as evident as expected. Two experiments were conducted in the preferred temperature range of 20-25 C (Ferguson, 1958). In only one experiment was the conversion rate superior to that at other temperatures. Food consumption rates and growth rates were highest in both experiments. Maintenance ration was fairly constant over a broad range of temperatures, and not until the upper lethal limit of 30-32 C (Ferguson, 1958) was approached was there an obvious increase in maintenance cost. Likewise, Kelso (1972) found no well defined optimum temperature for walleye (*Stizostedion vitreum*). Secondly, growth of perch continued to increase linearly as ration increased rather than approaching an asymptote. Similar results have been reported for the bluegill (Anderson, 1959; Gerking, 1971) and for the European perch, plaice (*Pluronectes platessa*), and sole (*Solea vulgaris*) by Birkett, 1969. Some of the data for sculpin (*Cottus perplexus*) and cutthroat trout (*Salmo clarki*) shown by Warren and Davis (1967) also are nearly linear; however, the general pattern among fishes is that food conversion declines at high rations (see Andrews and Stickney, 1972; Thompson, 1941; and reviews by Warren and Davis, 1967; Paloheimo and Dickie, 1966; Kerr, 1971). A linear response would occur if experimental fish were not consuming maximal amounts of food. This was unlikely for my perch and Anderson's bluegills because they were eating rations as high as 13% per day. Perhaps certain species of fish, under certain conditions, simply do not consume more food than they can utilize efficiently.

The interpretation of these, and other similar experiments are clouded by: (1) changes in water or nutrient content of fish (and hence the measure of growth) in response to amount of food; (2) possible effects of such factors as season, hormones, behavior, and previous history on appetite, metabolic rate, and food conversion efficiency; and (3) large variations among individual fish. In the future, improved experimental facilities and designs will be necessary to clarify the effects of these and other factors influencing the growth of fish.

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Table 1. Summary of experiments on food consumption and growth of yellow perch and bluegill

| Experiment number | Date | Number of fish* | Temperature(°C) |  | Initial wt. (g) |  |
|---|---|---|---|---|---|---|
|  |  |  | Mean | Range | Mean | Range |
| Perch | 1969 |  |  |  |  |  |
| I | 9/ 9-11/19 | 11-24 | 22.8 | 21.6-23.3 | 7.1 | 6.6- 8.2 |
| II | 10/22-11/19 | 12 | 24.4 | 23.3-25.6 | 10.6 | 6.4-15.9 |
| III | 11/19-12/16 | 12** | 22.9 | 21.6-24.4 | 11.1 | 8.2-15.6 |
|  | 1970 |  |  |  |  |  |
| IV | 1/15- 2/11 | 12 | 22.8 | 21.6-23.9 | 14.2 | 6.2-23.2 |
| VI | 3/17- 4/14 | 10 | 10.0 | 9.4-11.1 | 11.4 | 5.2-22.9 |
| VII | 5/4 - 5/31 | 7-9 | 15.6 | 14.4-15.6 | 10.6 | 7.9-17.1 |
| VIII | 7/17- 8/3 | 9-12 | 21.6 | 21.1-22.2 | 15.9 | 13.2-23.7 |
| IX | 9/15-10/12 | 9-12 | 26.7 | 23.3-27.8 | 17.4 | 12.6-22.5 |
| X | 10/29-11/24 | 18 | 25.0 | 23.9-25.6 | 15.3 | 5.4-23.6 |
|  | 1970-71 |  |  |  |  |  |
| XI | 12/8 - 1/4 | 13-14 | 15.6 | 14.4-17.2 | 10.9 | 6.8-15.6 |
| XII | 12/16- 1/12 | 7-8 | 27.8 | 27.2-28.3 | 16.8 | 11.0-22.1 |
|  | 1971 |  |  |  |  |  |
| XIII | 1/25- 2/21 | 7-8 | 27.0 | 26.7-27.8 | 18.3 | 14.2-23.6 |
| XIV | 2/2 - 3/7 | 13-14 | 21.2 | 18.3-23.3 | 11.2 | 8.5-16.8 |
| XV | 6/21- 7/19 | 16-21 | 19.9 | 18.9-23.9 | 12.8 | 9.2-19.3 |
| XVI | 7/13- 8/13 | 12 | 22.0 | 20.6-24.4 | 13.9 | 7.5-21.7 |
| XVII | 7/26- 8/22 | 8-10 | 26.2 | 21.6-30.6 | 13.7 | 9.2-17.7 |
| Bluegill | 1970 |  |  |  |  |  |
| I | 7/6- 8/2 | 5-7 | 23.3 | 22.2-24.4 | 16.2 | 8.1-21.1 |
|  | 1970-71 |  |  |  |  |  |
| II | 12/16- 1/13 | 12 | 21.1 | 20.5-22.8 | 13.4 | 8.4-21.6 |

* The smaller figure is the number of fish which survived the experiment and provided useful data; the larger figure is the number of fish which were used at the start of the experiment.

** Includes one fish transferred from experiment X.

Table 2. Effects of temperature and season on growth, food consumption, conversion (all on excess diets), and maintenance ration of yellow perch fed fish

| Temperature ( C) | Season | Experiment number | Maintenance ration (%/day) | Average on excess diet | | |
|---|---|---|---|---|---|---|
| | | | | Consumption (%/day) | Growth (%/day) | Conversion (%) |
| 10.0 | Early spring | VI | 1.2 | 2.5 | 0.466* | 18 |
| 15.6 | Spring, early winter | VII,<br>XI | 2.2 | 4.5 | 0.708 | 15 |
| 22.9 | Late fall | III | 2.0 | 7.3 | 1.853 | 26 |
| 25.0 | Fall | X | 1.9 | 7.2 | 1.409 | 17 |
| 26.8 | Fall-winter, summer | IX, XII<br>XIII, XVII | 3.0 | 6.6 | 0.901 | 13 |

* This group was fed a fixed ration; however the fish appeared to be satiated.

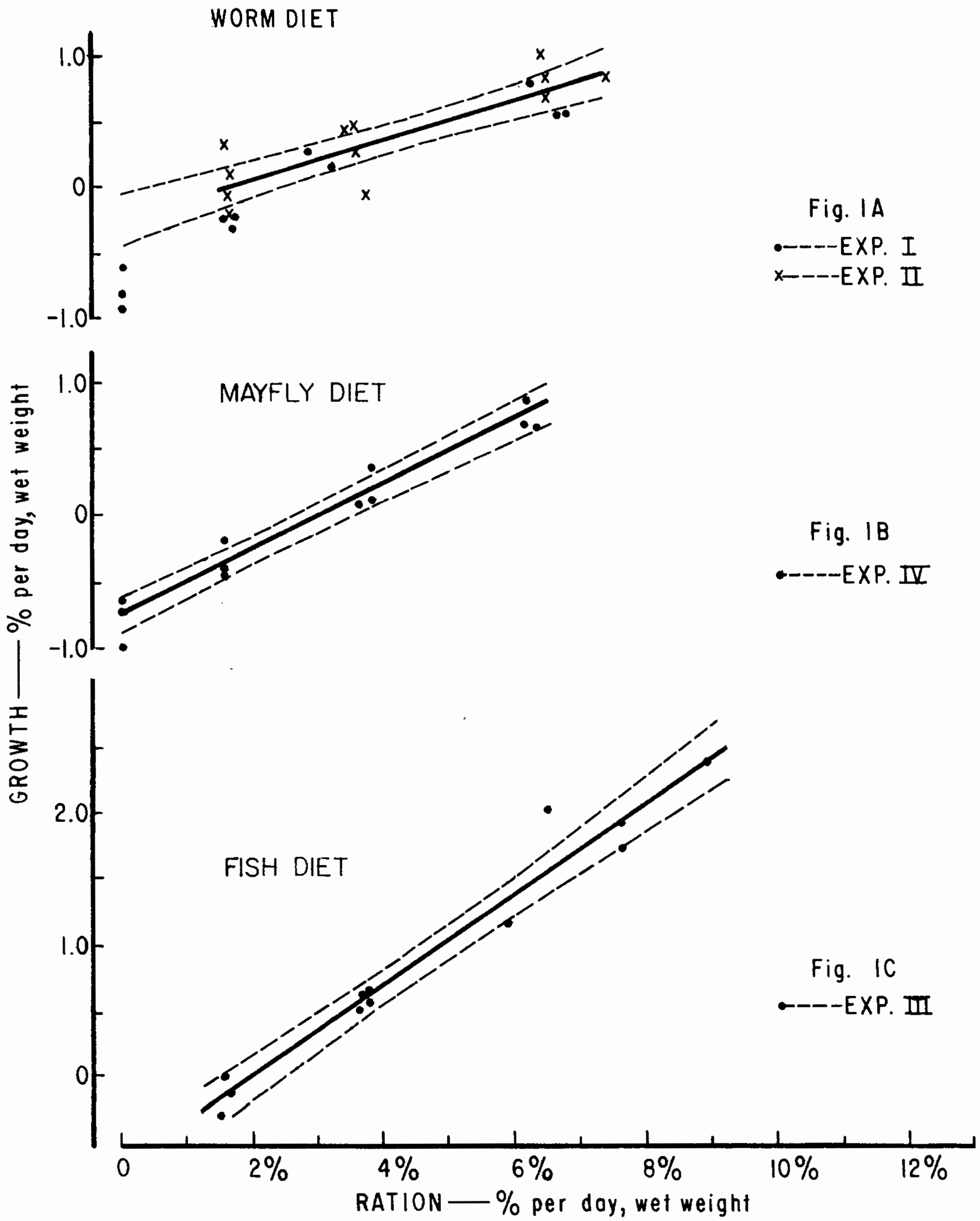

Figure 1. Specific growth of yellow perch on rations of redworms (experiments I and II), mayfly nymphs (experiment IV) and fish (experiment III) at 22.5, 22.8, and 22.9 C, respectively, in the fall of the year.

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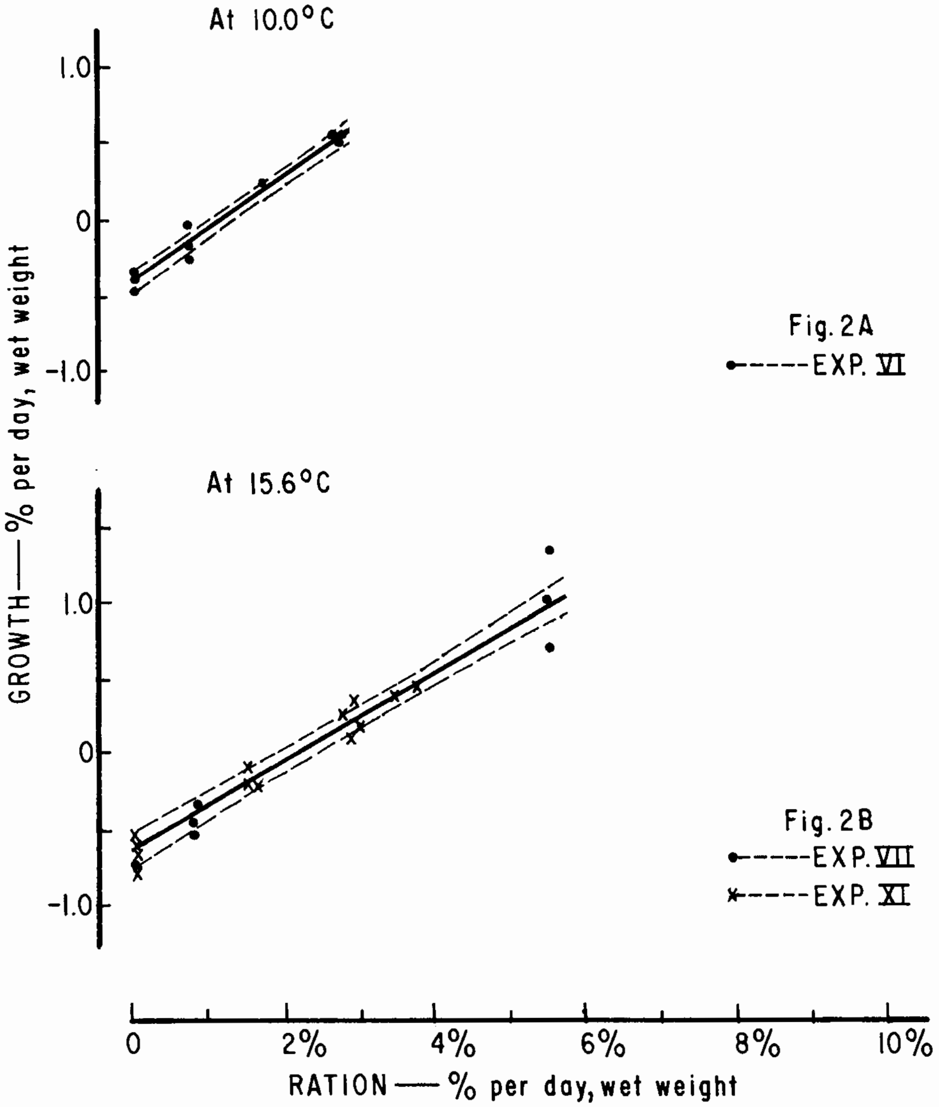

Figure 2. Specific growth of yellow perch on rations of fish at 10.0 C (experiment VI) and 15.6 C (experiments VII and XI) in the fall, early winter, or spring of the year.

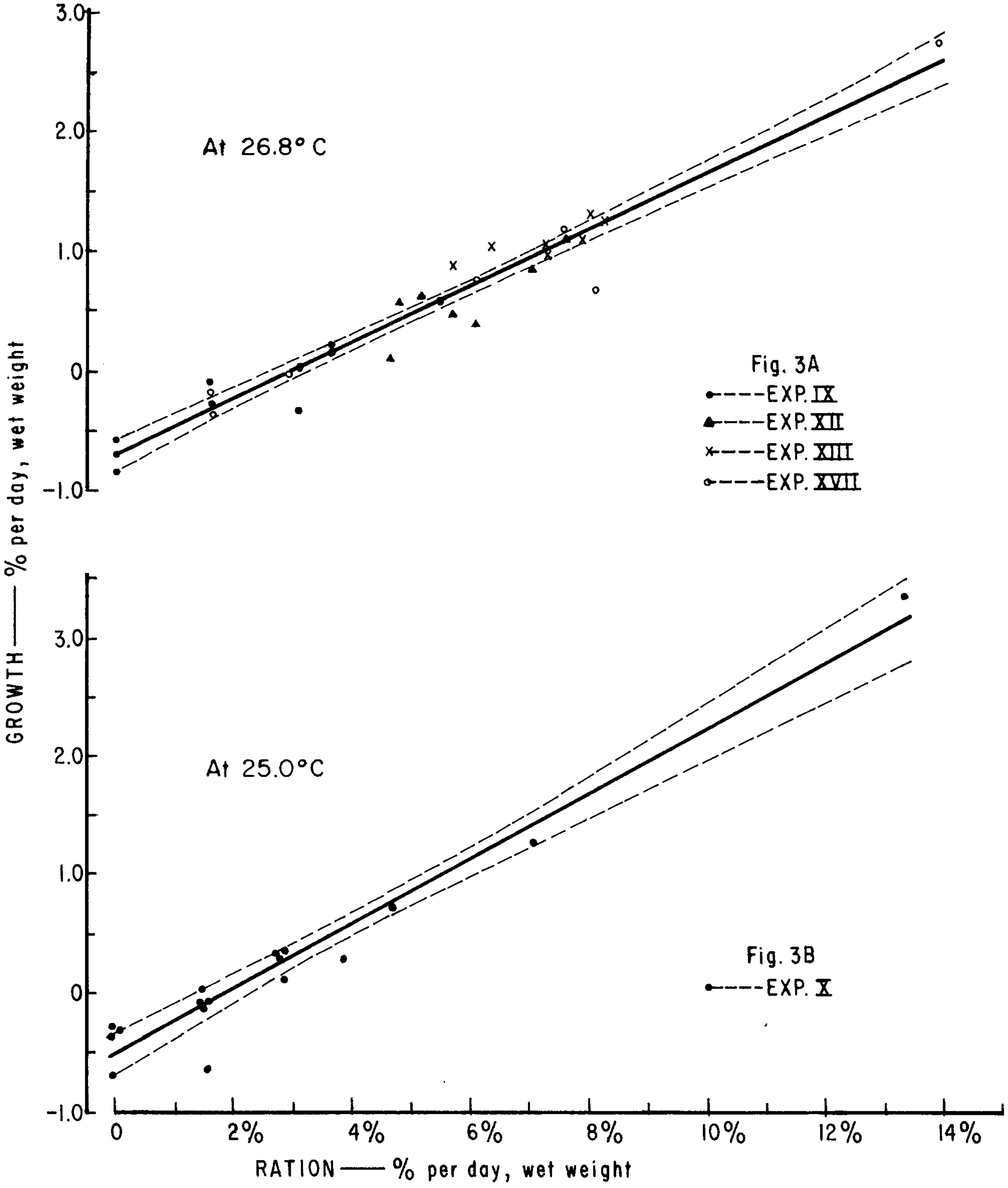

Figure 3. Specific growth of yellow perch on rations of fish at 26.8 C (experiments IX, XII, XIII, XVII) and 25.0 C (experiment X) in the fall, early winter, or spring of the year.

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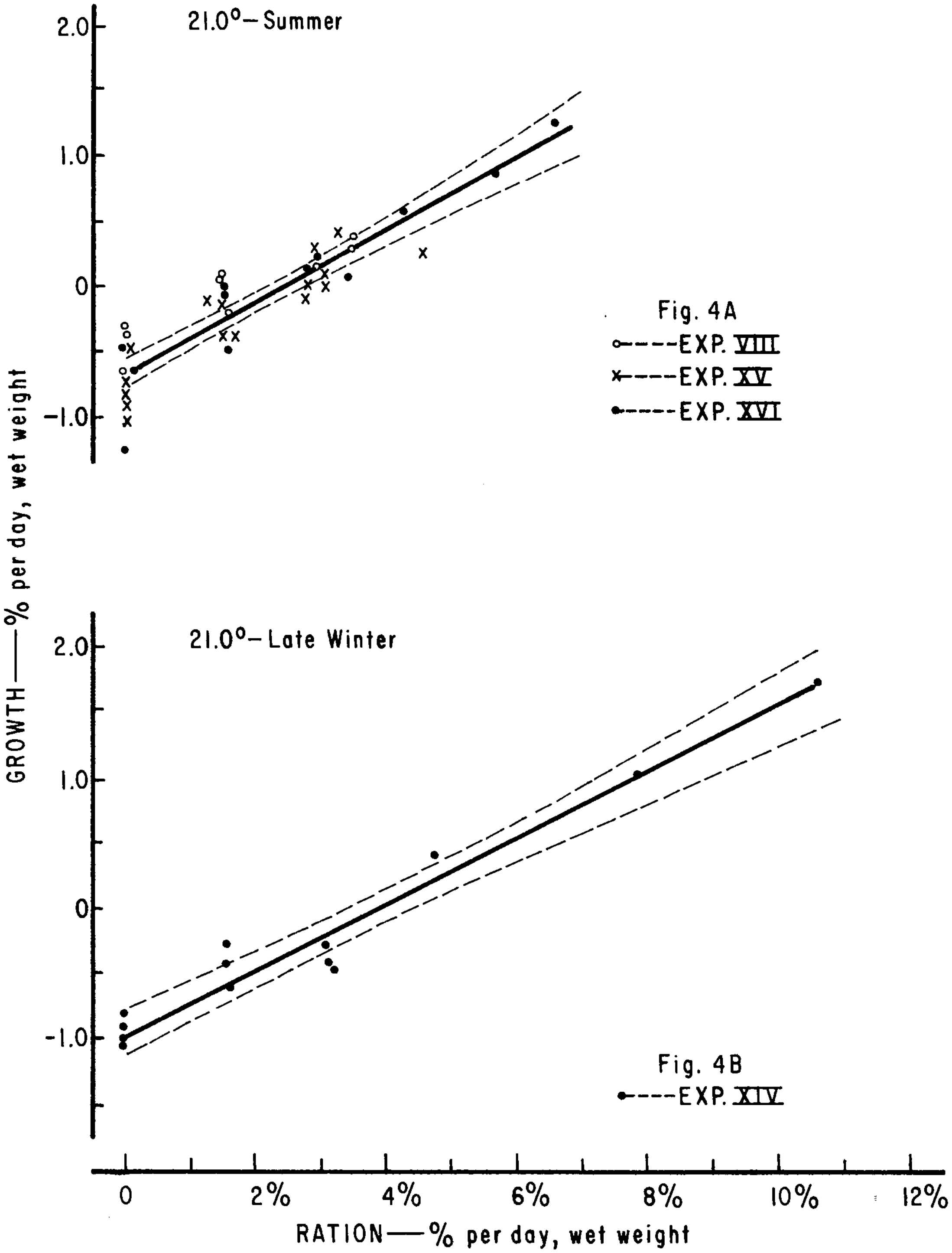

Figure 4. Specific growth of yellow perch on rations of fish at 21 C in the summer (experiments VIII, XV, XVI) and late winter (experiment XIV).

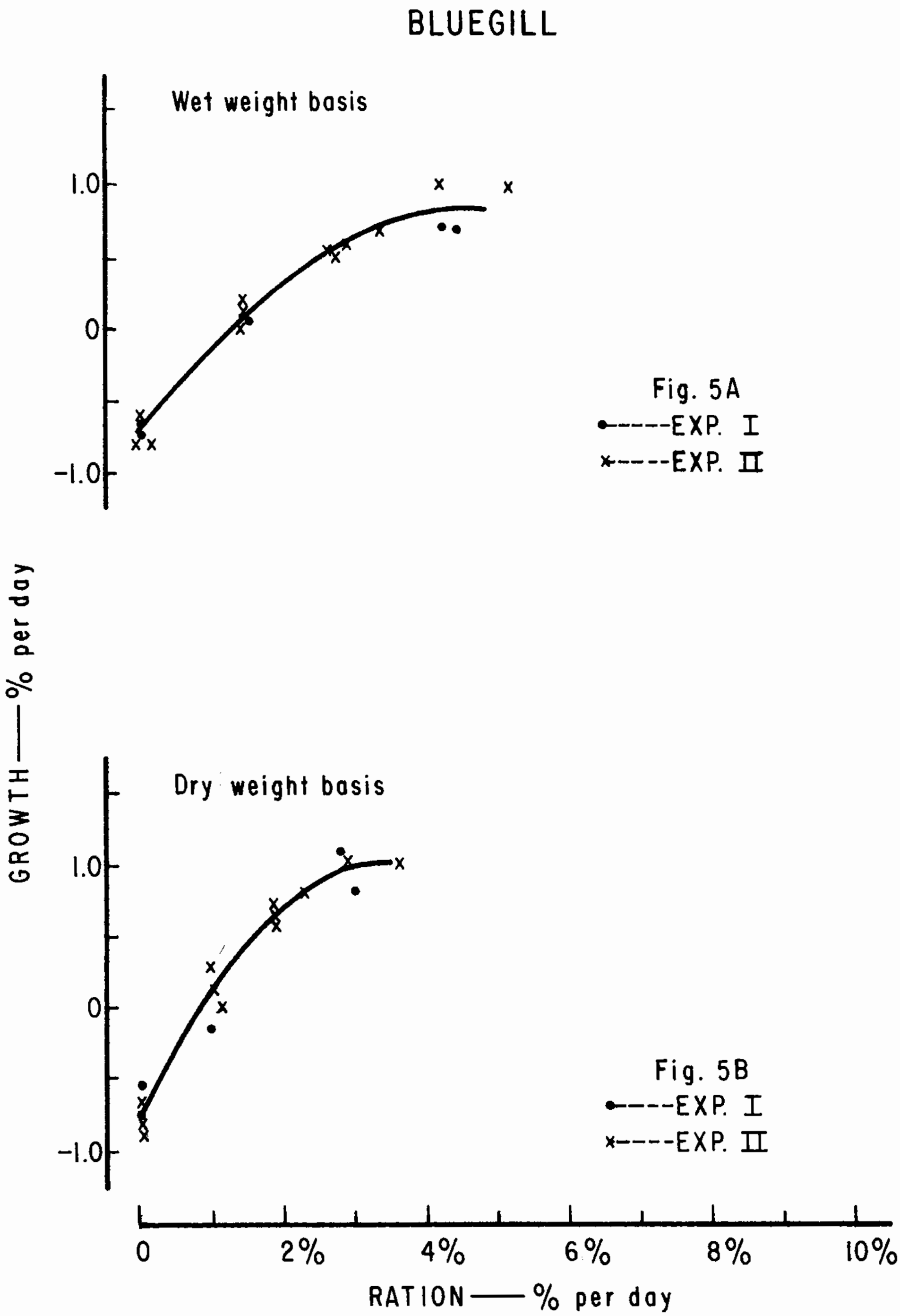

Figure 5. Specific growth of bluegills on rations of fish on a wet (Figure 5A) and dry (Figure 5B) weight basis at 22.2 C in the fall of the year.

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