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Seasonal effects of exposure to temperature and photoperiod regimes on gonad growth and plasma gonadotropin in goldfish (*Carassius auratus*)

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Summary. High temperatures inhibited goldfish (*Carassius auratus*) oogenesis at three different season(fall, winther, spring) in spite of an increase in plasma gonadotropin level. In winther, long photoperiod stimulated gonad growth. When fish were kept at a constant high temperature for 9 consecutive months from September to January, the gonads remained regressive during the first 4 months and then developed normally.

Introduction.

In the northern hemisphere, cyprinid fish spawn in spring when the water temperature reaches its maximum. In several species of cyprinid fish (*Couesius plumbeus* : Ahsan, 1966 ; *Carassius auratus* : Gillet *et al.*, 1977), a sudden rise of temperature in winter can apparently block gametogenesis in laboratory condition. In other species as *Lepomis cyanellus*, an increase of temperature associated with long photoperiod stimulates gonadal development in winter (Kaya and Hasler, 1972). These experiments suggest that temperature and photoperiod interact in the control of gametogenesis. In the present work, we have tried to analyze this phenomenon in the goldfish Endocrinological implications have also been investigated.

Material and methods.

In this experiment, we compared the effects of temperature either during a short 3-month period or over a long period extending from fall to summer. Adult goldfish from natural ponds were maintained :

— in fall from 19 September to 15 January at 20 °C ;
— in winter from 5 January to 6 March at 20 °C ;
— in spring from 15 March to 15 June at 20 °C or 30 °C.

At each period the control group was kept at the corresponding natural seasonal pond temperature (12 °C in fall and spring ; 10 °C in winter). In the long-term experiment, the rearing temperatures were 30 °C. In all cases, two photoperiodic regimes (16L-8D and 8L-16D) were studied.

Thirty fishes, weighing about 50 g each were used in each experimental group. They were kept in 150-liter tanks with the temperature regulated to the nearest 1 °C. During acclimation water temperature was increased by 1.5 °C per day. Photoperiod was controlled by electric clocks. Fish were fed *ad libitum* twice daily with pellets « Aqualim » for carp.

Blood plasma gonadotropin (c-GTH) levels were measured at the end of each experiment and during the acclimation period in spring on 30 fisches. In all cases, blood samples were taken at the onset on the light phase. GTH levels were measured by radioimmunoassay, according to the technique described by Breton *et al.* (1971).

The gonado-somatic index (GSI) was also determined at the end of the experiments on 10 fishes. Results were analysed using one or two-way variance analysis.

Results.

I. *Effects of seasonal adaptation to high temperature.*

a) *GSI* (fig. 1A, B, C).

During fall, high temperature inhibed oogenesis recrudescence. On the contrary in the control group, ovaries which were very small at the beginning of the experiment were significantly ($P < 0.05$) enlarged at the end. Interaction ($P < 0.05$) between photoperiod and temperature were also observed ; growth of ovaries was stimulated at 12 °C under short photoperiod (8L-16D) and at 20 °C under long photoperiod.

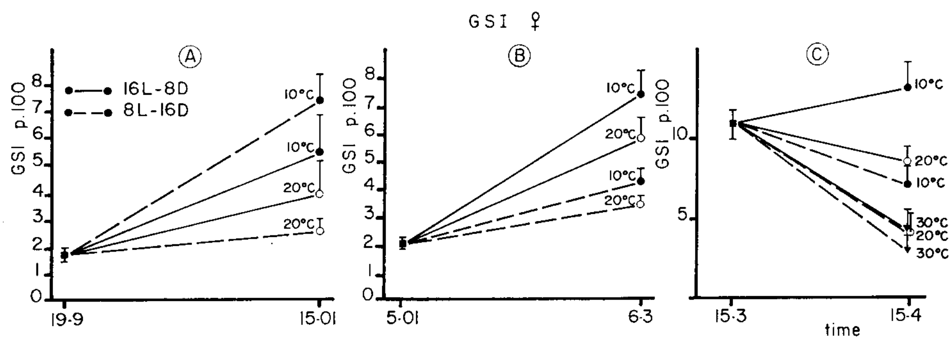

FIG. 1. — *Seasonal effects of adaptation of goldfish to high temperature on gonadosomatic index* (GSI). *a*) in fall ; *b*) in winter ; *c*) in spring.

In winter, the effects of high temperature were similar to those obtained in fall ($P < 0.005$) but there was no interaction between photoperiod and temperature. Long photoperiods strongly stimulated oogenesis whatever the temperature ($P < 0.001$).

In March, maintaining the animals at a warm temperature induced regression of the ovaries ($P < 0.05$) which were well developed at the beginning of the experiment. This regression occurred within one month and was accentuated with short photoperiod ($P < 0.05$).

b) *Gonadotropin secretion* (figs. 2A, B, C).

Seasonal effects of light and temperature. No differences were found between gonadotrophin levels in any of the experiments in reference to the photoperiod. Temperature stimulates plasma c-GTH levels in fall and spring, but there were no effects of this environmental factor in winter.

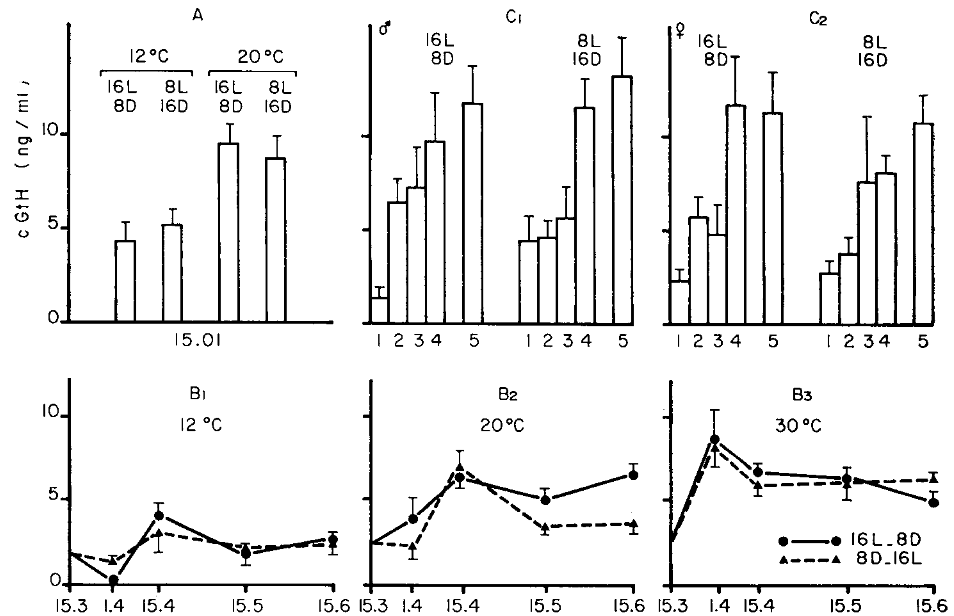

FIG. 2. — *Seasonal effects of adaptation of goldfish to high temperature on plasma gonadotropin levels. a)* in fall ; *b)* in spring ; *c)* effects of acclimation on plasma c-GTH in spring : **1** 15 °C March 18, 2 20 °C March 21, 3 25 °C March 24, 4 30 °C March 27, 5 30 °C April 1.

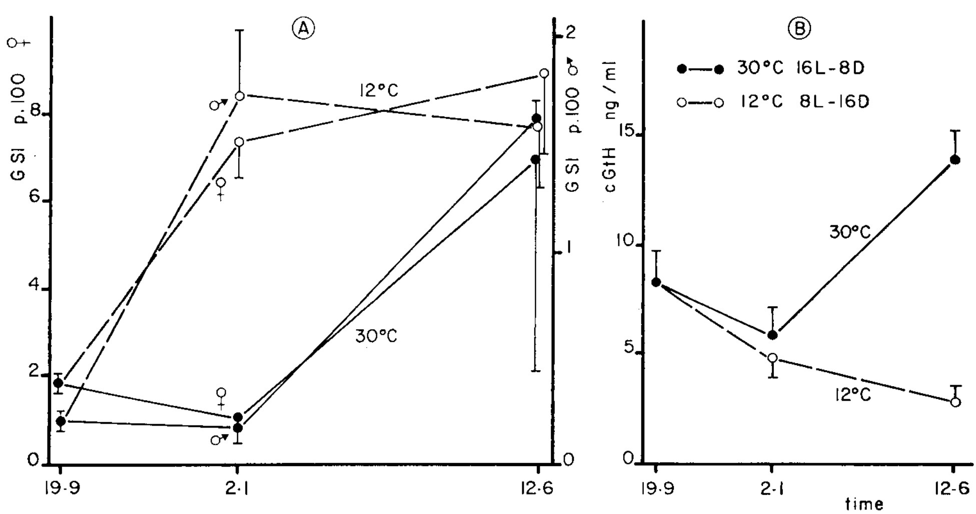

FIG. 3. — *Effects of prolonged exposures to high temperature. a) on GSI ; b) on plasma c-GTH.*

Acclimation effect on GTH secretion. In spring, c-GTH levels increased regularly with the temperature, and independently of photoperiod and sex of the animals.

II. *Effects of prolonged exposure to high temperature* (fig. 3-A, B, C).

In animals maintained at 30 °C, gonads (ovaries and testes) regressed until January and they developed normally from January to June. At this stage, there was no statistical difference between the GSI of these animals and that of the controls maintained at 12 °C during the whole period.

In the control group, the plasma gonadotropin levels remained very low from September to June. At 30 °C, GTH level increased between January and June ($P < 0.01$).

Discussion.

Gonadotropins and temperature. — These results demonstrate that in the goldfish long exposure to high temperature stimulated gonadotropin secretion. Similar results have been obtained in the rainbow trout (*Salmo gairdneri* : Breton and Billard, 1977) and in the tench (*Tinca tinca* : Breton *et al.*, 1975). On the other hand, in the carp (*Cyprinus carpio*), pituitary responsiveness to exogenous releasing-hormone stimulation appears in spring when water temperature increases and is enhanced from April to July (Weil *et al.*, 1975). Thus, the effects of temperature on gonadotropin secretion could be modulated by activation of the hypothalamic-hypophyseal complex for GTH secretion.

Recent work (Peter and Crim, 1978) has demonstrated the existence of nycthemeral GTH secretion cycles in the goldfish. These cycles differ with temperature and photoperiod. In our experiments, blood was sampled every morning at the beginning of the light period. Thus, the absence of photoperiod effect in our experiments indicates that the interaction between light and temperature did not affect GTH secretion at this time of day. Different hours of sampling during the day must be compared in further studies to define this problem.

Gametogenesis and temperature. — Increased GTH secretion was not always correlated with stimulation of gonadal development. In fall and winter, high temperatures inhibited ovary recrudescence. In spring, the same high temperatures induced gonadal regression. Temperature may have a direct action on the gonads by modifying ovary responsiveness to GTH. Nevertheless, the inhibitory action of high temperature on gametogenesis was not irreversible. After a 4-month inhibitory period, animals developed normal gametogenesis. A similar result was reported by Clemens and Reed, (1967). The results can also be compared with those obtained on carp (*Cyprinus carpio* (Gupta, 1975). When animals are acclimated at more than 20 °C as soon as hatching, they develop a total reproductive cycle in hot water after a precocious puberty and rapid growth.

Increasing the photoperiod never balances the inhibitory effects of the high temperature. As described earlier by Fenwick (1970) studying the same species in winter, a long photoperiod strongly stimulates oogenesis. The exact role of photoperiod remains to be defined in relation to temperature conditions. As mentioned by de

Vlaming (1972), both photoperiod and temperature may be important environmental factors in the determinism of the cyprinid reproductive cycle.

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Résumé. Nous avons testé les effets de la température et de la photopériode sur la gamétogenèse du Poisson rouge (*Carassius auratus*) à trois saisons différentes (l'automne, l'hiver et le printemps). Dans tous les cas, les températures élevées inhibent l'ovogenèse malgré une augmentation du taux de gonadotropine plasmatique. Les photopériodes longues stimulent la croissance des gonades en hiver seulement. Lorsque les poissons sont élevés à 30 °C pendant une période prolongée (de septembre à juin), leurs gonades demeurent régressées jusqu'au mois de janvier. Après cette période, les gonades se développent normalement.

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