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Thermal Ecology of two Fresh Water Fishes *Aphanius dispar* and *Gambusia affinis* from Central Saudi Arabia

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ABSTRACT. Temperature selection of two fresh water fishes *Aphanius dispar* (Ruppel 1828) and *Gambusia affinis Holbrooki* (Girard 1859) was investigated in a thermal gradient. One animal at a time was studied in three temperature gradients extending from 6 to 40°C (Low range 6-21°C; Medium range 13-31°C; High range 21-40°C). Most of *A. dispar* selected temperatures between 14-15°C in the low range, 19-22°C in the meduim range and 26-32°C in the high range, while *G. affinis* selected temperatures between 13-20°C in the low range; 22-30°C in the medium range and 22-32°C in the high range. The mean critical thermal maximum (C.T. Max.) for *A. dispar* and *G. affinis* was 38.1°C and 38°C respectively. The mean critical thermal minimum (C.T. Min.) was 4.2°C and 4.4°C for *A. dispar* and *G. affinis*. Both species showed a tolerance to high temperature, but the introduced species, *G. affinis* had a wider range and is better suited to adopt to the desert habitat, and hence could constitute a threat to the endemic species *A. dispar*.

Temperature is a very important factor for aquatic poikilotherms. The high specific heat and thermal conductance of water provide a challenging thermal environment to fishes whose gills function as efficient counter current heat exchangers. Temperature selection plays an important role in escape from predators, spawning, the timing and direction of migration, the maintenance of temperature optimum for metabolic activity (Norris 1963) and may also help in growth, especially when food is limited (Brett 1971). The selected body temperature can change with season (Sullivan and Fisher 1956), as well as with the time of the day (Brett 1971). Little is known of thermal preference and tolerance of the fresh water fishes *A. dispar* and *G. affinis* in the Arabian Desert habitat (Al-Daham *et al.* 1977, Hass 1982, Krupp 1988), though, a large amount of data on the subject is available from similar environments in North America (Brown and Feldmeth 1971, Beitinger and

Fitzpatrick 1979, Cincotta *et al.* 1984, Cincotta and Stauffer 1984, Soltz and Naiman 1981).

Aphanius dispar is the only native freshwater cyprinodont fish. The species is found troughout Arabia (Al-Kahem and Behnke 1983) and the general distribution is between NE Africa and NW India, living in freshwater brackish or marine conditions (Krupp 1983 a). The fish is tolerant to extreme environmental factors (Hass 1982), and its feeding habits allow it to colonise extreme habitats. Although *A. dispar* prefers to feed on mosquito larvae and tolerates extremes of environmental factors, yet it is a less competent fit against the invasion of the introduced species *G. affinis* (Ataur-Rahim 1981, Hass 1982 and Al-Akel *et al.* 1987). The latter fish was introduced to Arabia prior to 1930 (Khalil 1930) for the purpose of malaria control. Since then it has successfully colonised many of the fresh water habitats of the Arabian Peninsula. Competition is presumed between the two species since they occupy the same habitat, and both feed on mosquito larvae. Krupp (1983 b) reported that *G. affinis* does not seem to have any negative effect on the local ichthyofauna of Syria, but replacement of the native species by *G.affinis* has been reported in many regions of the world (Schoenherr 1981, Arthington 1989, Hurlburt *et al.* 1972, Saadati 1977). In Arabia, no study has been done to investigate the possible competition between the two species. In the present study an attempt was made to investigate the thermal preference and tolerance of the two species under the laboratory conditions.

Materials and Methods

Gambusia affinis and *Aphanius dispar* were collected from Al-Kharj irrigation canals, 80 Km south east of Riyadh, and were maintained in well aerated aquaria, at a constant temperature of 21°C. The photoperiod was maintained in the room at LD 12: 12. The thermal preferance of the two species was determined in a horizontal metal thermal gradient, 100 cm in length, 25 cm in width and 25 cm in height, with a water depth of 20 cm (Fig.1). it was divided into four chambers using plexiglass sheets, in such a way that the upper 2/3 of the water body was divided while the bottom was open from end to end. In each of the gradient chambers three thermometers were attached with their bulbs at three different levels. The two ends of the gradient were surrounded with water-filled outer enclosures, duly insulated. At one end an immersion cooling coil from a refrigerant machine was inserted, and at the other end an immersion circulation heater coil with an adjustable thermostat was arranged. When this apparatus was switched into operation a temporarily stable horizontal gradient with veritcal layer gradients in each of the divided chambers was achieved.

Trials were conducted in three different ecologically valid temperature ranges of 6-21°C, 13-31°C and 21-40°C, respectively. For each of the two species a set of 36 fishes (male and female) were tested (*A. dispar* 21-54 mm SL; *G. affinis* 22-55 mm SL). One individual at a time was introduced smoothly into the gradient using a fine mesh net, taking care not to disturb the maintained vertical gradients. After introduction, the fish was allowed to explore the gradient for 10 minutes. To move from one chamber to the other the fishes had to swim under the plexiglass partitions. In each trial movements of the fish were visually recorded, corresponding to the position of the fish with the thermometer reading that water layer. Each trial lasted for 30 minutes, in which the position of the fish was recorded at 1/2 minute intervals, by following the movement of the animal. A pause or a brief halt was registered as a reading. Any sudden burst towards the surface for breathing, or a fast dash was ignored.

A gradually heated container was used to delineate the Critical Thermal Maximum (C.T.Max.) and an approach of slow, even and gradual cooling of the test container was made to determine the Critical Thermal Minimum (C.T.Min.). A set of 20 seperate animals of each species were used. When the water temperature was nearly equal to that of room temperature (23°C) one or more fishes were introduced into the test apparatus and immediate observations were made syncronizing the reactions of the fish to the gradually warming or cooling medium. The C.T.Max. and C.T.Min. were determined when the fish showed an escape behaviour with rapid swimming and finally loosing equilibrium by turning upright on the belly. Recommendations made by Becker and Genoway (1979) were followed in determining thermal tolerance.

statistical analysis of the data was performed by using the Non-parametric distribution free sign test (Conover 1980).

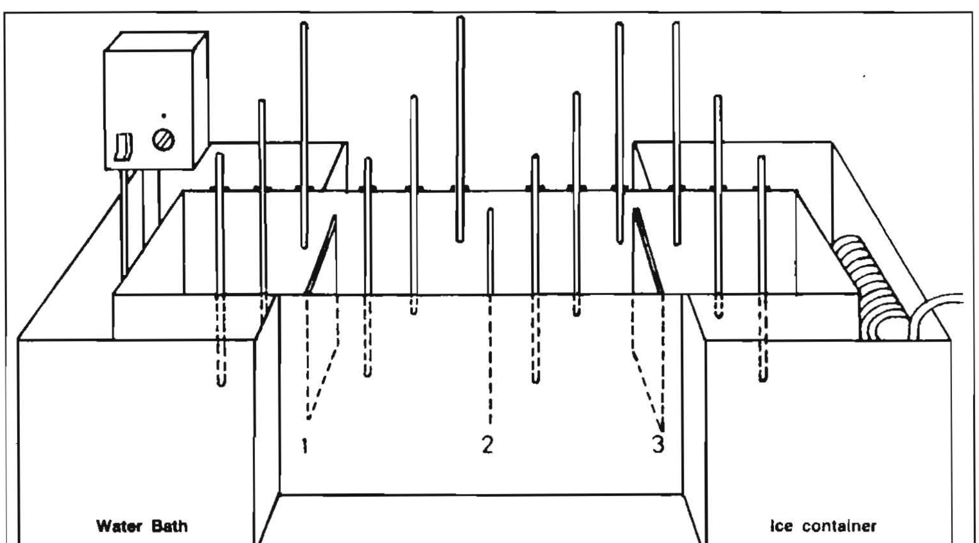


Fig. 1. Latero-frontal view of the thermal gradient (length 100 cms, width 25 cms, height 25 cms). The figure shows the external water bath and the ice container for heating and cooling and the three sheets of plexiglass (1,2,3) which divide the gradient into four chambers. Three thermometers were used in each chamber to indicate vertical and horizontal temperatures.

Results

Gambusia affinis was more active in the gradient than *A. dispar.* Distinctive preferential thermal values in each of the ranges was observed in *A. dispar*, contrary to *G. affinis* which did not show a definite preference at any of the ranges given. It was also noted that the selected values by *A. dispar* were in the middle of the temperature range, especially in low and medium ranges, while most of *G. affinis* selected temperatures were towards the upper values of these ranges (Fig. 2). The mean selected values in the thermal gradient for both the species are shown in Table. 1. Sign test at 5% level of significance between them proved to be significant only in the 21-40°C range and insignificant in the 6-21°C and 13-31°C ranges.

Table 1. Calculation of the mean selected temperatures and range of *G.affinis* and *A.dispar* of the three temperature ranges in the thermal gradient and the mean critical maximum and critical minimum of the two species

Species	6 – 21°C	13 – 31°C	21 – 40°C	Range	C.T.Max.	C.T.Min.
	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$
Gambusia affinis	15.9	23.4	28.4	12 – 32°C	38°C	4.4°C
Aphanius dispar	15.4	22.3	26	14 – 32°C	38.1°C	4.2°C

Aphanius dispar showed an escape behaviour when cooled below 9°C. The C.T.Min. was 4.2°C, and most of the fish recovered when warmed back slowly. Restlessness and rapid swimming in a bid to escape was observed at 34°C and the C.T.Max. was reached at 38.1°C. *Gambusia affinis* exhibited escape tendency at 10°C cooling, and it's C.T.Min. was 4.4°C. Escape mechanism was triggered at 35°C and sometimes the fish jumped out of the test apparatus. The C.T.Max. was 38°C.

Lower temperatures did not cause a significant adverse effect on the activity after recovery.The upper thermal tolerance in both species was significantly higher in small individuals (*Aphanius* 21-37 mm SL; *Gambusia* 22-28 mm SL) than in larger ones (*Aphanius* 38-54 mm SL; *Gambusia* 32-55 mm SL).

As a result of thermal stress a blackish red spot developed in *G. affinis* between the gill operculum and the pectoral fin, while this effect was not observed in *A. dispar*. Prolonged exposure to C.T.Max. resulted in a thermal shock in both species, causing a permanent impairing of equilibrium. Being more fragile species mortality was high in *A. dispar* (30%) than in *G. affinis* (10%) after thermal shock.

Discussion

Similar to the observations of Al-Daham *et al.* (1977), both species were observed for the tolerance of a wide range of temperatures. Although the Sign test showed insignificant differences between the low and medium range of temperature

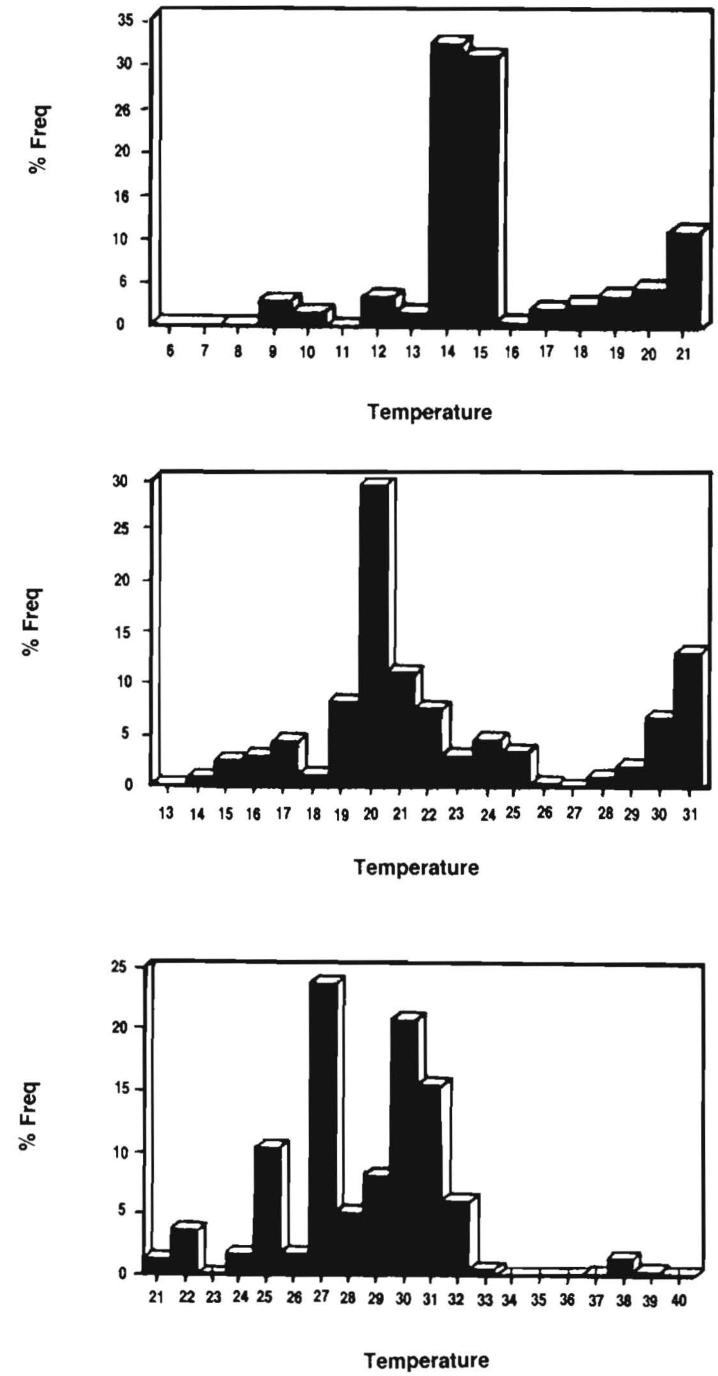
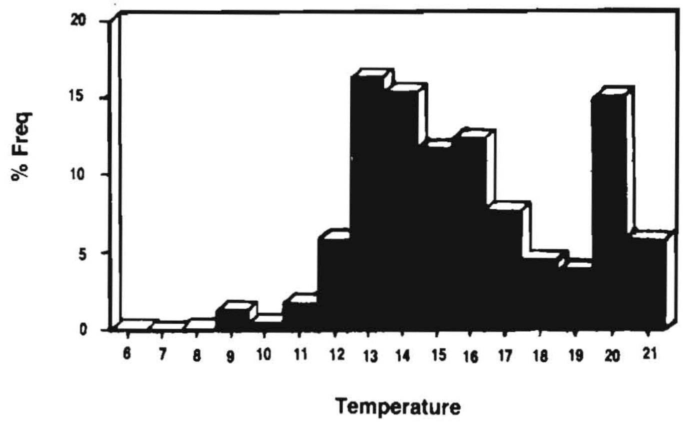


Fig. 2. The frequency distribution positions of *A. dispar* (left graphs) and *G. affinis* (right graphs) in the thermal gradient for the three ranges.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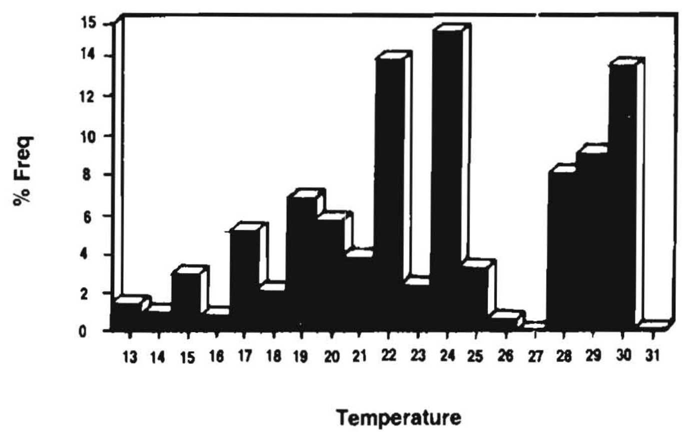
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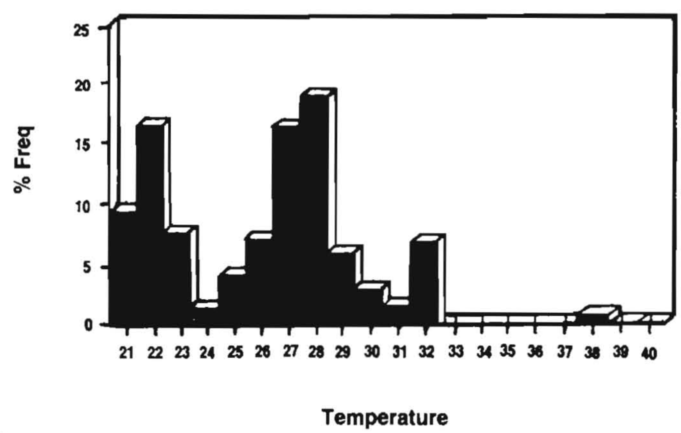
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Temperature

for either species, *A. dispar* showed a distinctive pattern in thermal selection, while *G. affinis* selected a wider range. In the low range about 62% of *A. dispar* selected a temperature between 14-15°C and about 55% selected a temperature between 19-22°C in the medium range. While 83% of *G. affinis* selected a temperature between 13-20°C in the low range, and 66% a temperature between 22-30°C in the medium range. This behaviour of temperature selection might explain the better adaptability of *G. affinis* in adjusting to a wide range of thermal regimes than the other species. It might also indicate the ability of this species to better exploit the available resources in their habitat, and hence might explain their ability to colonise a wider range. Both species proved to tolerate high temperature. However, *G. affinis* apparently can tolerate higher and wider range of temperature. This is evident from the results in the present study and also from earlier reports (Otto 1973, 1974). The higher temperature tolerance of smaller individuals of the two species is in line with the observations of Shrode (1975) that the young of several species prefer warmer waters than the older and larger individuals.

At low and medium ranges, the frequency of temperature selection of both species showed an increase at the natural habitat temperature of around 20°C. This phenomenon was also observed by Crawshaw (1975) in Brown bullhead fish (*Ictalurus nebulosus*) where the fishes acclimatized to different temperatures, usually selected a similar water temperature to that of their natural habitat within one day after placement in a temperature gradient. The C.T.Min. value for *A. dispar* is in line with the acclimatized C.T.Min. reported by Hass (1982), for *G. affinis* Brett (1956) reported far lower C.T.Min than observed in the present study. The higher value obtained may be attributed to the adaptation of this species to the desert environment. The C.T.Max. determined in the present study for *A. dispar* is higher than that reported by Fox (1926). Moreover, this species had survived at 40°C without any previous acclimatization (Al-Daham *et al.* 1977). When conditions demand in desert habitats, fishes can live just below their C.T.Max. in the field (Lowe and Heath 1969) and the maximum water temparature recorded for natural survival was 44.6°C for *Cyprinodon macularius* in the Sonoran desert of Arizona. The escape behaviour at 35°C for *G. affinis*, is apparently a characteristic behaviour that has also been observed by Winkler (1975) in a field study. However, comparison of the graphic representation of the preferred trend in temperature selection, does not show any similarity in any of the ranges. In the field, the two species were observed to swim most of the time in separate schools in the different layers of the stream, coupled with different times of emergence and foraging. This might indicate that the two species occupy different thermal niches, so as to exploit the habitat resources to the maximum, though *G. affinis* seems to be better adapted than *A. dispar*.

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البيئة الحرارية لنوعين من أسماك المياه العذبة
Gambusia affinis و *Aphanius dispar*
من وسط الجزيرة العربية

عوض متيريك الجهني و محمد يوسف

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أُدخلت أسماك *Gambusia affinis* إلى المياه العذبه في شبه الجزيرة العربية في أَوائل الثلاثينات من القرن الميلادي الحالي بهدف مقاومة الملاريا. وقد عرف هذا النوع من الأَسماك بتحمله وتأقلمه للظروف المناخية السائدة في المناطق الجافة. وعلى الرغم أن أسماك *Aphanius dispar* وهو النوع المحلي الوحيد من نفس العائلة والذي يتميز بتأقلمه مع ظروف المناطق الحارة، إلا أن هناك شواهد تدل على منافسة النوع الاول له في بيئته.

تمت دراسة الاختيار الحراري للنوعين في المختبر باستخدام حوض مائي حراري زود بجهاز تبريد في أحد طرفيه وجهاز تدفئة في الطرف الآخر ليعطي مجال حراري بين (٦ - ٤٠) °م. وقد جمعت الاسماك من قناة الري بالخرج وحفظت في المختبر عند درجة حرارة ٢١ °م. تم دراسة ٣٦ عينة من كل نوع بإدخال الأسماك كل على حده الى الحوض الحراري وتسجيل اختيار الحيوان كل نصف دقيقة بواسطة تسجيل درجة حرارة الماء لموقع السمكة وتكرار ذلك لمدة نصف ساعة. كما حُدِّدت درجة الحرارة الحرجة الدنيا والعليا لكل من النوعين بإستخدام حوض حراري يبرد ويسخن بالتدريج من الاسفل حتى الوصول لدرجة الحرارة الحرجة.

وقد دلت الدراسة الى أن هناك فرقاً بين النوعين في الاختيار الحراري، حيث لوحظ أن معظم أسماك *Aphanius dispar* تختار درجات حرارية محدودة في وسط المجال الحراري المتاح، بينما ينتشر اختيار أسماك *Gambusia affinis* على مجال أوسع وفي الطرف الدافئ من المجال.

إن مقدرة كلا النوعين على تحمل الظروف الحرارية القاسية واضح ولكن هذه المقدرة تظهر بشكل أوضح في أسماك *Gambusia affinis* وذلك من خلال الاستغلال الافضل للعوامل السائدة وهو ما يحتمل أن يؤدي الى التأثير على النوع المحلي واستيطان بيئاته.