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OBSERVATIONS ON THE RESISTANCE OF *TIGRIOPUS FULVUS* (FISCHER) TO CHANGES IN TEMPERATURE AND SALINITY

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(Text-figs. 1 and 2)

The harpacticid copepod *Tigriopus fulvus* (Fischer) has a wide distribution along the European coast, generally occurring in pools at or above high-water mark, where the environmental conditions are liable to sudden and extreme changes. Fraser (1936), while studying the life history and ecology of *T. fulvus*, has quoted Issel (1914): 'A few weeks of periodical observations of the pools since 1912 have drawn my attention to a phenomenon worth studying; as soon as the density of the water reaches a certain degree the copepod *T. fulvus* falls into a state of apparent death, from which it can awake even after a very long time and regain normal activity when the water is sufficiently diluted'. The experiments described in this paper were designed to investigate this phenomenon and other reactions of *T. fulvus* to changes in salinity and temperature.

EFFECTS OF SALINITY CHANGES

T. fulvus were collected from rock pools above high-water neaps at Port St Mary, Isle of Man, and transferred to sea water of salinity 34·0‰ in which they were conditioned for 2 days, to overcome the effects of the fluctuations in the salinity of the rock pools. Lower salinities were obtained by diluting the sea water with distilled water and higher salinities were obtained by adding Tidman's sea salt. The salinities were determined by titration with silver nitrate.

A graded series of twenty-three solutions was prepared with salinities ranging from 0·0 to 118·0‰. Approximately fifty specimens of conditioned *T. fulvus* were pipetted into 50 c.c. of each solution and left for a period of up to 15 days.

It was found that in distilled water the animals died after 84 h, while in solutions from salinity 4·2‰ up to 90·0‰ they were living normally after 15 days. In salinities above 90·0‰ *T. fulvus* fell into a state of apparent death, as described by Issel (1914); as soon as the animals were introduced into the solutions of salinity above 90·0‰ they ceased their activity and sank to the

bottom of the dish and lay motionless. But when they were transferred back to sea water of salinity 34·0‰ they regained their normal activity after a period depending on the strength of the previous solution and the duration of immersion in it.

In order to investigate this behaviour a further series of experiments was conducted. For this a set of four solutions was made with salinities of 98·0, 135·0, 180·0 and 225·0‰ respectively. Fifty specimens of conditioned *T. fulvus* were transferred to each of the above solutions. At definite intervals animals were transferred from the high salinity solutions to sea water of salinity 34·0‰ and the time taken for complete recovery was noted. The temperature during

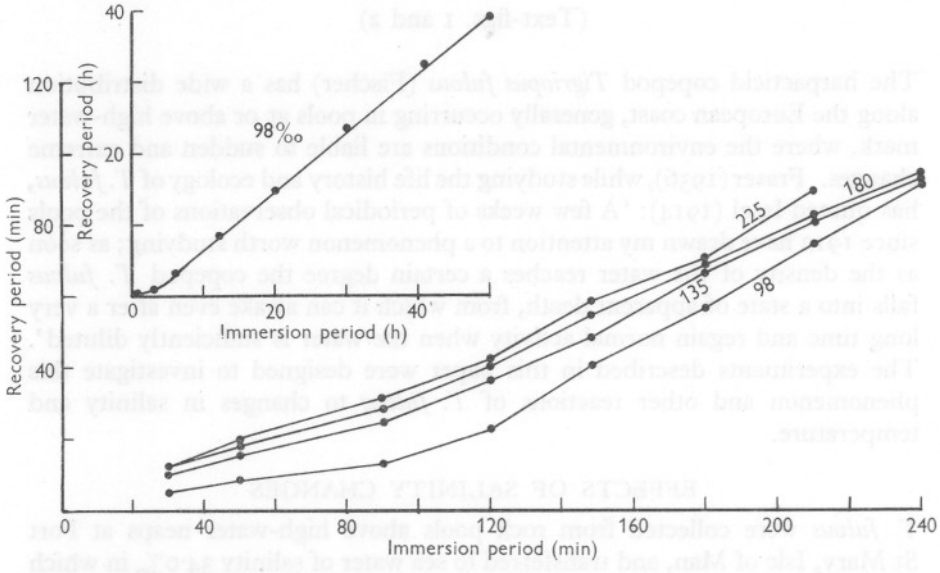

Fig. 1. *Tigriopus fulvus*. Relation between immersion period and the recovery period at salinities of 98, 135, 180, and 225‰, for various immersion periods up to 4 h. Inset: the same for a salinity of 98‰, when the immersion period was taken up to 50 h.

the experiments varied between 16·0 and 18·0° C. The relation between the immersion period and the recovery period is shown in Fig. 1. The points plotted are the means of two experiments; variation between the repeat experiments was very small. It will be seen that the strength of the high salinity solutions had some effect on the period required to regain normal activity after transfer, those which were immersed in stronger solutions requiring a rather longer recovery period. This factor was, however, of much less importance than the immersion period, and in cases of immersion for more than 4 h may be virtually neglected. The species was found to be unable to survive indefinite immersion in any of the solutions in which the 'apparent death' response was observed, the survival period varying with the salinity.

The maximum immersion periods, after which no recovery took place, were as follows:

Solution	Salinity (‰)	Maximum immersion period (h)
1	98	60
2	135	30
3	180	30
4	225	3

EFFECTS OF TEMPERATURE CHANGES

Two batches of twenty *T. fulvus* in 20 c.c. of sea water of salinity 34·0‰, immersed in a water-bath, were subjected to a slow rise in temperature at the rate of approximately 2° C per hour by means of a thermostat and heater. The animals behaved normally up to 34° C, but their movements became more rapid with increasing temperature until heat coma set in at 36° C when they became motionless and sank to the bottom of the dish. Death occurred when

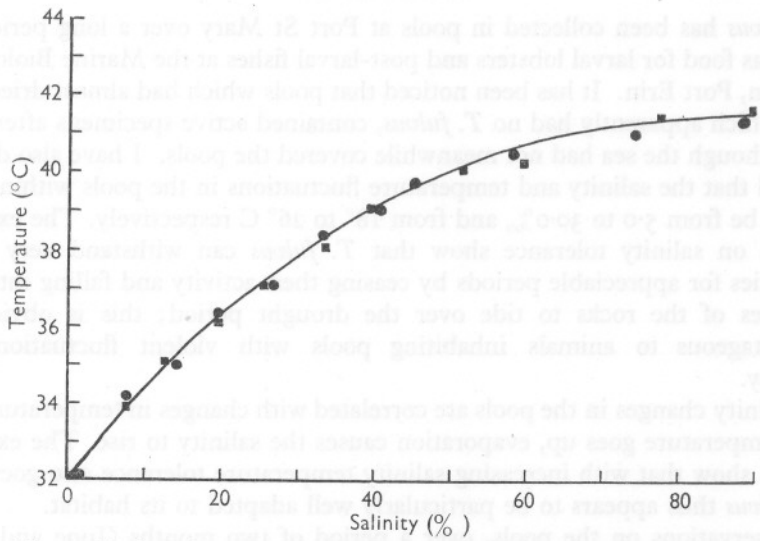

Fig. 2. *Tigriopus fulvus*. Lethal temperatures at different salinities. ■ First experiment, 18 August 1956. ● Second experiment, 26 September 1956.

the temperature reached 38° C. The death-point was determined when no recovery took place after transferring the animals to room temperature (16° C) for a period of 24 h.

In rock pools at high water, high temperatures are usually accompanied by increasing salinities on account of evaporation. An experiment, therefore, was set up to investigate the relation between the salinity of water and temperature tolerance of *T. fulvus*.

For this a series of eleven solutions of different salinities ranging from distilled water to 90·0‰ were made. Twenty specimens of *T. fulvus* were transferred from sea water to 20 c.c. of each solution in small dishes. These dishes were floated on a water-bath at 16° C and the temperature of the bath increased at a rate of approximately 2° C per hour. The *T. fulvus* were kept under continuous observation and the temperature of the water in each dish was taken at the 'death point'. This point was remarkably clear-cut, for about three-quarters of the animals always died simultaneously; the rest died within 3 min, during which the temperature never rose more than 0·1° C.

This experiment was repeated a month later with a fresh set of solutions and a new stock of *Tigriopus*. The second set of results agreed very closely with the first set, and both are shown in Fig. 2, which shows that the lethal temperatures varied over a range of 9·8° C depending on the salinity of the solutions. In distilled water death occurred at 32·0° C, while in salinity 90·0‰ the animals died at 41·8° C.

DISCUSSION

T. fulvus has been collected in pools at Port St Mary over a long period to serve as food for larval lobsters and post-larval fishes at the Marine Biological Station, Port Erin. It has been noticed that pools which had almost dried up, and which apparently had no *T. fulvus*, contained active specimens after rain even though the sea had not meanwhile covered the pools. I have also determined that the salinity and temperature fluctuations in the pools within 24 h could be from 5·0 to 30·0‰ and from 18° to 26° C respectively. The experiments on salinity tolerance show that *T. fulvus* can withstand very high salinities for appreciable periods by ceasing their activity and falling into the crevices of the rocks to tide over the drought period; this is obviously advantageous to animals inhabiting pools with violent fluctuations in salinity.

Salinity changes in the pools are correlated with changes in temperature; as the temperature goes up, evaporation causes the salinity to rise. The experiments show that with increasing salinity temperature tolerance also goes up; *T. fulvus* thus appears to be particularly well adapted to its habitat.

Observations on the pools, over a period of two months (June and July 1956) have shown that the fluctuations in salinity and temperature in the pools were from 5·0 to 42·0‰ and 13° to 27° C respectively. These changes are well within the tolerance limits of *T. fulvus* as shown in the foregoing experiments.

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SUMMARY

Tigriopus fulvus can live normally within a salinity range of from 4·2 to 90‰.

In waters of salinities above 90‰ it falls into a state of apparent death from which it can recover if transferred back to lower salinities.

The relation between immersion period and the recovery period is only slightly different at different salinities.

The lethal temperatures vary between 32·0 and 41·8° C depending on the salinity of the sea water, the lethal temperature being higher in higher salinities.

The fluctuations in salinity and temperature in the pools where the animals were collected are well within their tolerance limits.

T. fulvus is well adapted to its habitat.

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