# THE INFLUENCE OF TEMPERATURE AND SALINITY ON DEVELOPMENT AND SURVIVAL OF GOBY EGGS (*PISCES*, *GOBIIDAE*)

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## INTRODUCTION

In the transition area between fresh water and the sea, a clear distinction can be made between fresh-water fishes and sea fishes (VAAS, 1968). Many fish species can live in brackish waters, but only few are able to reproduce there, and it is of interest to know whether fishes are limited in their distribution by the same salinity boundaries as found for invertebrates (VÄLIKANGAS, 1933).

Gobies, small demersal fish with a size of about 5 to 10 cm, are particularly abundant in coastal areas. A series of closely related *Pomatoschistus* species occurs along the western European coast, with a distribution from estuarine (*P.microps* Krøyer, *P.minutus* Pallas) to neritic (*P.pictus* Malin, *P.lozanoi* De Buen) and deep neritic (*P.norvegicus* Collett). *P.microps*, the common goby, is abundant in coastal waters and estuaries at a depth of about 0.2 to 2 meters and salinities ranging from 0.5 to 35°/oo S. The sand goby, *P.minutus* (*P.minutus* var. *Guitelli* Le Danois, 1913), occurs in the same habitat at a greater depth, ranging from 1 to 30 meters. *P.pictus*, the painted goby, is common in coastal waters at about 2 to 35 meters depth, but not in estuaries. *P.lozanoi* (= *P.minutus* var. *minutus* Le Danois, 1913) occurs in the same habitat, whereas *P.norvegicus* (= *P.elongatus* Lebour, 1919) is only found at greater depths ranging from about 40 to 100 meters (FAGE, 1915; MILLER, 1963). All these gobies spawn on lamellibranch shells and the males show nest-building and breeding behaviour. The female attaches her pear-shaped eggs (size approx. 1 mm) to the hollow inner side of the nest shell, where they are guarded and ventilated by the male until they hatch (TAVOLGA, 1950, 1954; KINZER, 1960). The larvae live pelagically and change to demersal life after about one month (FONDS, 1970).

The salinity boundaries for reproduction were estimated for three *Pomatoschistus* species: *P.minutus*, *P.microps* and *P.pictus*. Rate of development and survival of the eggs were measured in a range of salinities at different temperatures, because osmotic and ionic regulation in poikilotherms is generally correlated with temperature (KINNE, 1964).

## METHODS

Mature gobies were kept in sea water basins (30°/oo S), with sand and pieces of white plastic which were readily accepted by the males for nest building (FONDS, 1970). The pieces of plastic were checked every morning for the presence of eggs.

Each piece of plastic with a batch of freshly spawned eggs was cut into smaller pieces. These subsamples were incubated in 24 plastic pails (volume 11 liter) at combinations of 4 temperatures (10, 15, 20 and 25°C) and 6 salinities (5, 15, 25, 35, 45 and 55°/oo S). Sea water in the pails was aereated in the centre, and the pieces of plastic with goby eggs were floating at the surface. The incubation time and the number of surviving eggs was estimated at two developmental stages:

1. at the stage with black pigmented eyes: survival as "number of embryos with black eyes in % of the total number of eggs";
2. at hatching: survival as "number of hatched larvae in % of the number of black eyed embryos".

Unfortunately, the gobies produced only few batches of eggs. The results of this investigation must therefore be regarded as a preliminary estimation of temperature-salinity boundaries for development of the eggs.

## RESULTS

Observations from 4 batches of *P.microps* eggs, 4 batches of *P.pictus* eggs and 2 batches of *P.minutus* eggs are presented in this paper. Some previous measurements on rate of development in relation to temperature have been included.

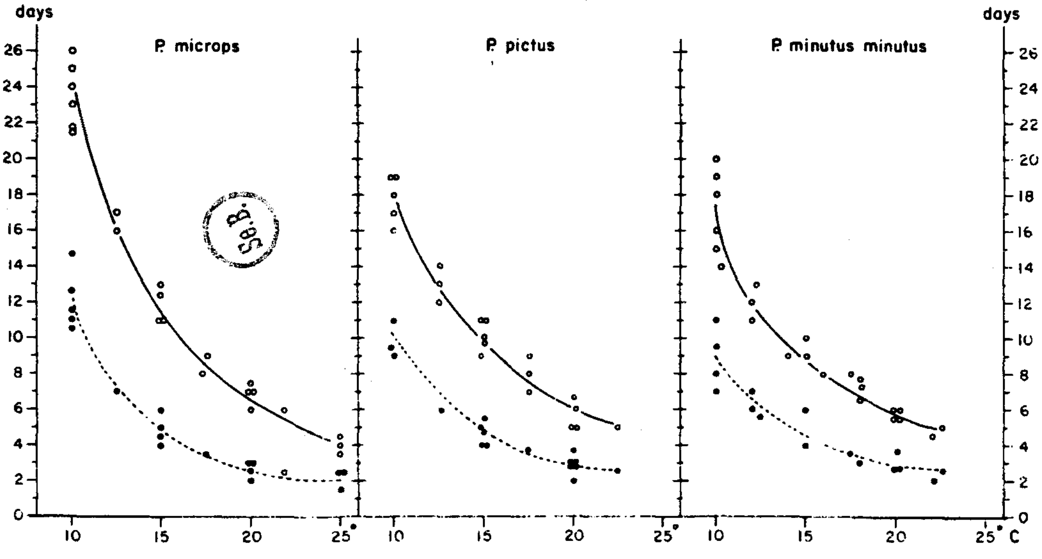

Fig. 1. Development of the eggs of three *Pomatoschistus* species in relation to temperature. Incubation time in days (24 hrs) to the black eyes stage (closed dots) and to hatching (open dots).

1. Rate of development. The incubation time, in days, to the black-eyes-stage and to hatching appeared to be largely independant of salinity, but strongly correlated with temperature (Fig. 1). The rate of development, in % per day, showed more or less the same relation to temperature for eggs of *P.minutus* and *P.pictus*. Early development of *P.microps* eggs, however, appeared to be much slower at the lowest temperature ($10^{o}C$) and more rapid at the highest temperature ($25^{o}C$) as compared to the other two species (Fig. 2b), and the rate of development to hatching of *P.microps* eggs was lower over the whole temperature range (Fig. 2a).

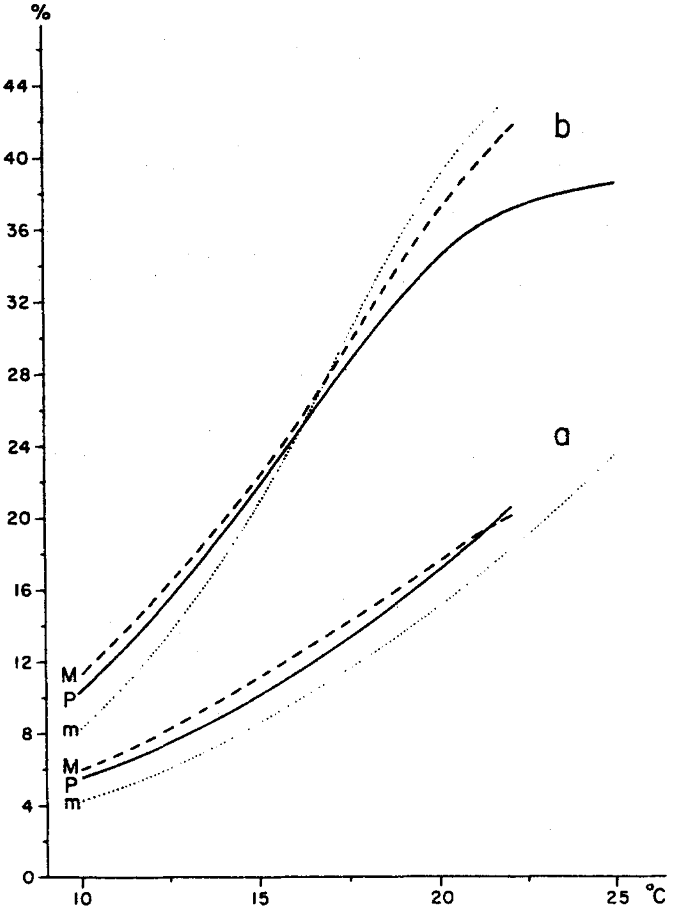

Fig.2. Rate of development in %/day (100/incub.time) of the eggs of *Pomatoschistus microps* (m), *pictus* (p) and *minutus* (M) in relation to temperature. a. Development to hatching, b. Development to the black eyes stage.

2. Survival. The survival of *P.microps* eggs was high at temperatures ranging from 15 to 20°C, but lower at 10°C and 25°C (Fig. 3). The eggs of *P.pictus* and *P.minutus* showed a high survival at temperatures from 10 to 20°C, and a very low survival (*P.pictus*) or no survival (*P.minutus*) at 25°C (Fig. 3). *P.microps* eggs survived well in salinities ranging from 5 to 35°/oo S, those of *P.pictus* and *P.minutus* in salinities ranging from 15 to 35°/oo S. Survival of the eggs of all three species was lower in 45°/oo S and all eggs died in 55°/oo S. The survival of *P. minutus* eggs was rather low in 5°/oo S and *P.pictus* eggs all died, before hatching, at this salinity.

3. Larval size. The newly hatched larvae of *P.microps* and *P.pictus* were collected and measured in two series of subsamples for each species, 10 larvae for each subsample and temperature-salinity combination. Total length of the larvae was related to incubation temperature (Fig. 4a, subsamples from different salinities taken together) and to incubation

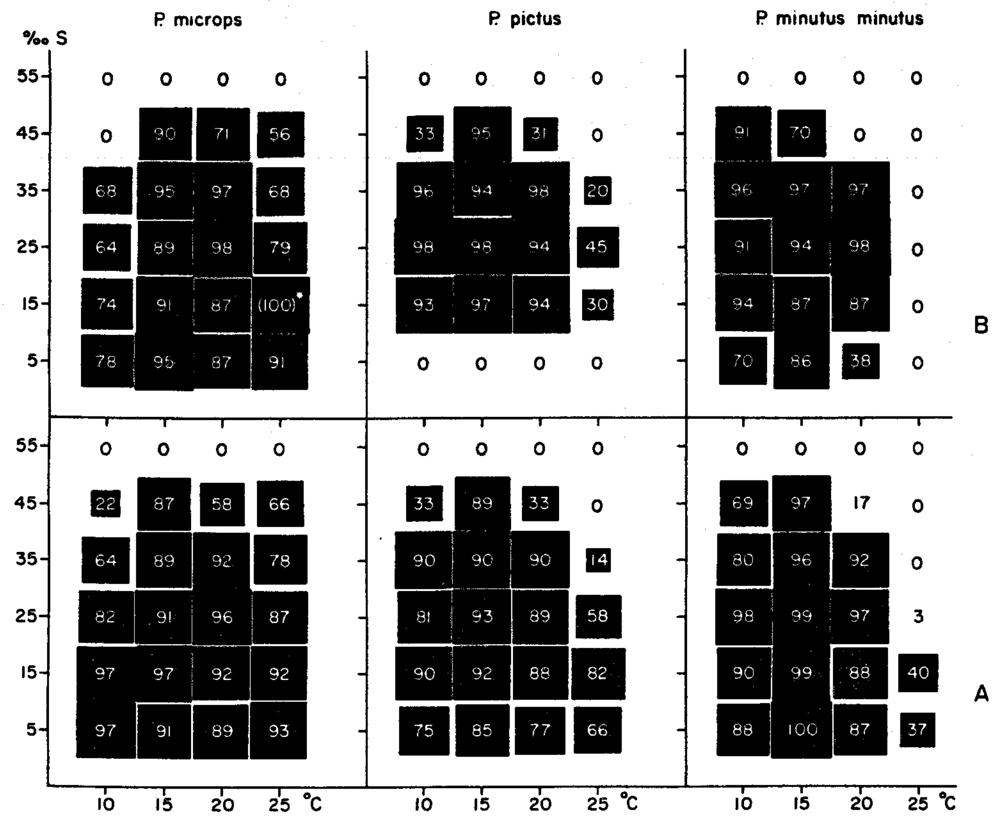

Fig. 3. Survival(%) of the eggs of three *Pomatoschistus* species at different temperature-salinity combinations. A: from fertilization to the "black-eyes" stage. B: survival of "black-eyes" embryos to hatch.

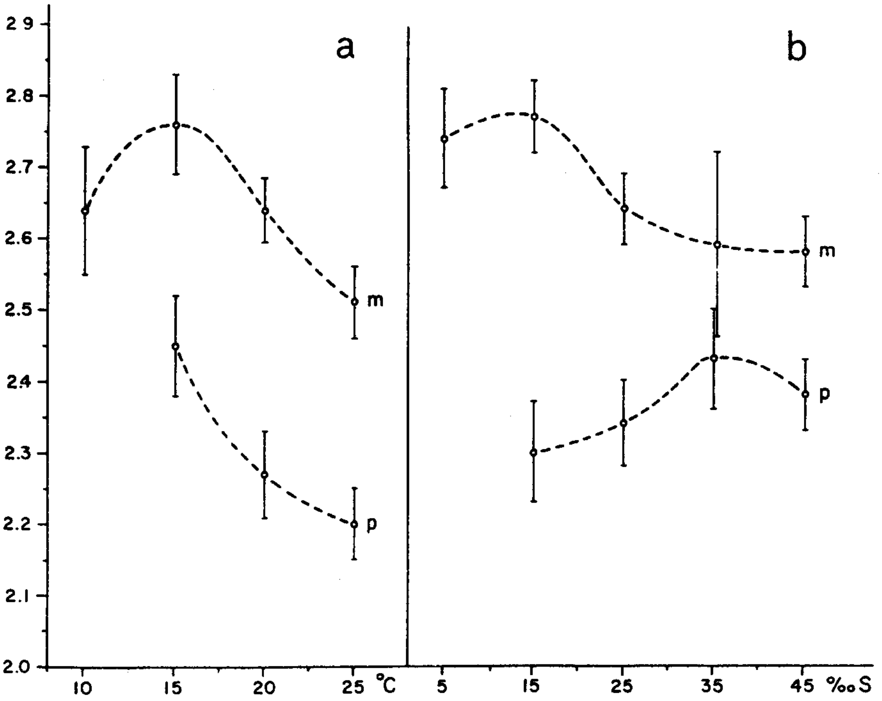

Fig. 4. Mean total length and standard error (vertical bars: 2S√n) of newly hatched larvae of *Pomatoschistus microps* (m) and *pictus* (p), in relation to incubation temperature (a) and salinity (b).

salinity (Fig. 4b, subsamples from different temperatures taken together). In both species the larvae showed a maximum size at about 15°C. The larvae of *P.microps* showed a maximum size at a salinity of 5 to 15°/oo S, those of *P.pictus* at 35°/oo S.

## DISCUSSION

The relation between temperature and rate of development of the eggs is more or less the same for the three *Pomatoschistus* species, but shifted for about 2°C to a higher temperature range for *P.microps*. This is also apparent from the high survival of *P.microps* eggs at 25°C and lower survival at 10°C, compared to a high survival at 10°C and very low (or no) survival at 25°C in the two other species. *P.microps* eggs also survived better at the lowest salinity (5°/oo) compared to *P.minutus* eggs, while *P.pictus* apparently reaches a limit for development of the eggs somewhere between 5 and 15°/oo S. In all three species the survival of the eggs was lower at combinations of high temperature-high salinity, and low temperature-high salinity (Fig. 3). With high temperature and salinity the oxygen supply may have been the limiting factor for development of the eggs. The rate of development, and probably also the respiratory rate of the eggs, increases rapidly with the temperature, whereas the amount of dissolved oxygen decreases with increasing temperature and salinity (KINNE and KINNE, 1962). The respiratory rate of the eggs at 20°C was probably about 3 to 4 times as high as at 10°C, whereas the amount of dissolved oxygen at 20-25°C and 35-45°/oo S was about 60% of the amount dissolved at 10°C - 5°/oo S. A breeding male goby may prevent respiratory stress for the eggs by an increase in ventilatory rate. In our experiments, however, the eggs were incubated without the parent fish and there was no compensation for respiratory stress.

The lower survival of the eggs at low temperature-high salinity may be related to a slight interaction of temperature and salinity on survival of goby eggs in the same way as found by WESTERNHAGEN (1970) for several marine fish species (see also ALDERDICE, 1972).

It can be concluded that the temperature-salinity boundaries for development of the eggs of the three goby species is more or less correlated with their distribution from estuarine to neritic.

*P.microps* spawns in shallow water in the estuaries, generally from April-May to August at temperatures from 10 to 20°C (see NYMANN, 1953; JONES and MILLER, 1966; HEALY, 1972b). It appears that the eggs are adapted to development at higher temperatures and low salinities. However, they also survive well at normal sea water salinity, which indicates that *P.microps* has extended, not shifted, its salinity range to lower salinities. The eggs of *P.pictus* and *P.minutus* are apparently not adapted to development at high temperatures (25°C). *P.minutus* generally spawns from April to June (LEBOUR, 1920; HEALY, 1971b). Numerous shells with eggs of this species were found in the southern North Sea (35°/oo S) at about 10 to 25 metres depth and at temperatures ranging from about 8 to 15°C (FONDS, 1971, 1973). This goby, however, is also abundant in enclosed brackish lakes (VAAS, 1970) and in the Baltic at a salinity of about 5°/oo S(LAWACZ, 1965). Hence, salinity seems to be less important than temperature for the reproduction of this species.

*P.pictus* generally spawns from May to July; eggs of this species were found in the North Sea at 25 m depth in July. *P.pictus* does not occur in estuaries and only rarily enters the Dutch Wadden Sea (sal. 15-30°/oo S), although the species is common in the adjacent southern North Sea (FONDS, 1964). From the survival of the eggs in our experiments it appears that *P.pictus* probably reaches a lower limit for reproduction at about 10°/oo S, which is much lower than the lowest salinity in the Wadden Sea. This indicates that other factors, such as the high summer temperature in the Wadden Sea or the rapid change in temperature and salinity, set a limit to the distribution of this species.

Finally, it can be concluded that the distribution of the three *Pomatoschistus* species from estuarine (*P.microps*) to neritic (*P.pictus*) is related to both temperature and salinity as limiting factors. *P.microps*, the most euryhaline species, probably depends on the higher temperature and high benthic food density in shallow inshore waters and estuaries. *P.pictus* is probably better adapted to the lower temperature and lower density of benthic food at greater depth offshore. *P.minutus* occurs both in estuaries as well as in coastal waters near estuaries down to 35 metres depth, and therefore can be classified as a semi-estuarine species. A close relative, *P.lozanoi* (DE BUEN, 1923) seems to be restricted to coastal areas outside estuaries (FONDS, 1971, 1973).

If only salinity is considered as a limiting factor, it can be concluded that the neritic *Pomatoschistus* species in the North Sea reach a limit in their distribution at about 10°/oo S, that is in the B-mesohaline zone where many invertebrates from coastal areas similarly reach a limit in their distribution (VÄLIKANGAS, 1933). Only *P.microps* and *P. minutus* will be found at salinities below 10°/oo S.

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