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Karyological and gonadal sex of eels (*Anguilla anguilla*) in the German Bight and the lower River Elbe

by

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Abstract

Yellow eels (*Anguilla anguilla*) taken from random commercial trap net samples in the littoral area of the North Sea Island Helgoland (n = 116) and from a freshwater area of the River Elbe below the port of Hamburg (n = 109) were examined on their karyological (i.e. existance of female chromosomes) and their gonadal sex. In 47% and 21% of the two samples, respectively, chromosomes were unidentifiable because of insufficient mitotic plates. According to literature in Helgoland, all specimens except one phenotypically undetermined eel exhibited female gonades: 48 had female chromosomes and 13 were karyological males. Consistant with earlier results in the River Elbe eels with male gonads predominated (n = 55); 25 were undifferentiated. Out of the gonadal males, there were 26 karyological males 16 karyological females, and the rest were not identified by chromosome patterns. Contrarily, the Elbe eels with female gonads (n = 28) showed all but one female chromosomes.

Introduction

European yellow eels (*Anguilla anguilla* L.) caught in the open sea have an extremely high proportion of females (Peňâz and Tesch, 1970; Löwenberg, 1979). American silver eels (*A. rostrata*) originating from brackish water also exhibit a comparatively high proportion of females (Winn et al., 1975). However, in fresh water areas of the lower River Elbe males predominate (Peňâz and Tesch, 1970; review by Tesch, 1977). This is also true in the case of American eels caught in fresh water adjacent to the brackish water area (Winn et al., 1975). As shown by Peňâz and Tesch (1970), females again predominate farther upstream (see also review by Tesch, 1977). This means the highest proportion of male eels are found near the entrance of the sea into the river where population density is higher, and an increasing proportion of females are found from this point either farther up- or downstream. A development of an increasing proportion of females has also been shown from 1910 to 1970 in the Baltic Sea (Svärdson, 1976). As population density and "population pressure" decreased, the sex relationship was in favour of the females. The interpretation of Svärdson (1976) is: "the higher the population pressure, the more are the females stimulated to get away." But Tesch (1977) argues that a different migratory drive is an inadequate explanation for the sex distribution and that the sexual differentiation is not entirely dependent upon genotype.

A step toward the resolution of this problem is through the identification of chromosomes. Karyological investigations have shown the existence of a distinctly heteromorphic pair of female chromosomes in the eel (Ohno et al., 1973; Kang, 1974; Passakas, 1976; Park and Kang, 1979). In the present study we have used the method described by Passakas (1976) to examine the chromosomes and the gonads of yellow eels from two samples of essentially different phenotypical sex relationships.

Material and Methods

We got 109 unsorted yellow eels at the end of July 1977 from a commercial fisherman who caught them by trap nets in the fresh water of the River Elbe immediately below Hamburg (near Wedel, 80 km from the estuary of the Elbe). In September 1978 a commercial fisherman provided us with 116 yellow eels. They were caught by trap nets in the littoral area of Helgoland. The sex of the gonads was examined macroscopically at first. After removal and preservation of as much of the tissue as possible of both gonads, we examined the squashed tissue microscopically. This was necessary especially with Elbe eels because they exhibited a considerable amount of undetermined gonads (Peňaz and Tesch, 1970; Saint-Paul, 1977).

We investigated the chromosomes on mitotitc plates originating from gill epithelium. Fragments of gill were put into a 0,05% solution of Colchicine; after 1,5 - 2 hours they were transferred to a hypotonic solution for fish for 1,5 hours. After fixation in 50% acetic acid for approximately 0,5 hour, the fragments were squashed under a pressure of 15 kg/cm². After the removal of the cover glasses by submersion in 70% ethyl alcohol, the squashes were stained in a Giemsa solution. We photographed the best metaphase plates and established karyotypes.

Results and Discussion

Figure 2 shows the length frequency distribution of karyological males and females each specifying the phenotypical sex as determined by examination of the gonads. In both areas an exact number of eels could not be determined by the karyological method because of the insufficient quantity of mitotic plates. The proportion of these undeterminable eels was greater in

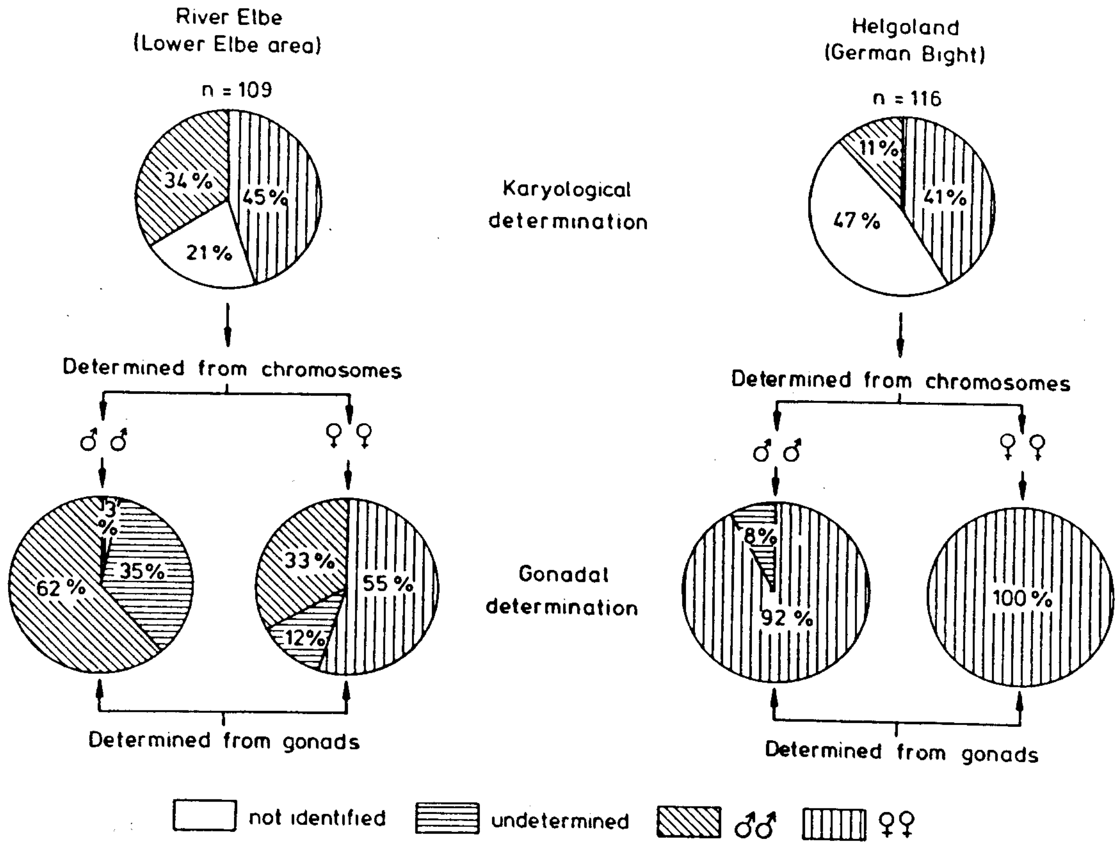

Fig. 1. Sex relationship (%) of yellow eels (*A. anguilla*) from Helgoland and the Lower River Elbe determined by karyological methods and gonadal sex. Undetermined specimens include hermaphrodites.

Helgoland than in the River Elbe, probably because the examination of Helgoland eels took place in the colder season (late summer to autumn) compared with the Elbe eels midsummer. Reddan et al., 1975, found also June to August to be the best for the study of the mitosis in the Opsanus tau.

Consistent with the results of earlier investigations on eels from Helgoland (Peňâz and Tesch, 1970; Saint-Paul, 1977; Löwenberg, 1979), all specimens showed female gonads. Karyologically, a considerable amount of these eels were males which means that nearly all male eels changed into phenotypical females (Fig. 1). In the River Elbe, however, the results were quite different. The earlier results which exhibited a comparatively high amount of eels with male or undifferentiated gonads (Ehrenbaum and Marukawa, 1914; Marcus, 1919; Wundsch, 1954; Peňâz and Tesch, 1970; see table 4 by Tesch, 1977) were confirmed (Figs.1 and 2). All karyological males, except one (3%) have developed male (62%) or undifferentiated gonads. The karyological females, on the other hand, showed a high proportion of phenotypical males (33%). In addition, this unsorted sample of eels from the River Elbe showed a comparatively high amount of large female eels. If specimens longer than 45 cm are discarded, the length frequency of the remainder is comparable with that of the Helgoland eels. The proportion of phenotypical female eels (45%) then also decreases to 14%, and this relationship compares with earlier results (Ehrenbaum and Marukawa, 1914: 7% and 36%; Marcus, 1919: 9%, 35%, 4%, 29%; Wundsch, 1954: 6% and 46%; see table 4 by Tesch, 1977). The samples of Wundsch (1954) consisted exclusively of small eels intended for transplant into inland lakes and rivers.

From our results it seems evident that the genotypical glass eel females entering the continental waters very likely in a normal proportion stay in the areas near the estuaries overcrowded with eels. They then partly develop gonads which leads to the unproportionally high amount of male yellow eels. The above-mentioned "population pressure" probably results more

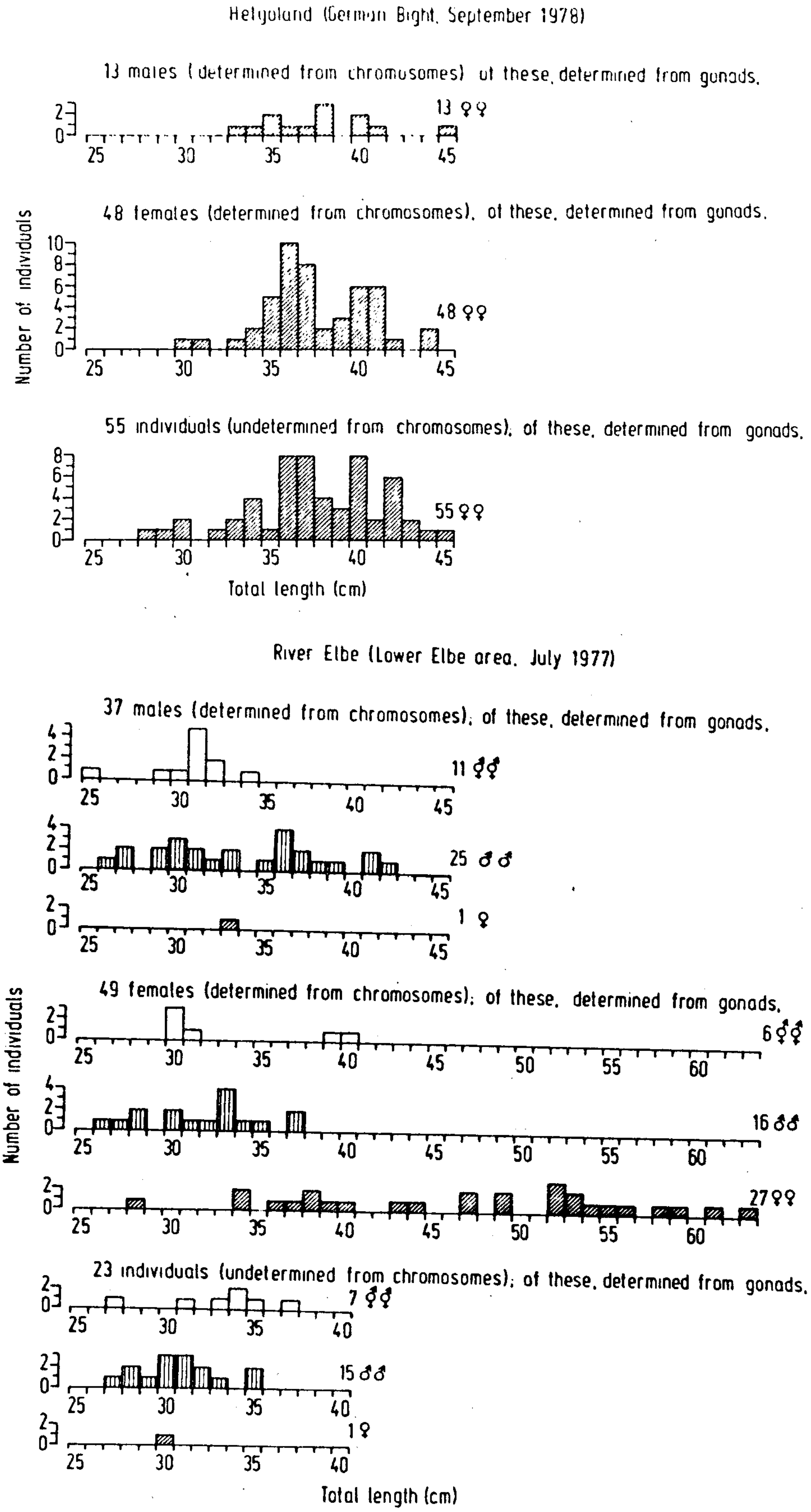

Fig. 2. Length frequency distribution of yellow eels caught near Helgoland and in the Lower River Elbe with specification of their karyological and gonadal sex. ⚥⚥ indicates undetermined or hermaphrodite gonadal sex. Of the 14 karyological Helgoland males with female gonads one specimen is not fully determined (length: 45 cm).

from malnutrition or other factors that change genotypical females into phenotypical males (Tesch, 1977, page 57) than by the emigration of females (Svärdson, 1976).

Our investigations confirm the results of earlier aquacultural experiments which suggest a dependence of the phenotypical sex on population density or nutrition (J.J. Tesch, 1928; d'Ancona, 1950; Gandolfi-Hornyold, 1932; Schnakenbeck, 1944; Fidora, 1951; Kuhlmann, 1975). Similarly, temperature can act through metabolism and therefore by nutrition (d'Ancona, 1957; Kuhlmann, 1975). Factors such as origin (North Atlantic or Mediterranean) and size of the glass eels (Bellini, 1907; Kuhlmann, 1975) in the case of the Elbe estuary areas may be of little or no significance for the abnormal sex relationship; their origin is the same and they are of similar size.

The next step towards a resolution of the problem should be cultural experiments and the application of karyological methods. In addition, it is necessary to examine the sex chromosomes of glass eels and leptocephali.

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