Fish with temperature-dependent sex determination face global warming

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In vertebrates with separate sexes, sex determination can be genotypic (GSD) or temperature-dependent (TSD). TSD is very common in reptiles, where the ambient temperature during sensitive periods of early development irreversibly determines whether an individual will be male or female. The number of males and females in a population is the sex ratio, a key demographic parameter crucial for population viability.

A number of previous studies have also suggested that TSD may also be very common in many species of fish, with increasing temperatures generally affecting the sex ratio of a species in one of three ways: increased numbers of males, increased numbers of females or increased numbers of males at high and low temperatures, with a balanced sex ratio at intermediate temperatures. However, to elicit a sex-ratio response to temperature, past experiments were often conducted only in the laboratory and not in the field, and the temperatures used were beyond the natural range of temperatures that the species experience in nature.

In a study directed by Francesc Piferrer, from the Institute of Marine Sciences in Barcelona, published in the open-access journal *PLoS ONE* on July 30, the Spanish researchers used field and laboratory data to critically analyze the presence of TSD in the 59 species of fish where this type of sex determining mechanism had been postulated.

The new study provides evidence that many cases where the observed sex ratio has shifted in response to temperature reveal thermal alterations

of an otherwise predominately GSD mechanism rather than the presence of TSD. The results also show that in fish species with TSD, increasing temperatures invariably result in highly male-biased sex ratios. Finally, the researchers show that even small changes of just 1-2°C can significantly alter the sex ratio from 1:1 (males:females) up to 3:1 in both freshwater and marine species.

This study shows that TSD in fish is far less widespread than currently believed, suggesting that TSD is clearly the exception in fish sex-determination. Thus, the scientists suggest that the evolution of sex-determining mechanisms in lower vertebrates, as is currently understood, needs to be revised. Further, species with TSD exhibit only one general change in sex ratio in response to temperature increase (leading to many males and few females). In many species, females determine the number of offspring for the next generation and so the viability of some fish populations with TSD can be compromised through alterations in their sex ratios due to temperature fluctuations of the magnitude predicted by climate change.

The researchers identify two key questions for future research. Firstly, whether the predicted effects can be observed in sensitive, natural populations – there are indications that this could be the case in some populations of South American silversides. Secondly, while it is already known that high temperatures inhibit the synthesis of estrogens, which are essential for female sex differentiation in fish and reptiles, more work needs to be done into the molecular mechanism linking environmental temperature and estrogen synthesis.

Citation: Ospina-Álvarez N, Piferrer F (2008) Temperature-Dependent Sex Determination in Fish Revisited: Prevalence, a Single Sex Ratio Response Pattern, and Possible Effects of Climate Change. PLoS ONE 3(7): e2837. doi:10.1371/journal.pone.0002837
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