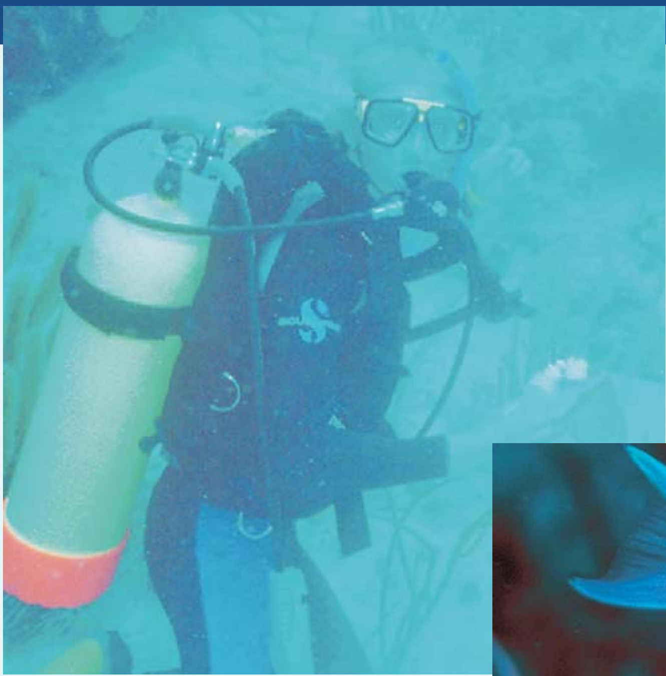
Trans-sexual **fish** from dimensionless **space**



David Allsop.

Variety may be the spice of life, but there could be common reasons for having a sex change, writes David Allsop.

Bluehead wrasse.

Trevor McDonald/NHPA

The idea of general rules that apply to the biology of all living things is controversial. Indeed, pretty much all research in modern evolutionary biology focuses on the study of variation. After all, natural selection acts on variation for the 'preservation of favoured races in the struggle for life', as Darwin said in 1859. However, while studying the evolution of sex-change during my PhD at Edinburgh I discovered some very interesting general patterns of no variation in the timing of gender change for 52 different species of fish.

Naturalists have long asked whether broad scale rules or patterns underlie the diversity of biological variation. Today we are getting considerably closer to the answer. We now know that all life on Earth, from viruses to man, shares a universal genetic code. This means that common mathematical rules could underlie higher-level biological processes, at least within taxonomic groups where species have been subject to similar selective forces during their evolution.

A good 'higher-level' biological process in which to search for commonalities across species is in the traits of an organism's 'life history'. Life history traits are the major life transitions an organism passes through as it journeys from birth to death. They include the onset of sexual maturation and the spacing between successive bouts of offspring production.

> 'Species usually change sex because one gender has more chance of producing offspring when bigger or older.'

I've been studying fish with a particularly curious life history trait – they can change sex at some point in their lives, and so can play both mother and father within the same lifetime. Organisms in a variety of taxa can change sex naturally. However teleost (bony) fish are the only vertebrates that we know of that do this. Nearly all fishes that change sex live in the shallow, warm and coral-rich seas around the tropics.

Species that change sex usually do so because when they reach old age, for one reason or another, one gender has more chance of producing offspring than the other. When it comes to mating, the fish species I've been studying all operate in harems. For example, the most commonly studied sex changing fish is the Bluehead Wrasse (*Thalassoma bifasciatum*). The largest males aggressively defend a group of females, with whom they mate exclusively. In the harem system, small males don't stand much chance of successfully challenging a much bigger male harem holder for access to the females. So there's not much point in being a small male and having to wait patiently, making little or no contribution to the gene pool, until you're big enough to take on the big guys. So in this mating system, most or all fish are born female, and produce at least some offspring whilst small. Later in


Parrotfish.

Linda Pitkin/NHPA

life, the biggest females can change sex, take over a harem and enjoy the high level of mating success of harem holding males.

The study of life history phenomena is not new, but looking at aspects of an organism's life history in a dimensionless way is. You can do this if the measurements for two aspects of an organism's life history have the same units (eg age at maturity in years and maximum lifespan in years). By removing the common dimension (years) you can look for relationships between the variables.

During my research, I made the startling discovery that all 52 species I was studying changed sex at the same relative size and age! That is to say, they all appear to be changing sex at a constant proportion when they were about 80% of their maximum body size. I also found that the fish were changing sex at the same age, relative to the age at which they became sexually mature – about two and a half times older than when they reached sexual maturity. This is a shocking result, considering the diversity of the species involved, and considering the variation we observe in the mating systems. For example, the result holds true irrespective of whether some individuals are born male and exhibit sneaky mating tactics, or whether the direction of sex change is female to male or vice versa.

There are a number of possible explanations for why all the fish share this rule for the timing of sex change. I believe it is the external manifestation of deeper level trade-offs governing the animal's biology in relation to the rest of the population in which it lives. For example, life history theory suggests a link between the onset of sexual maturity and the death rate in the population. The idea is that if population death rate increases for some reason (say a new predator arrives on the scene), natural selection lowers the age at which individuals become mature so that they can breed before dying. A similar argument for the timing of sex change might help explain why we see the same apparent rule for many species. Alternatively, a more mechanistic approach to explaining these general rules may involve shared physiological constraints. For example, all of the fish, being aquatic organisms, obtain their oxygen through gills. As fish grow, the volume of their bodies increases in a cubic fashion (tissue volume = body length^3). However the surface area of the gills only increase to the power of 2. Thus all aquatic organisms might be subject to oxygen limitation at some point in their lives (possibly at the same relative point for all fish), and the ratio of available oxygen to demand for oxygen could trigger major life history transitions.

‘All 52 species I was studying changed sex at the same relative size and age.’

The timing of sex change is probably explained by a combination of evolutionary and mechanistic approaches. However we interpret these findings, I believe their major offering is to stimulate further research into the bits of biology that diverse organisms share with each other. We are, after all, all descended from the same primordial goo.

David Allsop is an evolutionary biologist at the University of Edinburgh, Institute of Cell, Animal & Population Biology, Kings Buildings, Edinburgh EH9 3JT, tel: 0131 650 8667, email: david.allsop@ed.ac.uk