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Quantity versus quality of offspring

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Synonyms

Life history theory; Offspring; Quality versus quantity; Reproductive strategies

Definition

A key trade-off that organisms face concerning quantity versus quality in offspring: organisms that tend to invest heavily in offspring also tend to have lower numbers of offspring whereas organisms that invest little in offspring also tend to have higher numbers of lower quality offspring.

Introduction

Organisms continually face trade-offs for how to allocate limited energy and resources. One of the key trade-offs involves the quantity versus the quality of offspring. On the one hand, if organisms invest heavily in their offspring to better their developmental and survival outcomes, they tend to only have enough resources to produce a small number of "high-quality" offspring. On the other hand, if organisms make little parental investment per child, they can produce a large number of "low-quality" offspring – although each child has a lower chance of survival, there is a higher probability that at least some offspring will survive long enough to reproduce.

Ecological Conditions Affecting Reproductive Trade-Offs

According to life history theory (e.g., Stearns 1992), which concerns the allocation trade-offs that organisms face throughout their lifespans between somatic investment (maintenance and growth) and reproductive expenditures, different species as well as organisms within species tend to evolve a reproductive strategy that favors quantity or quality based on various ecological conditions. As described below, such ecological conditions can be broadly classified into two types: environmental harshness and environmental unpredictability.

Environmental Harshness

A key factor that affects reproductive trade-offs is environmental harshness. Environmental harshness is indicated by the rates at which external factors result in the death or disability of organisms at each age in a population. External causes of disability and death, or extrinsic morbidity-mortality (Ellis et al. 2009), include predation, droughts, and disease and can occur regardless of organisms' allocation of resources between the competing life functions of maintenance, growth, and reproduction. When adults face high extrinsic morbidity-mortality (e.g., homicide, famines), offspring quantity is favored over quality. That is, if the environment imposes high rates of unavoidable mortality, an adult organism would benefit by quickly producing a larger number of offspring to increase the probability that some will survive into adulthood long

enough to reproduce and propagate their genes. Heavily investing in a small number of high-quality offspring may not pay off in an environment with high risk of adult mortality, due to the higher likelihood of disability and death of the parent before the offspring receive the full benefits of their investment. For example, among the Ache, homicide, external warfare, and accidental deaths associated with food acquisition are some of the leading causes of death among adults. In turn, mating partnerships among the Ache are relatively short and women have children by several different fathers, reflecting a preference for offspring quantity over quality (Kruger and Nesse 2006). In contrast, when extrinsic morbidity-mortality affects the young, offspring quality is favored over quantity. An example of juvenile extrinsic morbidity-mortality can be found among red deer, where male juveniles have high mortality rates as a result of their greater susceptibility to food shortages due to their faster growth rates and greater nutritional requirements (Clutton-Brock et al. 1985). In this case, adult red deers are better off investing more parental care into a small number of offspring to better ensure their survival in the face of environmental harshness rather than to produce a large number of offspring who are all unlikely to survive without sufficient parental investment. However, a high-investment strategy is only valid when parental investment has an effect on offspring survival. In contexts where offspring survival rates are independent of parental investment, offspring quantity would be favored over quality.

The effects of environmental harshness on the trade-off between quantity and quality of offspring also depend on population density (Pianka 1970), resource availability, and predation. For example, research on Trinidadian guppies has shown that environmental conditions such as high extrinsic morbidity-mortality (due to high predation) and high resource availability favored offspring quantity over quality. Although the costs of mortality are high and unavoidable in harsh environments, the strategy of producing a large number of offspring can only be sustained if there are enough resources in the environment for these offspring. In contrast, environmental conditions such as low predation, high population density, and lower resource availability favor offspring quality over quantity. High competition for resources as a result of high population density and limited resources leads to greater investment in offspring growth in order for offspring to be more competitive in such environments. Indeed, guppies in such environments invest more heavily in a small number of high-quality offspring to improve their chances of survival in a highly competitive environment.

Environmental Unpredictability

Environmental unpredictability refers to variation in environmental harshness over time and space (Ellis et al. 2009). Many organisms live in environments where resources and mortality rates vary in unpredictable ways due to factors such as the behavior of predators or the weather. In unpredictable environments, morbidity-mortality risks are largely insensitive to the adaptive decisions and strategies of organisms and, therefore, are unavoidable. When there is high variation in adult mortality, adults are better off producing a large quantity of offspring rather than heavily investing in a small number of high-quality offspring due to their susceptibility to changing mortality rates.

However, when there is high variation in juvenile mortality, organisms may engage in one of two types of bet hedging: conservative and diversified (Einum and Fleming 2004). Conservative bet hedging corresponds to favoring offspring quality over quantity. In species where harsh environmental conditions affect an entire population over generations (e.g., years of drought), it is more beneficial to produce a small number of high-quality offspring who are equipped to handle the fluctuating conditions of the environment rather than a large number of low-quality offspring who are all unlikely to survive. In contrast, diversified bet hedging

corresponds to favoring offspring quantity over quality. In species where environments vary substantially across individuals and within single generations, a large number of offspring (who have high phenotypic variance) would be preferred to increase the probability that at least some offspring would have a phenotype that would allow them to survive long enough in their environmental conditions to reproduce and propagate their genes.

Offspring Quality Versus Quantity Preferences in Humans

Human environments generally consist of low extrinsic morbidity-mortality (due to low predation pressures as a result of humans being at the top of the food chain), high population densities due to low extrinsic morbidity-mortality and efficient hunting-gathering practices, and high levels of competition for limited resources. These environmental conditions have resulted in humans evolving a general preference for offspring quality over offspring quantity. Low levels of extrinsic morbidity-mortality allow parental investment to have positive effects on offspring's health, competitiveness, and reproduction; hence, it pays off for humans to invest heavily in their offspring to ensure their effectiveness in the highly competitive environment. In particular, it is adaptive in such environments for human males to produce only a few offspring, typically with the same mate, and to invest heavily in those offspring to ensure that they are of higher quality. As such, human paternal investment in children as well as monogamous marriage may reflect adaptive responses to morbidity, population density, and resource competition. Despite the fact that humans as a species are on the slow end of the life history continuum, however, there are key within-species differences in humans as a result of different environmental conditions.

Humans may evolve to favor either offspring quality or quantity depending on cues to extrinsic morbidity-mortality. When there are cues in the environment that extrinsic morbidity-mortality levels are high, humans tend to favor offspring quantity over quality. In these environments, heavy parental investment in offspring would not shield them from the dangers in the environment and would not enhance their fitness. Hence, parents would be better off producing a large number of offspring instead. One of the most important cues of extrinsic morbidity-mortality is low socioeconomic status (SES). Indeed, research has found that there is a negative correlation between SES and offspring number (Vining 1986) and a positive correlation between SES and levels of parental investment per child (Ellis et al. 1999). This could be because people living in low SES environments are more exposed to disability and death (thus cueing them to the harshness of their environment), but at the same time, they possess adequate resources to support the growth and reproduction of a large number of offspring.

Other important cues to extrinsic morbidity-mortality levels are personal knowledge of deaths among adolescents, exposure to violence, and environments characterized by short life expectancies. These cues inform individuals about their own and their offspring's probability of survival (which is likely to be relatively low) in their environment, thus causing them to favor offspring quantity over quality so that at least some of their offspring can survive. Harsh and neglectful parenting styles can also indicate to offspring that a parent favors offspring quantity over quality, which signals to offspring that this is the appropriate strategy for their environment, thus propagating this strategy in future generations (Bereczkei and Csanaky 2001).

Cues to the level of unpredictability in the environment are also informative. Interestingly, it is the level of unpredictability in the environment experienced during childhood that shapes preferences for offspring quantity versus quality. For instance, one indicator of childhood unpredictability is the number of parental changes as a result of divorce, death, remarriage, and adoption, among others. Frequent changes in parental figures indicate a high level of environmental instability and predict earlier age at first sexual intercourse, higher rates of premarital intercourse, teenage pregnancy, and premarital birth, which may all indicate a

preference for offspring quantity over quality. Another indicator of childhood unpredictability is the frequency of residential change. Children who frequently move experience changes in social groups and may be more likely to join delinquent groups, who are more accepting of newcomers. Joining these delinquent groups may expose them to harsher environmental conditions which may prompt them to favor offspring quantity over quality. Indeed, frequent residential mobility is associated with earlier age at first sexual intercourse, multiple sex partners, and higher rates of premarital sex and pregnancy.

Conclusion

The application of life history theory to explain the reproductive behavior of organisms has been fruitful and has the potential to guide further research regarding the evolution and development of specific phenotypic traits and strategies associated with the trade-off between offspring quality and quantity. Understanding this important trade-off may provide insights into how organisms make reproductive decisions in not only the environments where they evolved but also in the modern world. In such evolutionarily novel contexts, offspring quality is so highly favored by humans that the populations of many wealthy, industrialized societies – including all of Asia and parts of Europe – have been shrinking in recent decades. Researchers and policymakers who have been concerned with population growth rates and aging populations would benefit from a consideration of life history theory and, more generally, evolutionary biological perspectives.

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