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**Evolutionary Contributions to the Study of Human Fertility**

Rebecca Sear, London School of Hygiene and Tropical Medicine

**Abstract**

Demography, lacking an overarching theoretical framework of its own, has drawn on many other social sciences to provide theoretical insights which have informed its analyses. Here my aim is to bring to the demographic community’s attention work in the evolutionary sciences on fertility, and demonstrate that evolutionary theory can be another useful tool in the demographer’s toolkit. I first dispel some myths which impede the incorporation of evolutionary theory into demography, by making clear that evolutionary explanations for demographic behaviour do not assume that all human behaviour is hardwired and functions to maximise genetic fitness; are able to explain variation in human behaviour; and are not necessarily alternatives to social science explanations. I then describe the diversity of work on fertility by evolutionary researchers, particularly human evolutionary ecologists and cultural evolutionists, and illustrate the usefulness of the evolutionary approach with examples on age at first birth, and the fertility transition.

Running title: evolutionary demography and fertility

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**Introduction**

“*Evolutionary demography is best viewed not as an alternative to traditional approaches but as a general theoretical framework that can inform and enhance existing research endeavors.”* (Kaplan and Lancaster 2003)

My aim in contributing to this volume on the ‘long view’ of demography is to describe how evolutionary theory can help inform studies of demographic patterns, particularly fertility. Burch (2003) has argued that demographers need to become more comfortable with the idea of using several different theoretical models for the same phenomenon. Demography is the most biological of the social sciences, dealing with the processes of birth and death, and therefore evolutionary theory is an obvious candidate to become one of the theoretical frameworks which are used to shed light on demographic phenomena. The theory that human behaviour and physiology have ultimately been shaped to maximise reproductive success allows testable hypotheses to be generated, and provides a coherent theoretical framework for analysing human demography. As the quote above from evolutionary anthropologists Hilly Kaplan and Jane Lancaster implies, this does not mean that it is the only theoretical framework which has value in explaining demographic behaviour. Nor do I mean to suggest that all demographic behaviour functions to maximise reproductive success. But given that the human species has evolved through the same process of natural selection as every other species, a complete and holistic understanding of why people have children and why they have the number of children that they do requires input from evolutionary biology.

Demography and evolutionary biology have a long history (Kreager 2009, Sear in press). Darwin was famously influenced by Malthus when developing his ideas on natural selection in the mid 19th century. The two disciplines of demography and evolutionary biology remained closely associated into the early 20th century, but diverged after the Second World War, with demography aligning itself firmly with the social, rather than biological, sciences. This was likely due both to the desire to dissociate demography from the taint of eugenics, which significantly hampered the application of biology to the human sciences during the post-war period, but also perhaps the very rapid changes in demography patterns, particularly fertility, which were occurring in many countries, and which suggested demographic behaviour might have its basis in cultural, rather than genetic, change. Over the last few decades, the two disciplines have begun to successfully reunite (Carey and Vaupel 2005). Much of this new work in evolutionary demography has focussed on the study of mortality, however, so that there is room for more interaction between the two disciplines when it comes to fertility (but see: Low 1993; Rodgers and Kohler 2003; Wachter and Bulatao 2003). Here, I describe work done using an evolutionary framework which can contribute to the understanding of fertility, to bring such work to the attention of demographers. I will start by outlining why evolutionary theory should become a useful part of the demographers’ tool-kit.

**What can evolutionary biology offer demography?**

Demography is an integral part of evolutionary biology (Metcalf and Pavard 2007). Evolutionary biologists work on the assumption that both physiology and behaviour have been shaped by natural selection to maximise fitness (see Ridley 2003 for a textbook introduction). Evolution by natural selection requires that (1) traits are heritable; (2) there is variation in those traits; and (3) that variation is related to differential reproductive success. If these three things hold then those traits which result in higher fitness will spread throughout the population. Fitness in evolutionary biology refers to the representation of genes in future generations: an individual is biologically ‘fit’ if she succeeds in getting many copies of her genes into subsequent generations relative to others in her population. What individuals are actually maximising is ‘inclusive fitness’ – genes passed on to future generations through not only their own reproduction but also the impact of their behaviour on the reproduction of their genetic relatives (Hamilton 1964). A shorthand currency used to define fitness is ‘reproductive success’, most frequently measured as the number of children surviving to reproductive maturity, and I will use this shorthand term ‘reproductive success’ to mean ‘inclusive fitness’ throughout. Reproductive success is a composite of mortality and fertility: individuals must survive long enough to reproduce, and successfully raise these offspring to reproductive maturity. Note, that ‘maximising’ reproductive success does not always mean to produce as many offspring as physiologically possible: in many species, including our own, offspring require substantial post-conception investment from parents to become successful reproductive adults (Lawson and Mace 2011; Sear 2011). Given the central importance of reproductive success to evolutionary biology, Vaupel (2003) has suggested: “*If nothing in biology can be understood except in the light of evolution, an equally valid generalization is that nothing in evolution can be understood except in the light of demography”*.

The dialogue should be two-way, however. Demography can benefit from greater integration with the evolutionary sciences, because they can add a valuable body of empirical work to demography. The top-down, theoretically motivated, approach of evolutionary biology means that the human evolutionary sciences are very diverse, interdisciplinary and comparative. In order to answer the theoretical questions that interest them, evolutionary scientists work on both physiological and behavioural aspects of fertility; they draw on a number of disciplines, including not just biology, but anthropology and psychology; and they take a comparative approach to fertility, including both cross-species and within-species, cross-population comparisons. This approach, therefore, can add a broader perspective to the ‘object science’ of demography, which tends to focus on empirical observations first and causal explanations later (Carey 1997; Coleman 2000). Most importantly, however, evolutionary biology can provide a theoretical framework to help interpret demographic phenomena. Demography has been described (by its own practitioners) as being a discipline without a theory (Wunsch 1995, Tabutin 2007). Concern with this lack of theory (Crimmins 1993) has led to the incorporation of helpful theoretical frameworks from elsewhere, such as the successful union of economics and demography (Sigle-Rushton 2014), and the emergence of anthropological demography (Kertzer and Fricke 1997; Coast et al. 2007). Evolutionary biology is another theoretical framework which has the ability to generate new hypotheses and fresh ideas, and lead to a more holistic understanding of demographic phenomena (Carey and Vaupel 2005; Wachter 2008). Evolutionary theory *can* be used to help explain human demography – we have evolved through exactly the same process of natural selection as has every other species, and it is vanishingly unlikely that human demographic processes can be explained entirely without reference to evolved physiological and behavioural mechanisms – and if a *holistic*, complete understanding of demographic processes at every level is required, then evolutionary theory must be included as part of the framework.

With respect to fertility, there is still much that is not understood by demographers about what shapes fertility levels and trends. Here, theoretical frameworks can be enormously useful in helping fill in the gaps in understanding. Further, the question of ‘why do people have children?’ appears to be only answerable by including an evolutionary perspective. Children score relatively badly when it comes to helping their parents maximise the currencies that people are typically supposed to maximise – health (Ronsmans and Graham 2006), wealth (Kaplan 1994) and happiness (Kohler et al. 2005) – yet the majority of individuals still choose to have children, even in societies where they have free access to effective methods of contraception (Coleman 2000; Morgan and King 2001). The only possible explanation is that we have evolved physiological and behavioural mechanisms which result in the production of children, despite the high costs involved, because that is the primary way to achieve reproductive success.

**What is evolutionary demography and what is it not?**

Here I’ll define evolutionary demography as the application of evolutionary theory to demography: this approach starts with the assumption that physiology and behaviour have largely been shaped by natural selection to maximise fitness. From this framework, testable hypotheses can be generated to inform our understanding of demographic patterns. The assumption that human demographic patterns can be explained using an evolutionary framework is still somewhat controversial, since it is often assumed within the social sciences that humans’ reliance on social learning and cultural transmission of behaviours has resulted in our behaviour becoming entirely decoupled from fitness considerations. I believe this viewpoint stems from several misunderstandings of the evolutionary approach, and attempt to dispel these myths below:

1. *Evolutionary demographers are not genetic determinists*

The first misconception is that any trait which has a genetic basis is fixed and immutable. This is problematic for many social scientists since it does not fit with empirical observations of the flexibility of human behaviour. It is true that to take an evolutionary approach entails a commitment to the hypothesis that there is some genetic basis to the traits under study (both physiological and behavioural traits), but it does not entail committing to the idea that such traits are rigidly determined by genes. An individual’s phenotype (her observable physiological and behaviour traits) is determined by the interaction of her genotype with her environment. Evolutionary demographers therefore do not consider human traits to be fixed and immutable, but that they can be influenced by a change in environment: in biological jargon, this is known as phenotypic plasticity. This plasticity has arisen through natural selection to allow individuals to respond adaptively to the environment, and is not entirely unconstrained and unpredictable, but flexible in predictable ways. For example, in well-nourished populations, girls reach menarche relatively early; in poorly-nourished populations, average age at menarche is later. But there is still a relatively narrow range of ages at which girls reach menarche: there is no population where the average age of menarche is 30 years, nor 3 years of age (Morabia and Costanza 1998).

The evolutionary research I describe below is mostly agnostic about exactly what the link between genes and phenotype looks like: this is known as the phenotypic gambit (Grafen 1984). Some social scientists are perfectly happy with the idea that there is some link between genes and physiology, so that human physiology may have been shaped by natural selection, but argue that human *behaviour* is entirely determined by social learning, and has therefore been severed from genetic influence. This argument suggests that behavioural aspects of fertility are beyond the remit of the evolutionary sciences. I disagree: natural selection shapes behaviour just as it does physiology, and evolutionary demography allows for the influence of both environment and social learning in shaping human behaviour. This is illustrated in Figure 1, which compares the standard social science model of how human behaviour is transmitted between generations to that of the contemporary evolutionary behavioural sciences. The evolutionary approach takes into consideration both the genetic and social transmission of behaviour: in social animals, learning from other individuals may be the most efficient mechanism for matching behaviour to the environment (Rendell et al. 2010). It may be easier, for example, for a chimpanzee to learn how to make a fishing-rod for termite fishing by watching and copying the behaviour of another chimpanzee, rather than for every chimpanzee to reinvent the process of turning a branch into a termite fishing rod (Whiten 2005; Whiten et al. 2007). Social learning is then a mechanism by which adaptive behaviour can be brought about.

1. *Evolutionary demographers are not blindly adaptationist*

Another popular misconception is that evolutionists blindly assume every human trait to be perfectly adapted to its current environment to achieve the goal of maximising reproductive success. This is problematic, since it does not fit with empirical observations of human behaviours which appear to be maladaptive. But no evolutionary biologist assumes that all traits are perfectly formed adaptations to current environments. First, there are processes which influence the evolution of traits other than natural selection. ‘Evolution’ simply means change over time. Evolutionary biologists assume that natural selection is the mechanism by which most traits have arisen, but still allow for evolution within populations due to other processes. ‘Genetic drift’ is the process by which gene frequencies change in populations simply by random chance, for example. Transmission of behavioural traits through social learning is another process which might lead to shifts away from adaptive behaviour, since socially learned behaviours have the potential to mutate and spread more rapidly through populations than genetic change. Second, there are a variety of constraints which may prevent the ideal adaptation arising: for example, natural selection has to build on the characteristics already present in an organism, and cannot create perfect adaptations from scratch. Third, a recent change in environment may lead to previously adaptive behaviour becoming maladaptive in the new environment. This may be particularly relevant to our species, given the rapid changes in our environment that we have orchestrated in recent centuries.

The acknowledgement that not all human traits are adaptations to current environments does not mean an evolutionary approach is worthless. The assumption that most human traits evolved as adaptations designed to increase fitness in past environments is a valuable heuristic to use as a *starting point* when studying many facets of demography. Even in low fertility societies, where individuals do not seem to be maximising their fitness, our demographic behaviour may still be influenced by mechanisms which were adaptive in the past: social learning arose via natural selection, and our brains – which are the organs from which social learning emerges – have been shaped by millennia of natural selection to produce adaptive behaviour. Further, we can use evolutionary ideas to explore why individuals are no longer maximising their fitness. If we assume that our behaviour has been shaped to maximise fitness in past environments, then what particular environmental changes have led to a mismatch between our evolved psychological mechanisms and current environments?

Typically, then, evolutionary demographers are not interested in testing whether a particular behaviour is adaptive. Instead they use the overarching theoretical framework that most human traits have been shaped by natural selection to produce adaptive behaviour to test specific hypotheses deriving from this framework such as, is factor X correlated with fertility in this environment? If support is not found for this hypothesis, then details of the hypothesis are reconsidered, without necessarily throwing out the evolutionary framework altogether (Parker and Maynard Smith 1990). There are sometimes exceptions to this rule, however, the obvious one being the fertility transition: it is an evolutionary puzzle that fertility begins to decline as wealth increases in populations all across the world, as individuals are expected to direct any resources they have towards maximising their reproductive success (Borgerhoff Mulder 1998). Evolutionists have been actively engaged in exploring this puzzle (Kaplan et al. 2002; Shenk 2009). Much of this analysis would be very familiar to mainstream demographers: evolutionists have investigated the role of the economic costs and benefits of children (Lawson and Mace 2009; Gibson and Sear 2010; Lawson and Mace 2011), and of cultural transmission in the spread of fertility behaviour (Mace et al. 2006; Alvergne et al. 2011), or both (Borgerhoff Mulder 2009; Shenk et al. 2013; Snopkowski and Kaplan 2014). Some of this analysis is less common in demography: evolutionists have actively explored, empirically (Kaplan et al. 1995; Goodman et al. 2012) and mathematically (McNamara and Houston 2006), whether such behaviour may be adaptive in terms of long-term lineage fitness, and have proposed that our evolved predispositions towards accumulating wealth and status are misfiring in current environments, where large family sizes adversely affect such acquisition (Borgerhoff Mulder 1998). Even if behaviour is not adaptive in its current environment, it can still be studied within an evolutionary framework.

1. *Evolutionary demographers do not ignore human diversity*

The misconception that evolutionists are only interested in explaining the evolution of species-typical traits may lead to the assumption that evolutionary demographers have nothing of interest to say to social scientists, who are frequently interested in explaining human variation. While some human evolutionary research does fall into this category (for example work on the evolutionary puzzle of menopause: why do women become unable to produce any more children just halfway through their potential lifespans?: Hawkes et al. 1998; Shanley and Kirkwood 2001; Shanley et al. 2007; Alberts et al 2013), most of the human evolutionary sciences are explicitly engaged in explaining human diversity, for the obvious reason that there is considerable variation in our species to explain. The key to our success as a species may in fact be our behavioural flexibility, enabling us to colonise a range of environments, using a range of different subsistence strategies (Wells and Stock 2007).

1. *Evolutionary demographers do not assume individuals are consciously trying to maximise their reproductive success*

One problem for evolutionists working on our species is that their subjects have the ability to reflect on their own behaviour. A frequent objection against evolutionary theories is that it is blatantly obvious that the desire for genetic representation in future generations is not a conscious rationale used for any human behaviour. This objection hinges on the very big assumption that human behaviour is driven by conscious thought. Evolutionists are typically agnostic on this point. Every other species manages to maximise its reproductive success without conscious thought: clearly, humans must be able to do the same. When evolutionary scientists use agentic terms such as ‘strategies’, therefore, this is not intended to refer to conscious strategies.

1. *Evolutionary explanations are not necessarily alternatives to social explanations*

Perhaps the largest impediment to the integration of the evolutionary and social sciences is the assumption that evolutionary and social sciences are engaged in a zero-sum game, and that evolutionary and social explanations are alternatives and cannot co-exist (Carey and Vaupel 2005). But to propose an evolutionary explanation for a given phenomenon is not to claim that any explanation provided by social science is invalid. Traits can be explained at several different levels. Evolutionary explanations stem from an interest in explaining the ‘ultimate’ function of that trait in evolutionary terms: how does this trait serve to maximise fitness? Traits can also be explained using proximate explanations: what are the processes (behavioural, cultural, societal) which bring about this particular trait? Much social science focuses on these proximate explanations without being interested in whether the behaviour they observe serves an ultimate function in terms of maximising reproductive success. Many evolutionists are also interested in studying proximate mechanisms, but this research is guided by the framework that there is, or was, an ultimate, fitness-maximising motivation behind these proximate processes. Sometimes evolutionary and social science theories do make different predictions, and explicitly testing alternative hypotheses against one another can prove extremely fruitful in moving forward our understanding of a particular behaviour (Kaplan 1994). But for much of the time, evolutionary and social scientists are interested in explaining behaviour at different levels (ultimate versus proximate), so that many social science explanations for behaviour in no way obviate the possibility that there may also be an ultimate explanation for the behaviour, in terms of it maximising that individual’s fitness.

**Evolutionary approaches to fertility**

In this section I will briefly describe evolutionary approaches to the study of fertility, but will concentrate on research which has focused on the second and third requirements of natural selection (see p3): investigations of how *phenotypic* traits differ between individuals and how this variation is linked to differential reproductive success. This work largely comes from the evolutionary behavioural sciences, though not all the work I describe can be considered behavioural science, as many evolutionists are comfortable moving between both behavioural and physiological aspects of fertility (see Laland and Brown 2011 for an introduction to the evolutionary behavioural sciences; see also Wilson 1999 and Barthold et al 2012 for examples of demographers bringing evolutionary theory into their work on fertility). Some work on demographic phenomena has explicitly attempted to characterise links between genes and phenotypes. For example, the field of behaviour genetics attempts to quantify the heritability of traits, frequently using twin studies (Hughes and Burleson 2000). Work in this area has suggested that a number of demographically relevant traits are partly genetically inherited: these include age at first birth, age at first attempt to have children and number of children, and also traits linked to fertility, such as age at menarche, and sexual behaviour (see reviews in Rodgers et al. 2000; Kohler et al. 2006; but see Vetta and Courgeau 2003 for a critique). A number of previous articles have articulately made the call to include genetic research in demography and related social sciences (Freese et al. 2003; Hobcraft 2006), so here I will only describe work done on fertility by evolutionary scientists investigating this issue phenotypically. I will divide this research into that which has focused on questions of function (how does this trait serve to maximise fitness?) and those which focus on mechanism (what are the physiological, psychological and cultural mechanisms which brings about the trait under study?).

*Questions of function: what factors are correlated with fertility?*

There has been a considerable amount of research in the evolutionary social sciences directly analysing fertility, largely undertaken by human evolutionary ecologists (human behavioural ecologists is a more commonly used term, but this only refers to the study of behaviour. I use here the broader term of human evolutionary ecology which includes the study of both behavioural and physiological traits). This section of the evolutionary sciences is interested in investigating adaptive behaviour and physiology in its ecological context (seeSmith 1992; Winterhalder and Smith 2000; Nettle et al. 2013 for overviews ), *i.e.* investigating the function of particular traits (where function means the purpose for which it evolved in evolutionary terms). Here ecological context is interpreted in the broadest possible sense to mean not just the physical environment but social and cultural context too. Human evolutionary ecology puts particular emphasis on ecological(=environmental) influence, and how this interacts with the genotype to produce phenotypes, and is therefore particularly interested in explaining human variation. The bread and butter of human evolutionary ecology is to investigate what causes variation in reproductive success, to the extent that it has been given the nickname within the evolutionary sciences of ‘baby-counting’. This is a particularly rich area, then, for demographers to look for inspiration and points of common interest in the study of fertility.

The main theoretical framework of human evolutionary ecology is life history theory (Stearns 1992; Stearns 2000; Roff 2002). Life history theory is the branch of evolutionary theory concerned with the allocation of energy over an individual’s life course, and how this energy is allocated between the main functions of survival, reproduction and growth. It is based on the principle of allocation, which states that energy used for one purpose cannot be used for any other purpose. This principle leads to the expectation of trade-offs; for example, trade-offs are expected between survival and reproduction, and between growth and reproduction. Energy devoted to reproduction must then be divided between that devoted to obtaining a mate(s) and that invested in offspring; between current and future offspring; and between quantity and quality of offspring. Though life history theory is framed in terms of energetic allocation between traits, the outcomes of these trade-offs are frequently observed at the behavioural level. Further, there is growing recognition of the importance of social, particularly intergenerational, transfers in the evolution of life history patterns (Kaplan and Robson 2002; Chu and Lee 2006). Each human, for example, doesn’t rely only on his/her own energy budget to survive and reproduce but also receives energy transfers from others: this is referred to in some of the evolutionary literature as a ‘pooled energy budget’ (Kramer and Ellison 2010).

From this life history theory framework, predictions are derived which are then tested against data (see Table 1 for examples). What those human evolutionary ecology researchers interested in fertility largely do on a day-to-day basis, therefore, is to empirically analyse variation in fertility – an activity very familiar to most demographers. There are some differences in methodology. Many practitioners of human evolutionary ecology are evolutionary anthropologists, so that much human evolutionary ecology work on fertility has focused on the analysis of data from small-scale, subsistence-level societies, which the researchers may have collected themselves. Often these datasets are large and longitudinal, and have the advantage of providing a rich array of data on relatively homogenous populations (for an early and excellent example of evolutionary demography, see Hill and Hurtado 1996). There are also many similarities between the methods of human evolutionary ecology and demography: there is a growing trend for human evolutionary ecology to make use of the kind of large-scale, nationally-representative datasets familiar to demographers (Nettle et al. 2013), and there has always been a small sub-section of the community working on historical data (Voland 2000). Again, just like demographers, evolutionary scientists in this area occasionally make use of formal modelling approaches to explore their predictions. Further, human evolutionary ecologists have used this framework to develop conceptual models of fertility. Some of the most important evolutionary demography work on fertility has been produced by Kaplan and collaborators, who have used evolutionary theory to provide overarching models of fertility variation (e.g. Kaplan 1996; Kaplan et al. 2002; Kaplan and Lancaster 2003).

There is now a large literature on fertility from human evolutionary ecology: Table 1 lists some examples of questions which have been asked by evolutionary social scientists, with an indication of the methods and settings they have used to answer these questions. Life history theory has a lot to say about the timing of fertility, so that many of these questions relate not just to variation in total fertility, but also on other components of fertility, particularly age at first birth. These examples should illustrate the breadth of human evolutionary ecology research on fertility. Questions asked range from those focused on physiology (is a trade-off visible between growth and age at first birth, i.e., do girls who are taller in adulthood have later first births than those who are shorter?), through classic life history trade-off questions (are there trade-offs between fertility and child survival, or between current and future reproduction?), to questions familiar to many social scientists on relationships between socio-economic factors and fertility (do wealthier individuals have higher fertility? Do girls who suffer socioeconomic adversity in childhood have earlier first births?). While some of these questions may be familiar to social scientists, their aetiology may differ: questions on whether kin influence fertility, for example, stem from a hypothesis currently popular in evolutionary anthropology that humans are ‘cooperative breeders’, *i.e.* that mothers require help to raise expensive human children, either from fathers of their children and/or other members of their family and social group (Hrdy 2005, 2009; Kramer 2010).

*Questions of mechanism: what physiological, psychological or cultural mechanisms cause fertility to vary?*

Human evolutionary ecology is interested in the distal or ultimate explanations for fertility patterns, but tends to ignore the mechanisms through which variation in fertility may be brought about. There are some sections of the evolutionary human sciences interested in exploring these proximate mechanisms, which can broadly be divided into sub-disciplines interested in physiological, psychological and cultural (i.e. social learning) mechanisms.

First, reproductive ecology is the study of how reproductive physiology responds to its ecological context, particularly focused on the hormonal regulation of fertility (Ellison 2003; Vitzthum 2008). Reproductive ecology is a largely empirical discipline, which also uses the framework of life history theory, and its research has been guided by the expectation of trade-offs such as that between survival and reproduction. For example, it has shown that female reproductive hormones calibrate reproduction to energy availability by responding to both energy balance and energy ‘flux’, a measure of the rate of energy change (see Table 1), thereby ensuring reproduction is only attempted when the extra energetic demands of pregnancy and lactation will not prove too costly to the woman’s own health. It is also a field, somewhat unusual in reproduction research, which has not neglected men: there is now a substantial body of research on how both female and male reproductive hormones vary between and within societies (Bribiescas 2001; Vitzthum 2009b). Reproductive ecology has also explored the predicted trade-off between mating and parental effort by testing whether men’s hormonal profiles respond to partnering and fatherhood, finding evidence that testosterone may mediate a shift from mating effort to parenting effort in men (Gray and Campbell 2009).

Second, evolutionary psychology is the branch of psychology which assumes that the mind has been shaped by natural selection (Dunbar and Barrett 2007; Swami 2011). To understand fertility behaviour at all levels, an understanding of the proximate psychological mechanisms which drive fertility decisions is needed (Hobcraft 2006). So far there has been little research in evolutionary psychology on fertility, despite a substantial literature on mate preferences, which is relevant to fertility, though there have been few attempts to link research on mate preferences to partnership choices or fertility decisions (Sefcek et al. 2007). There have, however, been a handful of studies which have shed some light on evolved psychological mechanisms surrounding reproduction (see Table 1). Evolutionary psychology is an almost entirely empirical discipline, and is also unusual among the evolutionary social sciences in focussing largely on what are known in the discipline as WEIRD populations: Western, Educated, Industrialised, Rich and Democratic (Henrich et al. 2010). While some research has used surveys to explore possible psychological mechanisms which influence fertility – such as correlations between personality traits and fertility – much psychological research uses methods less known in demography, including lab- or internet- based experimental research.

Finally, some researchers in the field of cultural evolution (Whiten et al. 2011) are interested in how social learning and cultural influences affect fertility (see Table 1 for examples). This interest was evident in some of the earliest works in cultural evolution, which suggested that cultural transmission could help explain the fertility transition (Cavalli-Sforza and Feldman 1981). This is the area of the evolutionary social sciences most comfortable with the idea that human behaviour can be decoupled from classic Darwinian natural selection. As well as being interested in how behaviours are learned socially, researchers in this field also study how cultures evolve (through a process analagous to, but not necessarily driven by, genetic evolution: Mesoudi et al. 2004), and some espouse the idea of selection at the level of the cultural group, not just the gene (Boyd and Richerson 2002; Henrich 2004). Some researchers in the field are also interested in feedback loops between behaviour and both genetic and cultural change. Known as ‘niche construction’, this is the idea that humans (or other animals) are able to change their own selection pressures by changing their environment; new adaptations then arise to fit this new environment, either through genetic or cultural change (Laland et al. 2001).

This field has clear parallels in some of the demographic literature on the cultural spread of low fertility, but cultural evolution also has the ability to provide some fresh insights on fertility. Cultural evolution research on social learning, for example, is interested both in *how* people learn from others, and *what* they learn from others. Unlike the blank slate model favoured by some social scientists, where babies are assumed to be born capable of learning pretty much anything, cultural evolution considers how social learning is constrained by both content biases (*i.e.* what we learn is not random) and transmission biases (*i.e.* how we learn is not random) (Rendell et al. 2011). Common transmission biases are considered to be (1) prestige bias, where we are more likely to learn from prestigious or high status individuals, and (2) conformity biases, where we are likely to copy the most common behaviour. Both biases are thought to stem from adaptive heuristics, for example, learning from high status individuals may result in the acquisition of behaviours which lead to high status. These prestige transmission biases have been proposed as part of the explanation for fertility decline (Boyd and Richerson 1985). This hypothesis was proposed as a conceptual model which has been modelled mathematically but not tested rigorously empirically, as is true of much cultural evolution work on fertility, leading to the potential for dialogue between demographers and cultural evolutionists if the empirical expertise of demographers can be harnessed to test the models of cultural evolution (see Mesoudi and Whiten 2008 for examples of how empirical work on transmission biases has been used in other areas of cultural evolution). This may be a particularly beneficial area in which for social and evolutionary scientists to interact, since cultural evolution works on the very social processes of key concern to so many social sciences.

**How might evolutionary research on fertility be used to inform demography?**

Table 1 demonstrates that many of the questions evolutionary demographers ask, and the methods they use, are similar to those common in demography, though evolutionary demography also has some different interests and methodologies. Empirically, then, evolutionary demography can add pieces to the puzzle of why fertility varies. It can also add to the diversity of knowledge on fertility given evolutionary demography’s ability to move across disciplines (across the physiological, psychological and cultural causes of fertility variation) and across different kinds of populations, from low population-density, subsistence-level, high fertility communities to high-density, high-income and low fertility populations. The concern of evolutionary demographers with ultimate function can also help provide a unifying and holistic framework which answers questions to which demographers as yet have no answer, though this may be in some cases because they have not yet asked the question. Broadly speaking, evolutionary demography is interested in asking ‘why’ questions, whereas demography is interested in ‘how’ questions. There are times when evolutionary biology may be able to fill in gaps by taking a step back to understand why demographic phenomena are patterned as they are, rather than how variation in demographic phenomena is brought about. This was the case in the study of mortality, when demographers turned to biologists to help them explain the puzzle of mortality patterns at advanced ages, which standard demographic methods were stumped by (Vaupel 1997). To give a fertility example: demographic research on the cultural transmission of fertility has been criticised for only providing a mechanism by which low fertility spreads, but not explaining *why* low fertility should arise and spread through social networks (Pollak and Watkins 1993). The cultural evolutionists Boyd and Richerson (1985) have proposed that prestige bias may be part of the answer to this question. The typically positive relationship between status and fertility may reverse in modernising populations, for example, if lengthy periods in education become necessary to achieve status, so that only individuals with few children may achieve high status. Prestige bias may then result in other individuals copying this low fertility of high status individuals, which leads to the spread of low fertility.

An evolutionary perspective may also help explain why other social science models sometimes fail to fully explain human behaviour, perhaps because humans behave in ways that do not appear to be ‘rational’, such as not always maximising wealth or wellbeing. Natural selection has ultimately shaped us to maximise our genetic fitness, which may sometimes lead to behaviour which will not maximise health or wealth. For example, in contemporary industrialised populations, there is a clear link between low socio-economic status or childhood adversity and early childbearing. One school of thought suggests that such early childbearing is likely to damage the potential to invest in one’s own education and employment prospects (McLanahan 2004), implying that such early childbearing should be discouraged. A line of evolutionary research instead considers that early childbearing is perfectly rational within a fitness-maximising framework, as a strategic response to indicators of adversity, which in past environments would have been correlated with a high risk of dying before being able to successfully complete reproduction (Johns et al. 2011; Nettle 2011).

There are also times when evolutionary biology may be able to provide an extra layer of explanation which unifies existing work, to give a holistic account of fertility variation. For example, economic demographers are largely content with models of fertility which assume individuals will maximise some utility based on cost-benefit functions, though exactly what utility is being maximised may vary between models. An evolutionary perspective can add a further layer of explanation which states that the currency which individuals are ultimately maximising is fitness, and that other utility maximisation rules (of which there may be many) were designed in the service of maximising fitness.

**Conclusion**

This brief survey has only been able to scratch the surface of work relevant to fertility in the human evolutionary sciences, but I hope it has demonstrated that much work of interest to demographers exists. This work may be unfamiliar to many demographers because relatively little of it has been published in demography journals or done by researchers who characterise themselves as demographers. This survey should have demonstrated that evolutionary demography is not just interested in physiological processes or biomarkers, but that the evolutionary social sciences can contribute significantly to an understanding of how social and cultural processes shape demographic patterns too. Perhaps the key difference between evolutionary and demographic approaches is that demography is a ‘bottom-up’ discipline primarily interested in data (and much data description and analysis can be done without reference to theory), while evolutionary biology is a ‘top-down’, theoretically-motivated discipline (in which data is a means to an end: Kaplan and Gurven 2008). Despite these different approaches, there are questions in which both disciplines are interested, so that greater communication between evolutionary and demographic researchers has the potential to benefit both sides, and provide a holistic understanding of how and why fertility varies between and within populations.

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**Figure 1:** Models of the transmission of behaviour in standard social science and the contemporary evolutionary behavioural sciences (redrawn from Brown et al 2011)

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**Table 1:** aselection of studies on fertility from the evolutionary social sciences

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| --- | --- | --- | --- |
| **Research question** | **Methods** | **Setting** | **Reference** |
| ***Questions concerning function: what factors influence fertility?*** |  |  |  |
| Do wealthier men and women have higher fertility, and does this relationship vary across populations? | Analysis of both large- and small-scale survey data | Numerous, high- and low-income settings | Reviews in Low (2000); Nettle and Pollet (2008) |
| Do development interventions which lighten women’s workloads increase fertility?  | Analysis of small-scale survey data | (1) Ethiopian agro-pastoralists, (2) Mexican agriculturalists | (1) Gibson and Mace (2002, 2006), (2) Kramer and McMillan (1999) |
| Is there a trade-off between current and future reproduction? | Analysis of longitudinal small-scale survey data | Gambia | Sear et al. (2003b) |
| Do kin influence fertility outcomes? | Analysis of small-scale, historical and nationally representative data | (1) Gambia, (2) historical Poland, (3) UK British Household Panel Survey | (1) Sear et al. (2003a), (2) Tymicki (2004), (3) Mathews and Sear (2013a, 2013b)  |
| Does childhood adversity correlate with earlier first births? | Analysis of nationally representative data  | UK (1) Millennium Cohort Study, (2) National Child Development Survey | (1) Nettle (2010), (2) Nettle et al. (2011) |
| Do short women have relatively early first births? | Analysis of large-scale and small-scale survey data | (1) US Wisconsin Longitudinal Study, (2) Finland, (3) Gambia | (1) Stulp et al. (2012), (2) Helle (2008), (3) Allal et al. (2004) |
| Is polygyny correlated with fertility? | Analysis of small-scale survey and historical data | (1) Kenyan agro-pastoralists, (2) Tsimane forager-farmers, (3) historical Utah | (1) Borgerhoff Mulder (1989), (2) Winking et al. (2013) ,(3) Josephson (2002) |
| Is there a trade-off between fertility and child survival, and what factors affect its magnitude? | Analysis of both small-scale survey and nationally representative data | (1) Malian agriculturalists, (2) Ghana, (3) 27 sub-Saharan Demographic and Health Surveys | (1) Strassmann and Gillespie (2002), (2) Meij et al. (2009) (3) Lawson et al. (2012) |
| Does paying child support reduce men’s subsequent fertility? | Analysis of nationally representative data | US, Panel Study of Income Dynamics | Anderson (2011) |
| Are the economic costs and benefits of children, ecological risk factors, or cultural transmission better predictors of fertility in transitioning populations? | Analysis of survey data | (1) India, (2) Bangladesh | (1) Shenk (2009), (2) Shenk et al. (2013) |
| Does male contribution to diet in traditional societies increase fertility?  | Population-level analysis | 161 foraging societies | Marlowe (2001) |
| Is subsistence strategy correlated with fertility? | Population-level analysis | Numerous subsistence-level societies  | Bentley et al. (1993) |
| When to have another baby? | Mathematical model, based on household wealth and existing family size and gender composition | Model based on parameters derived from survey of North Kenyan pastoralists | Mace (1996) |
| ***Questions concerning mechanism*** |  |  |  |
| *Physiological* |  |  |  |
| Does ovarian function vary with ecological conditions? | Hormonal assays | Multi-country study, including high and low fertility populations | Ellison et al. (1993) |
| Does the age-related decline in testosterone vary between populations? | Hormonal assays | Multi-country study (US, Congo, Nepal, Paraguay) | Ellison et al. (2002) |
| Are breast-feeding practices or maternal energy budget stronger correlates of the resumption of postpartum fecundity? | Hormonal assays | Argentina | Valeggia and Ellison (2004) |
| Are reproductive hormones negatively correlated with energetic expenditure (even in the absence of low energy intake)? | Hormonal assays | Polish farmers | Jasienska and Ellison (1998)  |
| Does developmental experience influence levels of reproductive hormones in adulthood? | Hormonal assays, making use of natural experiment of international migration | Bangladesh and UK | Núñez de la Mora et al. (2007) |
| Are testosterone levels lower in partnered men and fathers than non-partnered, non-fathers? | Hormonal assays of (1) Cross-sectional, (2) Longitudinal data | (1) Numerous studies in both high- and low-fertility countries, (2) Philippines | (1) Reviewed in Gray and Campbell (2009), (2) Gettler et al. (2011) |
| Do anovulation rate and early pregnancy loss vary seasonally? | Hormonal assays | Bolivia | Vitzthum (2009a) |
| *Psychological* |  |  |  |
| Do women or men experience ‘baby fever’, a conscious longing for children? | (1) Qualitative analysis, (2) Analysis of survey data | Finland | (1) Rotkirch et al. (2012), (2) Rotkirch (2007) |
| Does personality influence fertility? | Analysis of survey data  | (1) US, (2) Senegal | (1) Jokela et al. (2011), (2) Alvergne et al. (2010)  |
| Does mortality priming increase fertility intentions? | (1) Internet experiment, (2) Lab experiment | (1) UK university students, (2) US university students | (1) Mathews and Sear (2008), (2) Griskevicius et al. (2011) |
| Is exposure to the deaths of acquaintances or close friends/family associated with lower intended or actual age at first birth?  | Online (SocialSci) survey | US | Pepper and Nettle (2013)  |
| Does an interest in infants mediate the relationship between socio-economic environment and adolescent girls’ intended timing of first reproduction? | Small-scale survey | UK adolescents | Clutterbuck et al. (2014) |
| *Cultural* |  |  |  |
| Do social norms become less pro-natal as societies modernise and social networks become less kin-oriented? | (1) Conceptual model, tested with (2) lab experiment of social influences on reproductive attitudes | (2) UK  | (1) Newson et al. (2005), (2) Newson et al. (2007) |
| Does contraceptive uptake spread through friendship or spatial networks? | Analysis of cross-sectional survey | Ethiopia | Alvergne et al. (2011) |
| Does cultural niche construction influence the spread of fertility norms? | Mathematical models |  | Ihara and W. Feldman (2004); Kendal et al. (2005) |
| Does community-level education accelerate fertility decline? | Analysis of small-scale survey data | Rural Poland | Colleran et al. (2014) |