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Desire, Marriage, and Overpopulation: The Sexual Lives of Insects in the Enlightenment

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ABSTRACT: During the eighteenth century, the discovery of sexual reproduction in insect species prompted the demise of spontaneous generation and new developments in natural history, theology, and political economy. The sexual lives of insects prompted debates on whether insects were governed by desire, free will, and even marital tendency. Fuelled by the democratisation of microscopy, early modern entomology took a new turn and breadth: the study of insects and of their sexual lives provided unexpected new insights into human sexuality, reproduction, and Malthusian fears of overpopulation. This article surveys the intellectual culture of entomology and natural history during the crucial decades when entomologists worked to quantify the reproductive capacities of insect species. Assessing the influences these entomological works had within political economy and theology, we argue that the sexual lives of insects – once analysed and delineated – influenced familiar ideological features of the intellectual landscape of the late Enlightenment, particularly in the theological philosophies of northern Europe and in the political economy of population in Britain.

KEYWORDS: Entomology – Malthus – Natural history – Political economy – Enlightenment – Sexuality

DÉSIR, MARIAGE, ET SURPOPULATION: LA SEXUALITÉ DES INSECTES DURANT LES LUMIÈRES

RÉSUMÉ: *Au XVIIIe siècle, la découverte de la reproduction sexuée chez les insectes précipita le déclin de la doctrine de la génération spontanée, et entraîna de nouveaux* *développements au sein de l'histoire naturelle, de la théologie, et de l'économie politique. Les insectes étaient-ils dès lors sujets au désir, au libre arbitre, voire à l'instinct matrimonial ? Alimentée par la démocratisation de la microscopie, l'entomologie prit un nouvel essor et une nouvelle ampleur au cours de la première modernité : les études des insectes et de leurs sexualités apportèrent de nouveaux éclairages sur les sexualités humaines, la reproduction, et les angoisses malthusiennes de surpopulation. Cet article explore la culture savante de l'entomologie et de l'histoire naturelle au cours de décennies cruciales pendant lesquelles les entomologistes travaillèrent à la quantification des capacités reproductives des insectes. Par une analyse de l'influence qu'eurent ces travaux entomologiques dans les champs de la philosophie naturelle, de la théologie, et de l'économie politique, nous montrons que la sexualité des insectes, une fois définie et catégorisée, influença de nombreux aspects familiers de la culture savante et intellectuelle des Lumières, des théologies philosophiques du nord de l'Europe à l'économie politique des populations en Grande-Bretagne.*

Mots-clés : *Entomologie – Malthus – Histoire naturelle – Économie politique – Lumières – Sexualité*

BEGIERDE, HEIRAT UND ÜBERBEVÖLKERUNG: DAS SEXUELLE LEBEN DER INSEKTEN IN DER AUFKLÄRUNG

Zusammenfassung: *Im 18. Jahrhundert führte die Entdeckung der sexuellen Fortpflanzung bei Insekten zum Niedergang der Lehre von der Spontanzeugung und zu neuen Entwicklungen in der Naturgeschichte, der Theologie und der politischen Ökonomie. Hatten Insekten nun Lust, einen freien Willen oder sogar einen Heiratsinstinkt? Dank der Demokratisierung der Mikroskopie erlebte die Entomologie in der frühen Moderne einen neuen Aufschwung und eine neue Dimension: Das Studium der Insekten und ihrer Sexualität lieferte neue Erkenntnisse über die menschliche Sexualität, die Fortpflanzung und die malthusianischen Ängste vor Überbevölkerung. Dieser Artikel untersucht die Gelehrtenkultur der Entomologie und Naturgeschichte in den entscheidenden Jahrzehnten, in denen Entomologen an der Quantifizierung der Fortpflanzungsfähigkeit von Insekten arbeiteten. Durch eine Analyse des Einflusses, den diese entomologischen Arbeiten auf die Naturphilosophie, Theologie und politische Ökonomie hatten, wird gezeigt, dass die Sexualität der Insekten, sobald sie definiert und kategorisiert war, viele vertraute Aspekte der gelehrten und intellektuellen Kultur der Spätaufklärung beeinflusste, von den philosophischen Theologien Nordeuropas bis zur politischen Ökonomie der Bevölkerung in Großbritannien.*

Schlagworte: *Entomologie – Malthus – Naturgeschichte – Politische Ökonomie – Aufklärung – Sexualität*

欲望、婚姻，和人口超量：启蒙年代的昆虫性生活

摘要：在18世纪时新发现的昆虫有性生殖，引发了自然发生论的消亡，以及在自然史、神学与政治经济学里全新的发展。其亦引致昆虫是否受性欲、自由意志甚至婚配倾向所引导的讨论。显微镜的普及使早期昆虫学获得深广的发展：研究昆虫及其性事，为人类的性事、生殖和马尔萨斯式的人口超量恐惧等课题带来新的洞见。本文检视在学者致力量化昆虫生殖能力的关键年代里，昆虫学和自然史的知识文化。评量这些昆虫学研究对政治经济学与神学的影响后，我们主张昆虫的性生活——在分析与界定后——确实影响了启蒙晚期知识地景中与此相关的意识形态特征，特别是在北欧神学哲学与英国人口政治经济学等方面。

关键字：昆虫学、马尔萨斯、自然史、政治经济学、启蒙时代、性事

ESQUISSE

L'article explore l'impact et les contours de la découverte de la reproduction sexuée chez les insectes au cours de la première modernité. À travers une analyse de la culture savante de l'entomologie des Lumières, il révèle notamment l'étendue des applications des débats sur la reproduction sexuée des insectes, au sein de champs aussi divers que la philosophie naturelle, la théologie, la loi naturelle, la démographie humaine et l'économie politique. Il est structuré en cinq sections.

Dans un premier temps, nous montrons comment les angoisses malthusiennes de surpopulation humaine émergèrent dans un contexte de vives discussions sur les capacités de reproduction sexuelle des insectes. Celles-ci, en apparence quasi illimitées, mues par le désir et incontrôlables, alimentèrent les parallèles avec la sexualité intempérante des classes laborieuses, renforçant l'idée que celles-ci représentaient un risque existentiel pour la société.

Nous explorons dans la deuxième partie comment la découverte de la reproduction sexuée chez les insectes précipita le déclin des théories de la génération spontanée. Cette transition, alimentée par la démocratisation graduelle de la microscopie, ne fut ni uniforme ni évidente, et entraîna de manière plus large une reconfiguration importante des concepts de nature et de force reproductive au cours du XVIII^e siècle.

Dans la continuité de cette reconfiguration, la troisième partie se concentre sur l'impact de la découverte dans le domaine religieux. Loin de précipiter la sécularisation de l'entomologie, la sexualité des insectes renouvela au contraire leur statut théologique, leur signification symbolique et morale, ainsi que leur exégèse scripturaire. L'humanisation des insectes via leur réintégration en tant qu'êtres sexués au sein du règne animal posa en outre la question de leur libre arbitre et de leur instinct matrimonial, et vit dès lors la sexualité des insectes servir de couverture critique aux débats sur la loi naturelle dans le paysage trans-confessionnel des Lumières européennes.

Dans la quatrième partie, nous analysons les pratiques culturelles d'observation et de comptabilisation des œufs d'insectes. La quantification et la mathématisation des capacités reproductives des insectes au cours de la période passèrent par un travail fastidieusement minutieux de la part des entomologistes, visant à identifier le nombre de descendants d'un même insecte géniteur au cours de son cycle de vie. Nous montrons que les quantités considérables révélées par ces investigations, non contentes d'alimenter les angoisses de surpopulation humaines, questionnèrent l'existence même d'un équilibre divin au sein du monde naturel.

En complément de cette analyse, nous examinons dans notre cinquième et dernière partie plusieurs cas d'essaims et de nuées d'insectes célèbres qui captivèrent les entomologistes dans la seconde partie du XVIII^e^ siècle. Nous montrons ainsi combien les explications des entomologistes sur l'existence et l'action de ces nuées renouvelèrent les arguments classiques de la théologie naturelle, de la nature du désir sexuel et de la démographie des populations, dans une perspective préfigurant les discours malthusiens.

Nous soulignons en conclusion que, loin de se limiter à une question technique au sein d'un sous-champ de l'histoire naturelle et de la taxonomie, la découverte de la reproduction sexuée chez les insectes entraîna un véritable bouleversement dans de nombreuses disciplines familières du paysage intellectuel des Lumières. La question entraîna un double mouvement d'humanisation des insectes et de déshumanisation des populations humaines assimilées à une prolifération incontrôlée. Notre article révèle ainsi combien l'attribution historiographique à Malthus et à Alexander von Humboldt des concepts de sexualité économique, de croissance des populations ou encore de conscience écologique obscurcit près d'un siècle de débats et de tentatives de quantification empirique sur ces sujets au sein de l'entomologie des Lumières. L'observation de ces dynamiques ne complexifia pas seulement les arguments d'équilibre divin dans la nature et d'utilitarisme dans la reproduction: elle identifia les débats sur la reproduction sexuée des insectes comme sources à la fois pionnières et méconnues de reformulations fondatrices pour les concepts de désir, de reproduction, et de surpopulation au cours de la période moderne.

In 1771, the Cambridge-educated physician William Richardson (1698-1775) spent the summer months counting aphids on a rose growing in the gardens of his Yorkshire home. He was, however, not interested in contributing to the Linnaean classification of insects which had seized the imagination of Europe's amateur natural historians. Aphid-counting was not part of what Immanuel Kant would decry as "a science of depositories," nor was it part of Alexander Humboldt's "sordid registrars" of natural history.[1] Within a broader context of mathematization of nature and applications of exponential growth in early modern political economy, aphid reproduction became an unexpected debate amongst agriculturalists, natural philosophers, and even theologians in the eighteenth century.[2] Contributing to such debates, Richardson was particularly interested in the *quantity* of offspring that were produced by aphids: somehow, each egg produced at the end of the summer seemed to contain a near-infinite number of potential offspring. Richardson counted both the average offspring produced on his roses and the number of generations – he thought nine generations were reasonable during a warm summer, and he calculated that the average number of offspring per female was fifty – thus leading to a terrifying and startling conclusion:

> Whoever pleases to multiply by fifty, nine times over, may by this means form some notion of the great number of insects produced from a single egg: but will at the same time find that number so immense, as to exceed all comprehension, and indeed be little short of infinity.[3]

Richardson's calculation meant that the number of individuals produced by one sexual act would be roughly 1.9531e+15, or 19 quadrillion. As we will see, such baffling reproductive capacities were quantified in a context where political economists and historians were largely sanguine about the joint threat of overpopulation and depopulation in the human realm.[4]

In this article, we argue that entomologists and natural historians greatly revised the metropolitan reader's understanding of sexual reproduction during the eighteenth century. The abandonment of the theory that insects were produced by spontaneous generation, combined with the mundane labour of enumerating insect eggs, revealed an aspect of the natural economy which

1 Müller-Wille, 2017.

2 For another example of exponential quantification of animal reproduction, see Vauban, 1842, p. 82-88 ("La cochonnerie ou calcul estimatif pour connaître jusqu'où peut aller la production d'une truie pendant dix années de temps"), and Meusnier, 2003.

3 Richardson, 1771, p. 191.

4 Glass, 1973; Blum, 2002.

invested sexuality with new powers to overwhelm and consume the earth. Historians have paid little attention to the impact of insect sexual reproduction beyond the realm of entomology. Such an impact has also been overlooked in the history of Malthusianism, on the basis that Malthus himself made very few references to insects. Yet, Malthus's warnings about how unchecked population growth would ultimately cover "all the planets in the cosmos" only appeared plausible because of the astonishing reproductive rates of insects. Beyond the new contributions of insect sexuality to early modern fears of human overpopulation, insects finally became models to discuss human reproduction, under the guise of entomology. The discovery of insect sexual organs led to their extensive anthropomorphizing during the Enlightenment, which included debates over whether insects also felt desire, had sexual lives, or even got married.

This article is arranged in five sections. First, we explore how insect sexuality fuelled Malthusian fears of unchecked overpopulation. The unbalanced reproductive powers of insects prompted parallels with the sexually intemperate behaviour amongst the lower classes, and presented their supposed inability to control their reproductive rates as a quasi-existential risk for society. In section II, we review the emergence of insect sexuality from the slow decline of theories of spontaneous generation in the seventeenth and eighteenth centuries. To understand how the sexual lives of insects reshaped concepts of nature and the reproductive force, it is essential to understand that the revelation of sexual reproduction in the insect realm was not straightforward or uniform. Section III of the article analyses how new discoveries about insect reproductive powers also prompted new developments in the landscape of early modern insect theologies, within the broader cross-confessional Enlightenment realm of sacred entomology. Traditional symbolism and biblical interpretations of insects were challenged, while insects became both a model and a cover to discuss the natural laws underlying human sexuality. Section IV discusses the culture and practice of attempting to observe and count insect eggs. The quantification of insect reproductive capacities depended upon the painstaking work of attempting to count and identify the numbers of offspring produced by a parent within their lifecycle: the results from this work often contained, as we see above, numbers that threatened the belief in a divine balance of the natural world. In section V, we finally examine several infamous cases of insect outbreaks and swarms in the latter half of the eighteenth century which captured the attention of entomologists. The explanations offered by entomologists for why these swarms occurred, we show, not only reshaped disciplines such as natural theology, but also preceded Malthusian arguments concerning sexual desire and population.

INSECTS AND HUMAN OVERPOPULATION

When Robert Wallace (1697-1771) tried to calculate the European population in 1753, he believed that the art of agriculture determined the size of the population. Societies which encouraged agriculture would enjoy expanding populations; societies that neglected agriculture would decline.[5] John Locke (1632-1704), Adam Smith (1723-1790) and other essayists of the period were content to believe that the human population was determined by its civilization stage: the capacity for sexual reproduction in humans was of no real importance, what mattered far more in determining population size were questions around economic and political organisation, mastery of technology, and agriculture.[6] The agricultural writer Arthur Young (1741-1820) also had little interest in the sexual reproductive potentials of humankind: although he held some concerns that if agriculture was neglected, the farming classes might diminish while the impoverished classes expanded. Speculating in 1771, he asked the reader to imagine:

> "[…] that in one night, five hundred thousand beggars, vagabonds, pickpockets, and idle people were to disappear; if you then took a fresh account of your total numbers, you would find a decrease of half a million; but who will be hardy enough to assert, that we should in consequence be a weaker, a poorer, or a less flourishing people?"[7]

One can infer from Young's discussion that he believed some classes might reproduce (for a time) indifferently to the state of agricultural practice: otherwise, the fruitful production of 500,000 redundant poor during a time of agricultural stagnation could hardly be entertained. But Young had no interest in the sexual habits of these classes (at least, none that he expressed in print or correspondence).

Before the appearance of the anonymous pamphlet *An Essay on the Principle of Population* (1798), written by the otherwise unknown Anglican minister Robert Thomas Malthus (1766-1834), the political essayist William Godwin (1756-1836) wrote the most sustained discussion of how sexuality related to population size. In his *Enquiry Concerning Political Justice* (1793), Godwin focused largely upon the possibility of a society that dispensed with the need for government, rid itself of the threat of disease, and permitted open unions

5 Wallace, 1753, p. 18-21.

6 For discussions of stadial theories, see Wolloch, 2011.

7 Young, 1771, p. 29.

between men and women. In a final chapter, Godwin (almost as an afterthought) addressed the question of whether such sexual liberty would overpopulate the globe. Most scholars of Godwin's harshest critic, Malthus, ignore the fact that Godwin admitted the possibility that increasing sexual freedoms *could* result in overpopulation.[8] Much of the chapter is, in fact, concerned with addressing how humanity might accommodate its increasing numbers. He suggested that ¾ of the globe was "uncultivated," allowing room for agricultural expansion.[9] And if humans became immortal, threatening even this increased food supply, Godwin suggested that future humans may simply become less interested in fulfilling sexual desires.[10] Malthus's pamphlet, written originally as a reply to Godwin and Condorcet (1743-1794), asserted against this possibility that "the passion between the sexes is necessary and will remain nearly in its present state."[11]

But what, precisely, did sexual passion mean in terms of numbers for Malthus? His "arithmetical" argument concerning the exponential increase of population and the geometrical increase of agriculture is a familiar feature of his essay, but he also, in passing, reminds his readers of something that he seems to presume his readers already know. "Through the animal and vegetable kingdoms," he writes:

> nature has scattered the seeds of life abroad with the most profuse and liberal hand.... The germs of existence contained in this spot of earth, with ample food, and ample room to expand in, would fill millions of worlds in the course of a few thousand years. Necessity, that imperious all-pervading law of nature, restrains them within the prescribed bounds. The race of plants and the race of animals shrink under this great restrictive law. And the race of man cannot, by any efforts of reason, escape from it.[12]

Malthus includes no more explanation of this fact: in 1798, he is confident that his metropolitan readers already understand that there are species whose reproductive powers could populate millions of planets in a short period of time. While Malthus's correspondence is largely lost, his biographer, Patricia James, traced his intellectual development through reconstructing the

8 James, 1979.
9 Godwin, 1793, p. 861.
10 Ibid., p. 866.
11 Malthus, 1798.
12 Malthus, 1798.

purchase of his books, held in a collection at Cambridge. Of particular interest to James was a volume by James Steuart (1712-1780) published in 1767, entitled *An Inquiry into the Principles of Political Oeconomy.* There, Steuart wrote:

> several kinds of animals … especially insects, multiply by thousands, and yet the species does not appear annually to increase. Nobody can pretend that particular individuals of any species have a privilege to live, and that others die from a difference in their nature. It is therefore reasonable to conclude that what destroys such vast quantities of those produced, must be, among other causes, the want of food. Let us apply this to man.[13]

Already, by 1767, the reproductive powers of insects were influencing political economists to rethink how fertility and sexuality play a role in determining population size. But for Steuart, the insect realm (and human realm) alike demonstrated the existence of balance.[14] "The generative faculty," he explained, "resembles a spring loaded with a weight, which always exerts itself in proportion to the diminution of resistance."[15] Entomologists, for their part, found a new field of research: identifying the behaviours and environmental pressures which checked population, in Steuart's words, like a spring loaded with a weight.

Mary Terrall has argued that, in the seventeenth and eighteenth centuries, "naturalists took for granted the existence of design and fitness in insects."[16] Both concepts, design as well as fitness, held obvious theological significance. Previously inexplicable behaviours gained meaning according to this new paradigm. The Swiss entomologist François Huber (1750-1831), who worked to improve the observations made on bees by René-Antoine Ferchault de Réaumur (1683-1757), was the first to observe that worker bees sometimes steal and consume the eggs laid by the queen.[17] « Que penser de la Nature », he wrote, « quand elle semble donner aux insectes la faculté de détruire leur propre espèce ? »[18] Writing in 1802 after decades of debate over the prodigious capacities for reproduction in insect species, Huber thought this behaviour might have adapted to curb population and prevent the ruin of the species (as well as the wider ecosystem). « Les Bourdons [a species of bumblebee] sont

13 James, 1979, p. 105-106. It is important to note here that Malthus mentioned Steuart as one of his major sources in his 1803 preface.

14 See Gislain, 1999.

15 Steuart, 1767, p. 32. On Steuart, see Tortajada, 1999.

16 Terrall, 2014, p. 16.

17 Huber, 1802, p. 259.

18 Ibid., p. 260.

les plus grands des insectes qui se nourrissent de miel, » he explained, « et si leur nombre étoit triple et quadruple, d'autres insectes ne trouveroient plus de nourriture, et peut-être leur espèce seroit-elle détruite. »[19]

Given their capacities to reproduce, the key to understanding insect behaviour and design was to uncover the checks on their multiplication, both environmental and behavioural. Writing on the breeze-fly (*Oestrus ovis*), which attacks oxen, the British entomologist Bracy Clark (1771-1860) observed that there were several flaws in the design of the insect which (thankfully) kept it from overwhelming the earth. "It is fortunate for the animals infested by these insects that their numbers are limited by the hazards they are exposed to," he explained. "I should suspect near a hundred are lost for one that arrives at the perfect state of a fly."[20] Years later, the naturalist James Rennie (1787-1867), in writing a popular history of the breeze-fly, commented that the insect would be invisible to the ox unless it made a buzzing sound – and that the insects indeed produced this sound to alert the ox, "to prevent an overpopulation, by rendering it difficult to deposit the eggs."[21] Waste, excess, and mass destruction were, unexpectedly, part of the natural balance.

From the nineteenth century onwards, such understandings would reinforce detrimental analogies between humans and insects, in a global context of increasing colonial expansion and the emergence of nation-states. High birth rates amongst the lower classes and racialized populations prompted dismissive comparisons with invasive insect species (especially "vermin", bugs, and cockroaches), thus leading to the dehumanization of marginalized populations, particularly from Malthusian intellectuals.[22] The sexualization of entomology in the Enlightenment did not lead to a lasting humanization of insects: their reproductive commonalities with humans, highlighted by the demise of spontaneous generation, soon prompted dismissive comparisons with human populations perceived as sexually intemperate.

ABANDONING SPONTANEOUS GENERATION

The transition to early modern insect sexuality from the classical doctrine of spontaneous generation was however far from uniform. Aristotle's own position on spontaneous generation was complex, and his commitment to the

19 Ibid., p. 261.
20 Clark, 1797, p. 293.
21 Rennie, 1869, p. 429.
22 Hodgson, 2009, p. 745-770.

thesis has been debated for centuries.[23] In *The History of the Animals,* Aristotle argued that the appearance of fishes in puddles and new ponds proved that some fish species are "produced spontaneously."[24] Aristotle also believed that spontaneous generation was necessary to explain the existence of eels, as no one had ever observed an eel egg (nor had anyone captured pregnant eels).[25] Some (but not all) insects are, for Aristotle, also the product of spontaneous generation.[26] As Karen Zwier summarises: "different types of insects are also generated spontaneously in different situations, depending on whether it is dew on foliage, mud, dung, wood, animal hair, flesh, or within a living animal."[27] Population surges in insect species could be explained by the availability of the right material conditions – but sexual economy played no part in this story.

Spontaneous generation, of course, was elaborated upon by early modern natural historians.[28] The entomologist Francesco Redi (1626-1697) is commonly regarded as having delivered crucial evidence against spontaneous generation in his 1668 publication *Esperienze intorno alla generazione degl'insetti* ("Experiments on the Generation of Insects") – however, as Parke has shown, Redi maintained a belief that certain insect species were not produced by mating pairs of their own species, but were instead produced by certain living trees and shrubs.[29] Despite these complexities, Daryn Lehoux has argued that we should view spontaneous generation as "a fact" of the Early Modern era, rather than a theory, as it was the reflection of raw data: almost everyone agreed that ordinary experience showed that maggots, larvae, and other early forms adopted by insect species emerged from excrement, rotting flesh, and impure waters.[30] The theory was also important for explaining the existence of the people of the New World. The Italian mathematician and physician Girolamo Cardano (1501-1576) (as well as Paracelsus) upheld that the peoples of the Americas could not have descended from Adam. Instead, they spontaneously generated from the earth – just like insects and snakes.[31] And spontaneous generation – or versions of the idea – remained popular even after the observations meant to refute the thesis. During the summer of 1745

23 Zwier, 2018, p. 355.
24 HA VI.15 569a13-19, 25-26. This passage is highlighted by Zwier, 2018.
25 HA VI.16 570a3-10.
26 Zwier, 2018, p. 369.
27 Ibid., p. 373.
28 Parke, 2014, p. 86.
29 Ibid., p. 88.
30 Lehoux, 2017, p. 105.
31 Pagden, 1982, p. 23.

at age 32, British naturalist John Needham (1713-1781) believed that he had proven that microscopic animalcules arise from the decomposition of organic matter by heating mutton gravy and then attempting to seal it from any eggs or infection from the atmosphere.[32] By this time, naturalists had observed and recorded the sexual lives of many species of insects: but the delineations between the world of insects and the invisible world of microscopic animalcules were unclear, and the larger questions about nature's economy were under profound revision from the wealth of reported observations and experiments on insect reproduction. In the 1830s, a British amateur electrical philosopher, Andrew Crosse (1784-1855), tinkered with running electric currents through soil – to his astonishment, while he argued that he had kept the soil free from any insects or invaders, some small insects crawled out from the soil several days later. Britain was (for a time) consumed with news stories that the famous scientist Michael Faraday (1791-1867) had confirmed that Crosse had spontaneously generated life out of soil with electricity (numerous letters survive written by Faraday begging newspapers to run corrections, saying that he never confirmed such a feat).[33]

New cultures of insect observation upended the dominance of the spontaneous generation theory. Francesco Redi, in the 1660s, had observed the behaviours of flies and wasps around meat and trees, and he observed that these insects laid small eggs, challenging notions that they were produced spontaneously through the decay of living matter.[34] Others, like the naturalist Béardé de l'Abbaye (d. 1771), recognised that insect swarms and population surges would need to be explained by appeal to sexual economy.[35] As he observed, "may-bugs, or chaffers, are very numerous one year, and very scarce the following. It is, perhaps, in the diversity of the population of insects, we might come to discover the cause of the diversity of several accidents."[36] Lorraine Daston was the first to investigate how entomology fitted into the wider culture of the Enlightenment, focusing on how the fascination within insects in the period was driven by the desire to "create value out of the least promising materials."[37] Focusing on the value attached by entomologists to focus, perception, and the art of minute study of insect anatomy, Daston argued that entomology became a site of activity important for both natural

32 Lehoux, 2017, p. 107.
33 Faraday, 1991, t. 2, p. 411-413.
34 Parke, 2014.
35 Orain, 2017, p. 43-77.
36 Béardé de l'Abbaye, 1776.
37 Daston, 2003, p. 10.

history and political economy.[38] Insects, after all, permeated the terrestrial globe and worked tirelessly to procreate their species – what role did such work play within the wider operations of nature? If nature's operations were concealed and hidden, the study of insects promised to reveal its workings.

The piecemeal demise of spontaneous generation was further precipitated at the end of the seventeenth century by the ground-breaking observations of Leeuwenhoek's microscopes, whose resolution of x300 outcompeted the average x20-x30 resolution common at the time.[39] This had allowed the self-taught Dutch microscopist to discover so-called "animalcula" in his own semen, and to identify spermatozoa as the agents of human reproduction. Leeuwenhoek's best microscopes remained a trade secret, and when they were eventually auctioned in 1747, most of them were only bought as curiosities and collectibles by local Dutch notables.[40] However, by the middle of the eighteenth century, the spread of Linnean taxonomy and the democratisation of new models of microscopes sparked new interest in the hidden sexual features of insects.[41] This coincided more broadly with the rise of an entirely new science of insects (then a still loosely defined category) exemplified by Réaumur's ambitious six-volume *Mémoires pour servir à l'histoire des insectes* (1734-1742).[42]

When the Parisian pharmacist Étienne Louis Geoffroy (1725-1810) wrote his *Histoire abrégée des insectes* (1762) – a popular book which synthesised a lot of the discoveries and debates made by Réaumur and utilised Linnean classification – the reproduction question seemed settled. « Les anciens Philosophes s'étoient imaginés que les insectes naissoient de la pourriture » he wrote, distancing himself from classical authorities.[43] Geoffroy declared this ridiculous and pointed to numerous recent naturalists who had proven that insects are born from sexual reproduction "like all other animals." Geoffroy was an influential and well-connected physician – the future American president John Adams corresponded with him when he was hoping to establish ties between American and French medical schools.[44] Geoffroy focused on the organisation

38 Ibid., p. 120.

39 Fisher and Meuti, 2018, p. 242; On the resolution of Leeuwenhoek's microscopes, see Wills, 2018, and Ball, 1966.

40 Robertson, 2015, p. 2-3.

41 For a descriptive list of eighteenth century models of microscopes, see Michael J. Davidson, "Eighteenth Century Microscopes", *Molecular Expressions: Museum of Microscopy*, 2015: https://micro.magnet.fsu.edu/primer/museum/museum1700.html.

42 Réaumur's definition of insects included starfish, snakes, lizards and even crocodiles. See Roger, 1997, p. 71-72.

43 Geoffroy, 1762, t. 1, p. 14.

44 "From John Adams to Étienne Louis Geoffroy, 20 December 1782," *Founders Online, National Archives*, https://founders.archives.gov/documents/Adams/06-14-02-0087.

of nature, although he drew different lessons than Lesser. Insects seemed designed solely to reproduce: « Lorsque l'accouplement est accompli, » he wrote, « souvent les mâles des insectes périssent très peu de temps après [...] la nature ne les avoit destinés qu'à féconder leurs femelles; dès qu'elle a pourvû à la propagation de l'espèce, ces mâles deviennent inutiles [...]. »[45] When it came to explaining their capacity for reproduction, Geoffroy wrote:

> ces œufs sont souvent en très grand nombre, par centaines, par milliers, [...] en général les insectes sont très féconds, il semble que plus les animaux sont petits, plus la nature les a multipliés. [...] Une pareille fécondité étoit nécessaire pour conserver ces espèces d'animaux, qui, servant de nourriture à plusieurs autres, sont continuellement exposés à devenir la proie d'un nombre infini d'ennemis.[46]

Appealing to the nutritional needs of larger animals was one efficient means of explaining the reproductive capacities of insects – but as we will see in section four, such explanations could not account for why the design of nature permitted for circumstances in which an insect species could exponentially increase its numbers.

INSECT GENITALIA AND SACRED ENTOMOLOGY

The gradual discovery of the reproductive organs of insects prompted new theological ideas about the place of insects within nature. As consensus gradually shifted away from spontaneous generation to explain the prodigious sexual reproduction rates of insects, their sexual organs and reproductive habits, long overlooked by natural history, received new attention.[47] But eighteenth-century sacred entomology was not solely concerned with the contested morality of elusive observations of sexual characteristics. Neither did it solely consist of a mere subgenre of natural theology: it also sought to reintegrate insects back into the great chain of being, as sexualized animals sharing procreative commonalities with humans. As a result, new natural understanding of insect's sexuality across the eighteenth century redrew traditional Christian biblical and spiritual interpretations about the meaning and telos of insect's growth, transformation, and proliferation. Jacques Roger noted that eighteenth century

45 Geoffroy, 1762, t. 1, p. 20.
46 Ibid., p. 21.
47 Roger, 1997, p. 72. See also Klerk, 2020.

"Entomology, like cosmology and anatomy, was a proof of God's existence," and that the study of insects and their prodigious propagation became associated by best-selling natural historians such as the abbé Noël Pluche (1688-1761) as a morally humbling form of natural theology.[48] Pluche's approach to the study of insects as an "experimental" form of natural theology echoed John Ray's (1627-1705) *The Wisdom of God Manifested in the Works of the Creation* (1691) and was part of a wider trend of early modern insect natural theologies, from Friedrich Christian Lesser's *Insecto-Theologia* (1738) to William Paley's *Natural Theology* (1802).[49]

The devout Jan Swammerdam (1637-1680) was a key influence to many entomologists and early modern insect-enthusiasts. Linnaeus praised him in his *Ordines et Genera Insectorum* (1773) as "deserving to be read" above all "with the greatest attention."[50] Swammerdam had a lifelong passion for insects, which he regarded as an overlooked and misunderstood part of God's creation. This was because of his attacks against traditional scholastic views which regarded insects as imperfect beings arising from spontaneous generation, with a lifecycle based on metamorphosis. Swammerdam's meticulous, microscope-based study of insects and of their sexual organs paved the way for a renewal of eighteenth century Christian understandings of insects, and of the role that sexuality played in their propagation.[51] Hinting further at the common connections between sacred entomology and mysticism, Swammerdam's *Ephemeri Vita* (1675) treatise on the mayfly intertwined his entomological research with his religious experiences in Germany within the sect of French mystic Antoinette Bourignon (1616-1680), with whom his colleague, the Dutch entomologist and anatomist Steven Blankaart (1650-1704), also corresponded.[52]

Part of Swammerdam's influence occurred within classification and taxonomy. Linnaeus's updated approach to insect classification in 1758 was still primarily based on wings, although it also included, when possible, the observation of insect's sexual organs and reproductive behaviour.[53] Building on Jan Swammerdam and later developed in Johannes Jacob Hegetschweiler's *Dissertatio Inauguralis Zootomica de Insectorum Genitalibus* (Zurich, 1820), Linnaeus's intuition that seemingly identical insect species

48 Roger, 1997, p. 72-74.
49 Fisher and Meuti, 2018, p. 243-248.
50 Linnaeus, 1773, p. 199.
51 On Swammerdam's pioneering observations of insects' sexual organs, see Klerk, 2020, p. 500. See also Jorink, 2022, p. 259-260.
52 Jorink, 2006, p. 233.
53 This was similar to Linnaeus's approach with plants. See Linnaeus, 1773, p. 11-13, 119, 151, 241-242, 255.

could be distinguished by their sexual organs has since become the traditional approach of modern entomology.[54] However, in the eighteenth century, such an approach was still limited or rendered unreliable by the technical limitations of microscopy: as in human anatomy, when distinguishable features could not be observed or only with difficulty, artefacts and accidental mutations were frequently mistaken for speciating characteristics.[55] This was reinforced by the fact that insects' external or observable genitalia often appear largely internal or hidden, and exhibit considerable diversity.[56] As a result, Linnaeus's approach to insect taxonomy, informed by his already controversial sex-based plant classification, initially met with methodological scepticism, both in his home country and abroad.[57]

Linnaeus's approach also raised considerable moral and theological objections. His research on reproduction and sexuality was seen by many as undermining the traditional Christian interpretations of plants as analogous natural models for moral edification.[58] As Peter Harrison has shown, Linnaeus himself believed that he possessed unique "taxonomic gifts" and regarded his work as a naturalist as a quasi-religious vocation; this prompted his detractors to recast the Swedish naturalist as a closeted materialist worshipper of nature, unable to distinguish God from his creation.[59] The Swiss polymath Albrecht von Haller (1708-1777) famously contended that Linnaeus's attempt to rename all the plants and animals of creation made him a delusional "Second Adam": for Haller, Linnaeus vainly sought to emulate Adam's original sacred nomenclature and arrogantly restore mankind's prelapsarian dominion over nature.[60]

But Linnaeus was not the only Swedish authority on insects and theology. In northern Europe, insect natural theologies coexisted with heterodox forms of sacred entomology, informed by Pietism, mysticism, and millenarianism. Mattias Forshage has for instance mapped how, at the turn of the eighteenth and nineteenth century, most of the leading Linnean Swedish entomologists were followers of the doctrines of the Swedish philosopher and mystic theologian Emanuel Swedenborg (1688-1772).[61] A former close colleague of Linnaeus at the Swedish Royal Academy of Sciences, enthusiastic gardener, and seeds

54 This traditional approach was only supplanted in recent years by chromosome identification. See Richmond, Park, and Henry, 2016.
55 On this artificial character, see Roger, 1997, p. 71-77.
56 Richmond, Park, and Henry, 2016.
57 Koerner, 1999, p. 14-33.
58 Harrison, 2009, p. 892.
59 Ibid., p. 892.
60 Ibid., p. 879-880.
61 Forshage, 2017.

collector, Swedenborg crafted across his theological publications a rich doctrine about the religious significance of insects as procreative sexual beings.[62]

Swedenborg's theology departed radically from Lesser and other sacred entomologists. In his milestone work *Arcana Coelestia* (London, 1749-1756), Swedenborg presented insects as prefigurations on earth of married love in heaven, commenting how freshly-transformed butterflies, newly "adorned" with colourful wings, "make marriages" and procreate in the air "which is their heaven."[63] Swedenborg contended that insects possess a similar "marital tendency" as humans, albeit limited to "nutrition and propagation" and driven by "instinct," a rudimentary form of free will shaped by their acute senses.[64] Such remarks tied into wider vivid debates in early modern political theologies about whether insects possessed souls and free will.[65]

Christian discussions of the new status of insect reproduction saw biblical depictions of insect swarms in early modern millenarian literature moving away from literalist interpretations. In his exegesis of the book of Revelation, Isaac Newton had noted with interest how John Milton (1608-1674) allegorically recast the insect-lord Abaddon as a mere name for the bottomless pit of hell, rather than as the entity who presided over an apocalyptic army of locusts in Revelation 9:1-11.[66] Milton himself more broadly viewed insect hives as a symbol of natural corruption of the divine hierarchy, and used insect metaphors to highlight humankind's inability to replicate the design of heaven.[67] As a dedicated exegete who published line-by-line interpretations of the books of Exodus and Revelation, Swedenborg also rejected traditional literalist readings of swarms of hornets and locust as actual insect plagues, arguing instead that the ruination of Egypt's land by clouds of "noxious flying insects" in passages such as Exodus 7:26 represented the clouded "spiritual ruination" of Pharaoh's nation by innumerable "spiritual falsities."[68] Allegorical associations of noxious swarms with evil corruption echoed broader Christian representations of

62 On Swedenborg's gardening and purchase of seeds from Joachim Wretman, see Acton, 1955, p. 509.

63 Swedenborg, 1784, n. 2758.

64 Swedenborg, 1768, n. 204 and n. 222. On insect instinct and limited free will, see Swedenborg, 1771, n. 335:6, n. 478, n. 499.

65 Kleiman-Lafon and wolfe, 2021, p. 261-297.

66 Milton, 1796 [1671], p. 428: "The name of the Angel of the bottomless pit, Rev. ix. 1 1; Abaddon, here applied to the bottomless pit itself. Newton." See also Ibid, Book IV, p. 81.

67 Jacobs, 2015, p. 798.

68 Swedenborg, 1784, n. 2758. On locusts and Abaddon as mere representations of spiritual falsities, see also Swedenborg, 1766, n. 419:4.

demons as anthropomorphic insects, such as the "lord of the flies" Beelzebub, and Satan himself.[69]

This is not to say however that scholars like Milton or Swedenborg denied nor ignored the existence of population surges and swarming behaviours. Swarms (especially bee swarms) generated considerable interest in the seventeenth and eighteenth century. Many scholars, from Bernard Mandeville and Margaret Cavendish to Théophile de Bordeu and Diderot all debated the possible causes behind the bees' extraordinary collective coordination.[70] But bees, which produced wax and honey and had long been depicted as allegorical representations of Christ, had a much more positive image than apocalyptic swarms of devouring locusts. What would God ever allow for endless numbers of insects to coordinate into nefarious, devouring swarms? Based on his observations and entomological readings, Swedenborg tried in 1763 to reconcile religious traditions of spontaneous generation, the evils inflicted by obnoxious insects, and insect reproduction:

> … everyone knows that marshes, swamps, dunghills, and rotting compost heaps are filled with such creatures, and also that noxious winged insects fill the atmosphere like clouds, and noxious vermin the earth like armies on the march, consuming its herbage even to the roots. In my garden I once observed that almost all the dust in a three or four foot area turned into tiny winged insects, for when I stirred it with my stick, they rose up like mists.[71]

Swedenborg partly attributed their reproductive powers to an initial spontaneous generation of infernal origin, which also allowed him to explain their evil, devouring behaviour. This led him to conclude that:

> … although the lower and harmful animals and plants arise as a result of an immediate influx from hell, still they reproduce after that by means of seeds, eggs, or offshoot. Consequently, the one proposition does not take away the other.[72]

This hybrid positioning highlights how, like many Christians preoccupied with reconciling natural philosophy with revealed theology, Swedenborg's sought

69 Connor, 2006, p. 1-35, p. 215-224.
70 Kleiman-Lafon and Wolfe, 2021, p. 261-297.
71 Swedenborg, 1763, n. 341.
72 Ibid., n. 342 and n. 347.

to revitalise Christian understandings of insects by highlighting their spiritual significance, while simultaneously accounting for their extraordinary reproductive rates.

These depictions of infernal movements in the belly of the earth giving rise to insect swarms – and subsequently to insect sexuality – were not mere theological elaborations. They influenced the practice of entomology in Sweden. The movement of Swedenborgian entomology included Linnaeus disciples such as the coleopterist Leonard Gyllenhaal (1752-1840) and Adam Afzelius (1750-1837), along with other Swedish entomologists such as Gustaf J. Billberg (1772-1844) and Olof I. Fåhræus (1796-1884); the famous coleopterist and silk-factory worker Carl Johan Schönherr (1772-1848), or the insect-collectors Per Hemming Odhner (1790-1844) and Carl E. Deléen (1767-1850).[73] Their perspective, combining natural-theological tropes and syncretic Enlightened Illuminism, provides a striking counter-example to historiographical narratives about the secularisation of natural science during the Enlightenment, in the broader context of the rise of Romantic biology.

COUNTING EGGS

Insects occupied a significant yet overlooked position in the early modern mathematization of nature. This was not only because of the extraordinary quantities of eggs they produced, but because of the hexagonal patterns of beehives, which prompted various physico-theological readings, along with debates about insect's agencies in building such structures.[74] Having received confirmation from the German mathematician Johann Samuel König (1712-1757) that bees geometrically maximised their wax-to-cell ratio in building their hive by resorting to hexagonal cells, Réaumur had enthusiastically concluded that the bees' optimal choice reflected "divine wisdom."[75] But the mathematization of insects remained, like the identification of their hardly visible sexual organs, technically challenging. Many trained mathematicians with an interest in entomology did not attempt the tedious and challenging task of quantification. Swedenborg had for instance received extensive training in mathematics and geometry, but like many, he never sought to apply quantitative methods to estimate the reproductive rates of insects. When faced with their seemingly miraculous exponential reproductive powers, the Swedish

73 Forshage, 2017, p. 109-130.
74 Kleiman-lafon and Wolfe, 2021, p. 263, 286.
75 Réaumur cited in ibid., p. 263-264.

philosopher-seer had resorted to a hybrid hypothesis of "infernal spontaneous generation" enhanced by sexual reproduction.

But for most naturalists with more secular commitments, such a syncretic and partially outdated explanation was impossible to accept. Moreover, the quantification of insect reproduction appeared as such a vast and meticulous task that it could not be tackled by a single individual. It is important to recognise that the work which went into entomology – like other areas of natural history – involved labour by artists, collectors, taxidermists, and other trades. All of this labour became largely invisible once the treatise or pamphlet was produced bearing the entomologist's name; creating a false illusion that the larger studies of the eighteenth century were indeed the products of isolated amateurs working alone. Dominik Hünniger, in his work to recover the shared labour of entomology in the eighteenth century, uncovered a revealing passage recorded by the entomologist Johan Christian Fabricius (1745-1808) after visiting the London home of Joseph Banks (1743-1820), when he was acting as president of the Royal Society: "the daily workers, a group to which I have long belonged, have their own places, their own table, their own magnifying glass and their own drawer for their papers and things, and everyone uses everything with the same freedom that he would have at home."[76] Not all entomologists were as wealthy or well-connected as Banks, of course – but Réaumur and others all relied upon help at home and correspondence networks to develop the science.[77]

Friedrich Christian Lesser (1692-1754) understood insects as "small machines" – but nonetheless they were machines which reproduced sexually and whose minute operations were of crucial importance.[78] Lesser owned a microscope, and could do many of the anatomical observations himself – still, he hired an artist to produce the anatomical drawings that he included in his work. His guiding principle was that God must have given all living things the power to procreate. Lesser included descriptions of insects' reproductive organs, he attended to insect eggs, and described the tremendous fecundity of some insect species. "One insect generally lays a great number of eggs; from thirty to sixty and even some hundreds," he explained. Observation was always crucial – consider how Lesser appealed to his own authority on the numbers involved in insect reproduction:

76 Quoted in Hünniger, 2021, p. 189.
77 Opitz, Bergwik, and Van Tiggelen, 2015.
78 Trepp, 2020, p. 132.

> This I learnt by the following circumstance. On the 6th of June in 1736, a forester brought me a butterfly, the upper wings of which were dark, spotted with eight white spots, and the under wings orange coloured. I fixed it with a pin to a board, and on the afternoon of the same day, found that it had laid four hundred and thirty-one eggs the size of a grain of millet … The next day the same butterfly had laid 170 eggs making in all six hundred and one.[79]

Here, for any sceptical reader, was an observation easily repeated. The vast numbers involved were, for Lesser, still part of a theological question. Why, Lesser asked, did insects not take care of their eggs? "By this they are distinguished from all other animals," he observed. He also wondered, bluntly, where they all went. "As insects produce such a number of eggs it is easy to conceive that there must be a proportionable number of the animals themselves."[80] Lesser pointed to several biblical passages on insect plagues as evidence of their awe-inspiring capacities to reproduce. "One thing which contributes greatly to the prodigious multiplication," he explained, "is the little time they require from their exclusion by the parent female to their being capable of laying eggs themselves…. We must not therefore be surprised that insects multiply so remarkably, and that such pains are requisite to destroy them."[81] Here, Lesser found a pleasing way to explain insect reproductive powers that accounted both for their awesome power to create swarms and invasions, and also God's design in managing their reproductive powers. God had ensured that females produce so many eggs as insects could not care for their young; they were such an important food source for other animals that without this tremendous fecundity, the species would disappear.[82]

Economy and the industrialisation of insects drove some entomologists to engage in quantifying the reproductive powers of insects. Francois Xavier Bon de Saint Hilaire (1678-1761) believed that spiders could provide a substitute for silkworms in the European textiles market. Acting as President of the Court of Auditors (*Chambre des comptes*) at Montpellier, Bon wrote to Hans Sloane at the British Royal Society to set out the means by which spider cultivation could be profitably carried out. He began with the increased reproductive power of spiders, writing: "we could breed spiders as they do silkworms; for they multiply much more, and every spider lays 6 or 700 eggs, whereas the *Papilios*, or

79 Lesser, 1799, p. 59. See also Terrall, 2014, p. 17.
80 Lesser, 1799, p. 61.
81 Ibid.
82 Ibid., p. 62.

Flyes of silk worms, lay but 100, or thereabouts."[83] When Réaumur was tasked with putting the feasibility of breeding spiders to produce spider silk to the test, he discovered to his dismay that the newly-hatched spiders consumed one-another unless separated – difficult work.[84] He also added new figures – estimating that 55,296 spiders would be needed for every pound of silk.[85] Réaumur developed innovative means of observing the laying of egg packets by insect species. When one caterpillar species seemed to only lay eggs in the dark, Réaumur assembled a dark box which provided him a means of opening in time to try and catch the caterpillar in the act of laying eggs.[86]

Réaumur's particular focus on counting insect offspring was related to the controversy over aphid reproduction. Mary Terrall's extensive study of Réaumur's work on aphids traced the collaborative efforts between Réaumur and Charles Bonnet (and others) who hoped to explain how aphids seemed to be both viviparous (giving birth to live young) and oviparous (producing eggs). A little contemporary context might help: aphids reproduce by parthenogenesis during the warm months, which means that oviparous females (labelled "fundatrix") are capable of asexual reproduction. Importantly, the individuals in one chain are all genetically identical.[87] When the weather turns cold, males are produced and a period of mating occurs during which eggs are produced, which must survive the winter. Entomologists in the eighteenth century witnessed the viviparous reproduction with astonishment: and testimony that sexual mating and egg-laying among aphid species towards the end of the summer created great debates over how the species reproduced, and whether sexual reproduction was necessary in propagating the species. As Terrall has argued, these debates held enormous significance in the development of a science of sexuality in the eighteenth century. A popular story within the history of science relates how Charles Bonnet regarded a single "fundatrix" aphid in captivity for eleven days, keeping it isolated from its birth and within his own sight until it produced, by his testimony, 95 offspring.[88] The experiment was repeated with success by several entomologists across Europe.[89] It was out of this observational culture that William Richardson, in Cambridge, was driven to speculate on the mathematics involved in one sexual act providing the generative power for the innumerable potential offspring of the following season.

83 Bon de Saint Hilaire, 1712, p. 12.
84 Terrall 2014, p. 29.
85 Ibid., p. 30.
86 Ibid., p. 38.
87 Ogawa and Miura, 2014.
88 Terrall, 2014, p. 169.
89 Ibid.

Explanations of parthenogenesis differed from authority to authority: but all agreed on the daunting success and magnitude of the number of offspring produced.

The reproductive powers of these insect species thus fit a theological understanding that their prodigious numbers were, indeed, essential to their position within the economy of nature. But other insect species which seemed merely parasitic, serving no benefit to any other species, also seemed to enjoy tremendous powers of reproduction. Writing on "the yellows in wheat", popularly identified as a mildew, the entomologist Christopher Gullet remarked that "through a pocket microscope, it appears a large yellow maggot of the colour and gloss of amber, and is so prolific that I last week distinctly counted 41 living yellow maggots or insects, in the hulk of one single grain of wheat, a number sufficient to eat up and destroy the corn in a whole year."[90] The flies were so fertile, that Gullet remarked "one of those yellow flies laid at least eight or ten eggs of an oblong shape on my thumb, only while carrying by the wing across three or four ridges."[91] There was little to explain the reproductive capacities of this species in terms of providing a food source to larger animals – it seemed more to be an unfortunate consequence of the expansion of grain cultivation.

INSECTS, REPRODUCTION, AND DEVASTATION

Industry, agriculture, theology, and cultures of natural history had all compelled many to try and enumerate the reproductive capacities of insects. Sexuality emerged not only as a constant within the natural world, determining the continuation of all species: it also now commanded the power to inundate and overwhelm the planet with offspring. As entomologists counted eggs, it became easily apparent that mass death and destruction were critical to the balance of nature in order to spare the earth from being overrun by insects. And this fragility of life emerged at all steps in the cultures of insect collecting and observation. Gilles-Augustin Bazin (1681-1754), a correspondent of Réaumur, observed in one letter on caterpillar collection that he might begin with a bounty of 100 eggs. After hatching, numerous inchworms would die every day, and on occasion only one or two individuals would survive.[92] The sexual reproductive cycles of the insects could not be changed or altered (these were assumed to be part of the fixity of species and authored by God),

90 Gullet, 1772, p. 350.
91 Ibid, p. 351.
92 Terrall 2014, p. 53.

but it was obvious that the destructive forces could be manipulated – for our benefit and for our own ruin.

This was not a discussion restricted to scientific networks and treatises: British newspapers featured regular observations that human agricultural activity upset natural balances. A member of the Agricultural Society in the English town of Chester wrote angrily in 1806 on the subject of farmers destroying bird nests. "Those who have not reflected much on the subject, would hardly conceive the extent of the mischief arising from the destruction of birds' nests," they complained. "Our gardens and our cornfields are thereby left a prey to caterpillars and myriads of insects, which would otherwise be devoured."[93] Such letters were not irregular: four years earlier an anonymous reader styled "Varro" had written a letter to the same paper pleading that magpies be spared from attack. "They are indefatigable in their pursuit of insects, and indeed almost subsist on the larger and destructive kinds, as slugs, caterpillars, etc."[94] The Agricultural Society in Holderness held a forum to debate whether permitting birds to nest in agricultural areas bestowed more benefit than harm by consuming insects. One member believed that the question should be addressed mathematically, and undertook to observe crows feeding their young with grubs. Some useful numbers emerged: the crows carried an average of 33 grubs per trip back to the nest, and made roughly 70 journeys per day. "A family of rooks," the agriculturalist concluded, "would in that time [one year] destroy 1,445,500 grubs."[95]

On occasions when insect swarms in Britain drew the attention of the press and entomologists fearing a crisis, the balance of predators with population size became important in attempts to manage the fears of the public. This happened in London in 1782 when, two years after the Gordon Riots destroyed whole segments of the metropolis, the city's suburbs and green spaces disappeared under mysterious webs. Unable to identify the species immediately, the newspapers filled with advertisements and threats that this insect could be an unknown or invasive species which would destroy crops and, potentially, bring with it plague.[96] William Curtis (1746-1799), an entomologist who lived in London and taught botany and natural history to medical students, hastily published a pamphlet aimed at the wider public to assuage fears of the insects. Titled *A short history of the brown-tail moth, the caterpillars of which are at present uncommonly numerous and destructive in the vicinity of the populace*,

93 Anonymous, 1806, "Destruction of Birds' Nests." *Chester Chronicle*, 25 April, p. 4.
94 Anonymous, 1802, "Birds." *Chester Chronicle*, 5 March, p. 4.
95 Anonymous, 1808, "Holderness Agricultural Society." *Hull Packet*, 21 June, p. 3.
96 Lidwell-Durnin, 2022.

Curtis's pamphlet included a color plate which would have been expensive to produce but served a vital role in telling a visual story of how the population had exploded (and why it would return to normal levels).[97] Why did such population surges occur? Curtis had no answer, but surmised that the "most probable causes" would be "the peculiarity of the weather, and the plenty or scarcity of the enemies of the insect."[98] In this case, Curtis believed two predators would swiftly decimate the caterpillars: the first were birds, whom he explained would feast on the caterpillars before their wings expanded. This was crucial, as if their wings *were* to expand, they would have a chance to multiply and establish a second season of increased numbers.[99] The second predator, the Ichneumon fly, infested the egg nests of the brown-tail moth and Curtis had, already, ratios at hand for the rate of infection. When collecting tent specimens for use in teaching, Curtis explained that he regularly found that nine out of ten such tents were already destroyed by the Ichneumon fly. He even included the Ichneumon fly in his illustration of the life-cycle of the moth, showing it attacking and emptying an egg nest.[100] Even if these predators failed, Curtis adopted a pre-Malthusian view on the population: there simply was not enough nutrition available on the shrubs and trees of the countryside to nourish them all to the point where their wings could expand and they could propagate their species.[101] Such a conclusion may have comforted some: others would have seen that the species had the capacity to strip the island bare.

Several disastrous episodes of invasive species in the long eighteenth century also underscored that human activity could, unintentionally, upset the balances which constrained insect populations. An oft-quoted example of this fear comes in the memoirs of the traveller and naturalist Pehr Kalm (1716-1779), who, in 1751, found the dreaded New Jersey pea-beetle in a sample of peas he had brought with him to Europe from his travels in America. Quickly killing the living insects that crawled out of his samples, he reflected "I at once had a full view of the whole damage which my dear country would have suffered, if only two or three of these noxious insects had escaped me."[102] Etienne Stockland, in his study of the accidental introduction of locusts to l'Isle de France (Mauritius), notes that the naturalist Jean Baptiste Christophe Fusée-Aublet

97 Curtis, 1782.
98 Ibid., p. 9.
99 Ibid., p. 9-10.
100 Illustration of the life cycle of the brown-tail moth, colour leaf plate, in Curtis, 1782, Wellcome Images, public domain https://wellcomecollection.org/works/tjfxq44b.
101 Curtis, 1782, p. 8.
102 Pauly, 2002.

(1720-1778) readily observed that agrarian practice on Mauritius had rendered the island a welcoming habitat for the invading pests.[103] Following the work of Richard Grove in his monograph *Green Imperialism*, Stockland traced the efforts of Pierre Poivre (1719-1786) to abet the degradation of the island and reform its natural resources. Despairing of a means of destroying the locusts, Poivre elected to introduce the Mynah bird (*Acridotheres tristis*, L.) from India, having heard of its voracious appetite for locusts. « Dans le cours de mes voyages j'avais pensé que le seul moyen de délivrer l'Isle de France de ces insectes destructeurs était de leur apporter les moyens que la nature a pris pour diminuer la multiplication des insectes nuisibles. »[104] While some tried to claim that the birds became a worst pest than the locusts had been, the experiment was gauged by most contemporaries as successful.

Could human civilisation and the cultivation of the earth also upset the restrictions on insect populations? Within decades of the first treatises and communications on insect reproduction, we find agriculturalists and entomologists reassessing the causes and conditions behind insect swarms in agriculture. In 1761-2, a moth outbreak in Angoumois threatened to decimate wheat yields. Henri Louis Duhamel du Monceau (1700-1782) and Mathieu Tillet (1714-1791) were sent by the French Royal Academy of Sciences to investigate. In their tour, Duhamel and Tillet recorded that the intensity of the infections correlated with the richness of the land – areas largely abandoned with sparse land and few farms were relatively untouched, areas that otherwise boasted abundant harvests were the worst affected.[105] The species itself was benign: « l'unique fonction de ces papillons, » they wrote, « de même que de ceux des vers à soie, est de travailler à la multiplication de leur espèce. »[106] However, by increasing cereal cultivation, humans had greatly shifted the balance between food supply and predators for the species – resulting in swarms on the best land.

No investigation would have been complete without seeking to quantify the rate at which these caterpillars reproduced. Trapping females under crystal to observe them laying eggs, the authors observed:

> Aussitôt que les œufs sont fécondés, les femelles cherchent à s'en délivrer, et elles font des pontes très abondantes. Ayant renfermé dans un gobelet de crystal les deux sexes accouplés, […] pour voir la femelle jeter çà et là des paquets d'œufs, au nombre de 60, 80 et 90. Ces œufs sortent comme

103 Stockland, 2014, p. 212.
104 Ibid., p. 211.
105 Duhamel du Monceau et Tillet, 1762, p. 14.
106 Ibid., p. 25.

> un jet, ordinairement 3, 4, ou 6 à la fois; d'autres fois par trentaine: à chaque jet la femelle change de place.[107]

Out of the sexual economy of insects, long-familiar dangers such as swarms of locusts and other pests took on new significance and meaning. By quantifying the reproductive rates, a new understanding emerged of the threat posed by these insects to agriculture: if human activity altered the balance of nutrition available or the behaviour of predators, insect populations could overwhelm entire provinces, potentially even countries.

There was certainly an interest for the sake of entertainment in tales of insect plagues and ravages. English travel writers of the late-eighteenth century sought out stories of locust plagues, termite attacks – they clearly relied upon the insect world to add colour and adventure to their inventories of rural towns and agricultural habits, but even these stories can help us to understand the shifting perception of insect swarms as driven by sexual reproduction and human interference with the balance of nature. Joseph Townsend (1739-1816), writing on locust swarms in Spain, observed that locust females refuse to lay eggs in cultivated land where they could be destroyed; and thus only lay eggs "in the deserts."[108] Townsend took this to show that the extension of agriculture could, itself, potentially eliminate the threat of locusts; at the same time, the increased cultivation of lands bordering deserts ideal for locusts represented a disaster. Recurrent locust swarms from 1754 to 1757 in Spain and Portugal had occurred at the peak of scientific curiosity around insect reproduction, and writers like Townsend included as much information as they could gather on human responses to the swarms. Townsend records an anecdote where three thousand men at Zamora collected together over ten thousand bushels of locusts.[109]

Townsend borrowed information from the travel writer John Talbot Dillon (1734-1800), whose *Travels in Spain* (1780) provided one of the only English-language sources on agriculture and natural history on the Iberian Peninsula. Dillon's explanation of locust swarms became authoritative for decades within British natural history: particularly because Dillon seemed well-informed on the sexual economy of the locust species that had caused the most damage. British curiosity about locusts was not entirely disinterested: there were occasional scares on the coast of Britain over the possibility of locusts being blown to the island. In 1694, one such swarm fell upon the Welsh coastline, prompting

107 Ibid., p. 28-29.
108 Townsend, 1791, t. 1, p. 205.
109 Ibid., p. 211.

letters and correspondence within the Royal Society over the dangers posed by them. Even at this early date, the potential danger of the locusts was viewed as characterised by the lack of predators on the island, although their capacity to reproduce was not discussed. One letter to the Society observed:

> You have probably been already informed …of swarms of locusts that have lately appeared on our British Coasts …I see not much reason to doubt but that these are the very same species of locusts, so famous in history for their wandering over, and depopulating whole regions…. In Wales there are no creatures to devour them, unless the badgers and crows may take off some.[110]

Dillon blamed the swarms primarily upon the imbalance between males and females. “The males,” he wrote, “are far more numerous than the females. If an equal proportion was allowed, only for ten years, their numbers would be so great, as to destroy the whole vegetative system…. In 1754, their increase was so great from the multitude of females, that all la Mancha and Portugal were covered with them, and totally ravaged.”[111] But the balance of male and female could only explain part of the threat posed by the locusts: of equal importance was Dillon’s belief that the locusts existed in a constant sexual haze. “The amours of these creatures,” he explained, “are objects of surprise and astonishment, and their union is such, that it is difficult to separate them.”[112] He wrote of seeing six males piled at once upon one female. Even their consumption of crops was, Dillon believed, sexual:

> the males climb up the plants, as sailors do the shrouds of a ship; they nip off the tenderest buds, which fall to the females below. At last, after repeated devastations, they light upon some barren ground, and the females prepare for laying their eggs.[113]

All aspects of the threat of locust swarms were sexualised in Dillon’s account: the very consumption of the crop was a mating ritual, which would be followed by an intense and violent period of mating, after which there were no additional reasons to exist: the males died shortly after mating and the females died after laying eggs. Dillon had little hope that humanity would ever develop

110 Floyd, 1694, p. 45-47.
111 Dillon, 1780, p. 265.
112 Ibid.
113 Dillon, 1780, p. 267.

means to cope with or manage adult locusts: the only solution would be to attack the eggs before they hatched. This suggestion was by no means new: older communications to the Royal Society of London had documented efforts to dig up locust or "grasshopper" eggs to prevent ravages from the next season. A communication from Avignon observed that an emergency band had been assembled to try and dig up locust eggs after a swarm fell upon their corn fields close to the end of the season. Trying to estimate the volume of the eggs they uprooted from the ground, Henri Justel (1619-1693) wrote "we took of them 180 quintals, being 9 tons …but since their hatching they have taken above 15 tons of the young grasshoppers which are not yet bigger than flyes."[114]

In 1781, the traveller and explorer Henry Smeathman (1742-1786) wrote a communication to Joseph Banks on the famous termite mounds of Western Africa. Smeathman had, with assistance, been shown how to excavate the termite mounds: as his letter explains, he relied upon local expertise to be shown the different types of ants which lived together within the mounds, the different chambers they carved within their towers, and their mating habits. Smeathman was primarily interested in the reproductive habits of the ants, observing that no one had ever seen mating between males and female queens (as this never happens until the mating pair have arrived to the safe enclosure of a new nest).[115] However, Smeathman was able to capture queens and then to count the number of eggs they produced in a day. He was particularly interested in the sexual dimorphism, noting that "the abdomen of this female [the queen] begins gradually to extend and enlarge to such an enormous size, that an old queen will have it increased so as to be fifteen or thousand times bulk of the rest of her body, and twenty or two thousand times the bulk of a laborer, as I have found by carefully weighing and computing the different states."[116] How, Townsend wondered, were the mating pair at the centre of the nest able to populate a mound which might stretch as tall as four meters in the air? Measuring the rate at which his captured queens produced eggs, Smeathman deduced that a mature queen could produce 60 eggs in a minute, and potentially 80,000 in a 24-hour period.[117]

Like Dillon, Smeathman viewed this sexual economy to be at the heart of the organisation of the mound: all labor and instinct related to communicating the eggs to nurseries, feeding the eggs, and encouraging swarms to leave the nest and colonise new territory. But this tremendous capacity to reproduce

114 Justel, 1686, p. 148-149.
115 Smeathman, 1781, p. 170.
116 Ibid., p. 170.
117 Ibid., p. 171.

still served a clear purpose in the natural economy. Smeathman saw a theological (or natural) explanation for why the ants had been given such tremendous reproductive potential and capacity. "When anything whatever is arrived at its last degree of perfection," he explained, "the Creator has decreed it shall be totally destroyed as soon as possible."[118] The termite ants could, given their reproductive capacities, expand in population size according to the need to destroy all ailing or deceased organic substances within their purview: for Smeathman, the capacity to rapidly increase population size was tied to this more primordial need for the imperfect and degenerated aspects of the natural world to be swiftly consumed and eliminated. It was easier for Smeathman to observe the ants during the swarm phase of departing their home nest and seeking to colonise a new abode: and here, Smeathman focused once more upon their sexual instincts. "They run exceeding[ly] fast, the males after the females," he explained. "I have sometimes remarked two males after one female, contending with great eagerness who should win the prize, regardless of the terrible dangers that surrounded them."[119] Smeathman was clearly engrossed in the large casualties that befell swarming ants – death seemed to be the rule, with a very few fortunate couples succeeding to survive. But Smeathman's interpretation was clear: any instinct of self-preservation would mean the end of the species. Their economy only endured because of this unchecked instinct to reproduce at all other costs.

CONCLUSION

During the early modern period, the study of insects triggered new discussions about the nature of sexuality itself, and hinted at new lessons for the regulation of human populations. The discovery of insect's astonishing reproductive powers as sexual beings, coupled to their nefarious devouring behaviour as swarms, brought the question of humankind's own reproductive rates, and of their sustainability in case of overpopulation. The early modern discovery of insect's sexual reproduction was made possible by the technological development and gradual commercial democratisation of microscopy, which allowed for the joint observation of insect sexual organs and the mathematization of entomology through egg-counting. Quantification of the seemingly miraculous reproductive powers of insects complemented more traditional discussions about the hexagonal patterns of beehives in early modern political theologies.

118 Ibid., p. 146.
119 Ibid., p. 169.

The popular spread of scientific microscopy in the eighteenth century then went hand in hand with the gradual demise of spontaneous generation, and prompted new developments within the heterogenous field of sacred entomology. Such a field, which featured natural theologies presenting insects as ideal proofs of God's creation, also included fresh allegorical understandings of insects in Scripture. The sexual reproduction of insects not only reshaped traditional insect symbolism, but also prompted numerous debates about their taxonomical classification, free will, and status as a particular sub-reign of animals. In his *Dialogues Concerning Natural Religion,* the religious sceptic David Hume (1711-1776) explained that all of nature consisted of the kind of mass death and destruction visible within the insect realm:

> Consider that innumerable race of insects, which either are bred on the body of each animal, or flying about infix their stings in him. These insects have others still less than themselves, which torment them. And thus on each hand, before and behind, above and below, every animal is surrounded with enemies, which incessantly seek his misery and destruction.[120]

Our purpose in drawing attention to these enquires into insect sexuality and reproduction is not merely to push back the date at which ecological awareness became concerned with population size. It is true that Malthus is still commonly regarded as introducing concepts of a sexual economy and population growth into the wider scientific discourse of the nineteenth century – and in synthesising work by many historians of entomology, we hope to have shown here that such an approach obscures a century of empirical and quantitative investigation into sexual reproduction and population. A substantial aspect of Malthusian scholarship, dating at least to Patricia James, has also focused on Malthus as an Anglican minister writing on the sexual economy – but this article provides a new context for understanding the longer theological tradition of focusing upon sexuality and population. It would be difficult to show that Malthus was concerned with entomology: but we are not interested in such a narrow question concerning scholarship and influence. More important is the recognition that there was an empirically informed Europe-wide discussion predating figures like Alexander von Humboldt (1769-1859) currently associated with the birth of ecological conscience.

We hope that this article has thus shown that entomology played a central role in eighteenth century intellectual traditions – theology, economy,

120 Hume, 1779, p. 176.

and natural history were all influenced by the problems tackled by entomologists in this period. Crucially, entomology rendered many working concepts of nature and economy obsolete: the observations of Réaumur and others refuted naïve concepts of balance and utility. Instead, they reinforced the importance of imperfection (realised in the eggs that never hatch), self-destruction (observed by Huber in the cannibalistic consumption of eggs in beehives), and, most importantly, the triumph of sexual desire over self-preservation. Of course, as historians like Ross Brooks have observed, the eighteenth and nineteenth centuries witnessed insect sexuality interpreted according to their contemporary cultural norms and expectations.[121] There is more work to be done to delineate the extent to which entomology contributed to (and in places contested) the heteronormative ideology developing in Europe during this period. But even within the narrow interest of observing what was understood to be heterosexual mating and reproduction in insect species, familiar concepts of sexual reproduction and the propagation of the species proved to be no longer straightforward or workable.

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