'Biologically Degenerate, Ecologically Marginal': Parasites as a Case Study in Societal Values Impacting Ecological Research

Meghan Barrett[*], Thomas Raffel[†], Bob Fischer[‡]

Since parasite ecology was first popularized in the late 1970s, researchers have identified and rejected many foundational assumptions about parasites that turned out to be erroneous. What explains the existence of so many erroneous assumptions about parasites and their neglect in mainstream 20th-century ecology, relative to ecologically similar organisms such as predators? We argue that longstanding negative societal values associated linguistically with parasites probably played some role in shaping negative scientific assumptions about parasites in a way different to other categories of natural enemies with different value associations. We review two examples where more recent research has corrected mistaken assumptions about parasites' roles in ecosystems. In each case, we argue that cultural values may partially explain why earlier scientists opted not to explore hypotheses that framed parasites as powerful, important assets to their ecosystems.

Keywords

ecological theory • parasites • predators • value associations • bias

1. Introduction

> *No matter how much the natural sciences lay claim to a direct access to phenomena, this access will always have to be articulated in a language defined by cultural norms and traditions* (Gullestad 2011).

[*]Department of Biology, Indiana University Indianapolis, Indiana, United States of America, meghbarr@iu.edu
https://orcid.org/0000-0002-1270-4983
[†]Department of Biological Sciences, Oakland University, Michigan, United States of America, raffel@oakland.edu
[‡]Department of Philosophy, Texas State University, Texas, United States of America, fischer@txstate.edu

Received 25 March 2024; Revised 11 December 2024; Accepted 05 March 2025
doi:10.3998/ptpbio.5837

Parasite ecology research has taken off since the 1970s (Raffel et al. 2008; Moore 2012; Lively et al. 2014; Poulin 2021; but see Preston et al. 2016; Andrew et al. 2021). Many factors explain the rapid shifts in the field, including the development of key mathematical models (e.g., Anderson and May 1978), insights from community ecology (e.g., Holmes 1973), and new genetic tools (e.g., Wickström et al. 2003). This progress has overturned some erroneous hypotheses about parasites, including (1) that they are degenerate and simplified creatures; (2) that they do not play important roles in regulating ecosystem dynamics or shaping food webs; and (3) that parasites only weakly influence their hosts' evolution, population dynamics, and behavior (among others; see Mittelbach 2005; Vickerman 2009; Moore 2012; Poulin 2021).

Strikingly, such mistaken assumptions about the ecology of parasites of animal hosts (hereafter, animal parasites) appear to have been more pervasive and fundamental than in related fields, such as predator-prey ecology, resulting in a prolonged period of parasite exclusion from mainstream ecological research (as reviewed in Poulin 2021 and below). Additionally, parasites have continued to be misunderstood despite the progress in ecological parasitology. Just over a decade ago, for instance, it seemed reasonable for researchers to argue that "basic assumptions about parasites, their ubiquity, and their relevance need to be reexamined or abandoned" (Gómez and Nichols 2013, 225). More recently, researchers have claimed that parasites are still being neglected, contending that "their omission from the design and analyses of ecological studies poses real risks of flawed interpretations" (Timi and Poulin 2020, 759).

This situation raises two questions. First, what explains the accumulation of so many erroneous assumptions about animal parasites? Secondly, why have some of these assumptions lingered long after there was ample evidence against them?

Complete answers to these questions will cite many factors. Animal parasites are, of course, small and difficult to study in their natural environments (frequently, inside their hosts). And before the takeoff of ecological parasitology, researchers lacked many of the tools that are now regarded as essential to understanding parasites properly. So, it may not be surprising that earlier generations of scientists had poor models of these organisms and their ecological significance. Moreover, it takes time for scientific developments to be disseminated and fully integrated into subsequent work; so, it may not be surprising that certain errors persist decades after they are known to be errors.

While these are, no doubt, central parts of the story, our aim here is to argue for the importance of another component. As Reynolds (2018, 2) argues, the metaphors that scientists adopt "can be integral to the formulation of a theory and constitute the core of action-guiding programs of research. They also incorporate implicit value judgments about the nature of the subject matter under investigation and the proper route to its scientific understanding." And "parasite" is itself a metaphor, a piece of language originally applied to humans that was co-opted for scientific use (as we'll discuss below). We argue that the negative cultural perceptions of parasites caused a range of negative associations with the term "parasite" and its cognates, even for scientists who study these organisms, and that these negative associations resulted in cognitive biases regarding animal parasites that influenced research priorities, the development of new explanatory frameworks, and the eventual acceptance of these frameworks.

We are hardly the first to note the prevalence of erroneous assumptions about, and the neglect of, animal parasites in ecology (Moore 2012; Poulin 2021). However, previous authors have neither detailed the historical roots of this problem nor provided contrasting cases to bolster the hypothesis that cultural and linguistic value associations influenced the development of ecological theory. We do both here. We provide a novel comparison of the value associations for two categories of natural enemies, animal parasites and predators, that are commonly used as biological-social metaphors. After describing generally how language is known to impact

the development of scientific theory, we move to exploring the case of parasites and predators by: (1) demonstrating the disparity in treatment between predators and parasites in ecological literature, (2) identifying the historical origin of the relevant value associations prior to these terms' ecological adoption, and (3) providing two case studies that illustrate how these value associations impacted ecology. We conclude with some suggestions about how negative value associations in science might be addressed.

2. The Impact of Language on Scientific Theory

Scientists often borrow terminology from the broader culture to describe phenomena of interest. Often enough, the societal values associated with that language partially explain why that language is perceived to be useful, despite the ostensible desire for value neutrality in scientific discourse (e.g., Lewontin 1992, Larson 2011). One such example is the male 'king bee' (now queen bee), who reigned over honeybee colonies from Aristotle's 350 B.C.E. *History of Animals* to Hyll's 1579 beekeeping manual. Western philosopher-scientists adopted the term 'king' to describe the sex and social position of the dominant bee in each colony because of their assumptions – implicit or explicit – about who has power and who can lead (Wilson 2014a). Once adopted, the term nudged scientists towards a "general orthodoxy of the king bee," (Wilson 2014a) hampering our understanding of bee sex and social organization (Maderspacher 2007).

The (correct) alternate hypothesis existed throughout this entire period, though it was not popularized nor rigorously tested: the 'mother' bee is mentioned in sources as far back as Aristotle's contemporaries, though, notably, none proposed that the female rules the colony (Maderspacher 2007; Grinnell 2016; Videen 2016). It was only following Queen Elizabeth I's reign (1558–1603) that the first scientific works about a *female queen* bee circulated in England (Butler's 1609 *The Feminin' Monarchie*), though her rule did nothing to change the entanglement of bee colonies and metaphoric royalty.[1]

The case of the "king bee" illustrates that cultural values can subtly inform scientific theory. If those theories become prominent, then inertia can anchor the scientific community in ways of thinking that are basically misguided (Chu and Evans 2021). There is ample evidence that background beliefs can nudge scientists in many ways, affecting how researchers allocate their attention (Rees et al. 1999), how they interpret data (Brewer and Chinn 1994), what they perceive when making observations (Gunstone and White 1981), and what they judge worth communicating in their publications (Holton 1978). This can lead to long periods during which scientists try to make existing theories compatible with recalcitrant evidence (as illustrated by astronomical epicycles; Gingerich 1993) or simply miss such evidence entirely (as in the study of the evolution of the female orgasm; Lloyd 2006).

Early ecologists provide another example of cultural values informing theory, though the consequences are more complicated. When Haeckel, for instance, defined ecology as "the economy of nature" in 1869 (Egerton 2013), that phrase no longer meant something like "the order of nature," as it had in the pre-Darwinian period. Instead, it was now informed directly by Darwin's 1859 *Origin of Species*, which systematically employs economic concepts in the theory of natural selection – competition, the division of labor, scarcity of resources, and so on – borrowed from the likes of Adam Smith and Thomas Malthus. And just as economies were thought to tend toward stable equilibria, regulated by the "invisible hand" that emerges when all actors pursue their own self-interest, Haeckel thought that ecological systems did too: such systems are

1. In the case of the "king bee," the choice was certainly unfortunate, as the scientific use of this language was then used to legitimize human power hierarchies: Shakespeare, for instance, used the "king bee" as a metaphor for a rightly ordered patriarchal, monarchal society (1599; see also Allen 2004).

governed by the "balance of nature," where "the absolute number of organic individuals populating our world … remain[s] constant, and … only the relative numbers of the individual species … alter continually in relation to each other" (quoted in Egerton 2013, 227). Earlier biologists had understood the "balance of nature" in religious terms, attributing homeostasis to the divine ordering of the natural world. The economic view of ecological systems allowed scientists to preserve a sense of the correctness of that order without positing supernatural action. This may well have delayed scientists' appreciation of nature's stochasticity, not to mention many objectionable uses of the theory of natural selection to prop up certain hegemonic (power-structured and dominance-maintaining) human institutions.

These examples do not show that it is inherently objectionable to use value-laden language for scientific purposes. Instead, they illustrate the importance of thinking systematically about when and why to co-opt value-laden language for scientific purposes. In any case, our focus here is on one particular context where value-laden language had impacts on science. As mentioned earlier, we'll explore this issue by contrasting the cases of parasites and predators. Despite ecologists' appreciating that parasites and predators are similar in important respects, they paid parasites much less attention than predators and understood their ecological traits quite differently. Again, we do not want to suggest that values associated with parasites and parasitism were the only or even primary factors in this neglect, only that history suggests that they had some important role to play.

3. Ecological similarities, research disparities

> *Parasites, in a phrase, are predators that eat prey in units of less than one* (Wilson 2014b, 112).

Though obviously different in many respects (Lafferty and Kuris 2002; Raffel et al. 2008), parasitism and predation share characteristics common to all consumer-resource interactions (Thomas et al. 2005b; Hall 2008). Early ecologists explicitly acknowledged this similarity – Elton (1927, 75) wrote, "it is best to treat parasites as being essentially the same as carnivores" – and other prominent ecologists have continued to associate parasites and predators (Hairston et al. 1960; Janzen 1970; Wilson 2014b). Notably, parasites were not completely ignored by all biological disciplines, such as taxonomy ("old school natural history"; Poulin 2021, 1073). Moreover, in part because parasites were targeted for eradication due to their impacts on the economy and human health (Cox 2002), parasitologists themselves began asking ecological questions about parasites long before ecologists began to seriously consider parasites as important players in ecological communities (e.g., Farley 2003; Worboys 1983). Still, it remains the case that animal parasites were at the margins of ecology throughout its early history (Jackson 2015).

This disparity in ecological research priority was apparent early in the 20th century. When reviewing recent progress in food cycles, Lindeman (1942, 405) wrote that "the various categories of parasites are somewhat comparable to those of the predators, but the details of [parasites'] energy relationships have not yet been clarified, and cannot be included." This may be due to untested assumptions about the roles of (weak) parasites and (powerful) predators in controlling other species (about which we'll have more to say later). Muir (Williams 1931, 26), for instance, stated that "theoretically, other things being equal, a predator should be more valuable [read: influential] than a parasite" and Elton (1927, 81) stated that "in [the food cycles of] an animal community … parasites do not play a very important part" – without providing evidence for the claim. By comparison, the introduction of a review by Errington in 1946 suggested that studies of predation "surely number in the many thousands of titles…. Whatever else may be

said of predation, it does draw attention" (144).

The disparity grew as mid-to-late-20th century ecologists continued to demonstrate the important roles of animal predators in their ecosystems (e.g., Paine 1966; Slobodkin et al. 1967; often called 'trophic cascades', Paine 1980). Predators were described as "powerful" (Hutchinson 1957); "dominant" (Van Valen 1973a); "ubiquitous" (Ricklefs 1987); "major importance/regulator" (Blair 1950; Slobodkin et al. 1967); and even "keystone," which was coined by Paine (1969a) in reference to influential, high trophic level predators before being more broadly redefined to include parasites (Power et al. 1996; Estes and Palmisano 1974). By contrast, parasites were either ignored or subsumed by predators (e.g., in Lotka-Volterra equations; Lotka 1925; Volterra 1926a, 1926b; Kingsland 2015). This systemic disparity produced an ecological literature where "competition and predation have been traditionally considered as major biotic determinants of community structure, [while] parasites have been virtually ignored" (Thomas et al. 2005a, 124).

Anderson and May's (1978–1982) seminal models of parasite-host dynamics, drawing on the extensive predator-prey literature, began the process of integrating parasites into ecological theory in a more systematic way. As Heesterbeek and Roberts (2015) contend, while others were either pursuing highly abstract modeling or focused on understanding particular infectious agents, Anderson and May managed to model general epidemiological phenomena *without* losing sight of the biological mechanisms at work, which lent itself to improving decision-making in public health. Moreover, because they worked with a wide array of collaborators and students, Anderson and May created a new cohort of parasite and wildlife disease modelers who pushed parasite ecology research forward. As a result, the 1970s and 80s have been cited as the dawn of a parasite research revolution by many ecologists (Mittelbach 2005; Poulin 2007; Vickerman 2009; Moore 2012; Englund 2014; Jackson 2015; acknowledging that others played important roles as well, e.g., Hamilton 1980; Zuk 1982; Van Valen 1973b).

Nevertheless, the disparity in research priority between parasites and predators has persisted through the late 20th and early 21st centuries (Poulin 2021). In a study of ecological research network dynamics between 1975 and 2014, predator-prey ecology was one of the main clusters of ecological research from 1980–2014, while parasite ecology did not appear even as a subcluster (Réale et al. 2020). Of the 100 highest-ranked papers in ecology published between 1858 and 2014, predators featured in 45 compared to only 18 for parasites (14 of which also featured predators). The mean ranking for predator papers without parasites was 48 (published 1934–2014), including 50% of the top ten spots, while the mean ranking for parasite-only papers was 81, with only one paper in the top 50 and all published between 1978 and 1981 (Courchamp and Bradshaw, 2017).

Similarly, Loreau et al. (2005) found that the journal *Ecosystems,* chosen because it reflects the incorporation of parasites into theories about ecological systems and not simply their taxonomic inclusion, had not published a single paper on parasites, parasitism, or parasitoids from its founding in 1998 to the time of their publication (versus 110 hits for predat- between 1998 and 2005; our search of the same journal yielded 90 results for parasit- and 475 results for predat- between 1998 and 2023). The proportion of papers featuring parasites relative to predators in ecology journals from 1991 to 2006 showed predators featured in at least twice as many publications as parasites (Raffel et al. 2008). Broad topical treatment by ecologists is consistent with this analysis of the primary literature: 21st-century ecology textbooks still largely neglect parasites in comparison to predators, with the majority featuring parasites at less than 50% the rate of predators (Figure 1).

If early ecologists recognized the similarities between predators and parasites, why have parasites continued to be relegated to the margins as less important than predators in the development of ecological theories? To help answer this question, we should briefly review the

societal associations with the terms 'parasite' and 'predator' prior to their adoption by scientists.

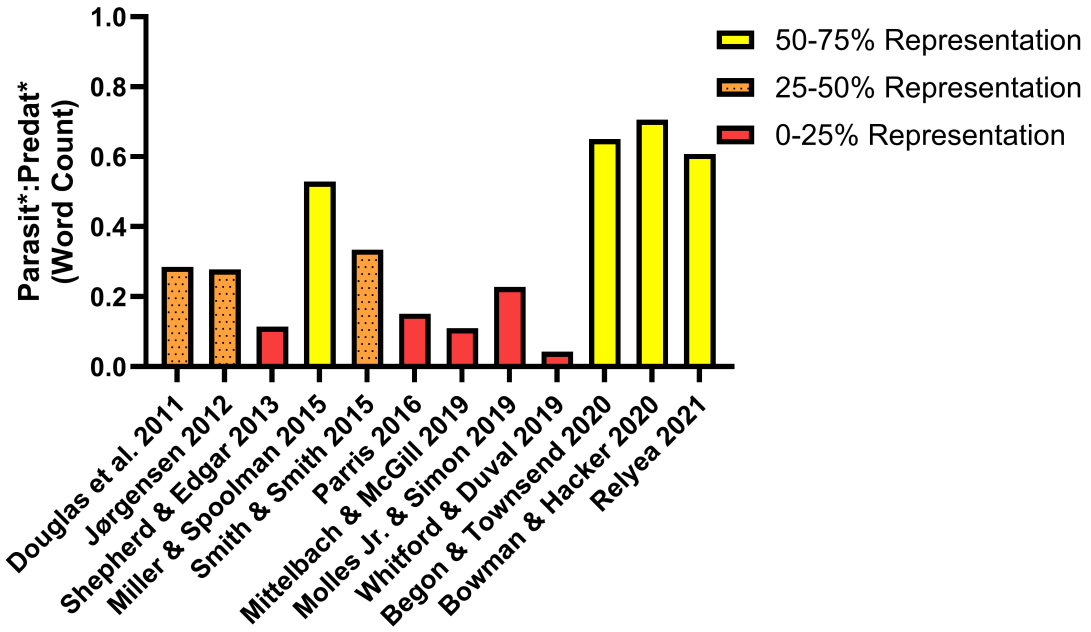

Figure 1: Parasites are neglected in ecological textbooks compared to predators. Twelve online ecology textbooks published in the last decade were searched for parasit* or predat* containing words using the ProQuest, RedShelf, or Amazon kindle search tool. The number of parasit* containing words was divided by the number of predat* containing words; a ratio of less than one means that parasites are not equivalently represented.

4. The Origins of 'Parasite' and 'Predator'

'Parasite' has almost always been associated with weakness, dependence, lack of social importance, negativity, and threatening moral depravity. Contrary to the common supposition that the social (human) parasite is modeled off the biological parasite, the word referred solely to humans for over 2,000 years. The Greek *parasitos* dates to the 5th century B.C.; at that time, it referred to temple assistants receiving free meals in return for festival duties. Greek comedic playwrights molded the *parasitos* into a trope for the stage: irreverent flatterers dependent on free food secured at the tables of the rich. The *parasitos* was popularized as a unidimensional 'type' – overwhelmingly the punchline of jokes and often an example of unethical behavior (Gullestad 2011; Musolff 2014, 2016).

Ridicule morphed into vicious insult targeted at specific individuals both in creative (e.g., a 1665 satire about Pierre de Montmaur, *Epulum parasiticum;* De Smet 1996) and religious works (e.g., English Catholic scholars calling John Wycliffe "a vile heretic, a most pernicious flatterer and parasite," Rainolds and Bruce 1593). Specific species of animal parasites (e.g., the flea) were represented as simultaneously threatening to society's most important moral values (e.g., female virginity during the British Tudor and Victorian periods) yet individually puny/weak, often through association with socially unimportant or derided individuals (Marlowe 1592; Donne 1633; Orme 2011; Prystash 2016; Filo 2019).

'Predator' (meaning pillager/plunderer) appears in the 15th century, also solely in reference to humans, with a connotative duality as divinely powerful yet morally contemptible (e.g., the

disgraceful nature of the king's predation described by 15th-century political prisoner George Ashby, Bateson 1899; and Cæser, a tyrant and 'predator' in 1584 *Don Simonides,* OED 2021). According to these authors, predators were authoritative, important male figures, generally kings and emperors ruling by a natural, divine right that justified their hostile dominance. Specific animal predator species were frequently associated with power, masculinity, wealth, and social importance (e.g., the eagle on the Roman legion standard and lions on English royal crests, among others; Mylonas 1946; Julian 2004; Hünemörder 2006; Hayes 2014; Holmes 2020). Hunting, the act of human-as-predator, was generally considered the domain of strong and able men, and in some societies became a sport associated with wealth, power, and masculinity (Goldberg 2020; some of these associations lasting to the modern era, see Littlefield 2010).

When 'parasite' was adopted and popularized in the scientific community in the 17th century, the associated values and concepts such as weakness, social (e.g., system-level) unimportance, depraved moral threat, and "negatively valued metaphors of dependence" (Osborne 2017, 212) came with the term (Gullestad 2011; Musolff 2016). Ecologist Elton (1927, 75) wrote in his foundational text, *Animal Ecology,* that "it is common to find parasites referred to as if they were in some way more morally oblique in their habits." The moral/functional degeneracy and negative dependence of even a free-living and familiar-looking brood parasite, via a social metaphor, can be clearly seen in the popular natural history works of Neltje Blanchan and her accounts of cowbirds:

> Its marital and domestic character is thoroughly bad. Polygamous and utterly irresponsible for its offspring, this bird forms a striking contrast to other feathered neighbors, and indeed is almost an anomaly in the animal kingdom … an unnatural mother may be seen skulking about in the trees and shrubbery … selecting in a cowardly way a small nest … there leaving the hatching and care of its young to the tender mercies of some already burdened little mother … keeping with its unclean habits and unholy life and character. (Blanchan 1897, 49-50)[2]

As these examples illustrate, and as documented more thoroughly in the quotes by ecologists in supplementary table 1, the concepts of social unimportance, weakness, and degeneracy colored the way many early ecologists viewed parasites. These associations persisted and became common in the field despite the absence of scientific evidence for them; moreover, they proved to be surprisingly durable. For instance, Lack (1954) stresses parasites' unimportance, Haldane (1955) critiques this claim, but MacArthur (1958) repeats Lack's view anyway – even though MacArthur engages with Haldane's work.

'Predator', by contrast, was widely adopted by scientists in the early to mid-20th century. Animal predators were valorized as naturally powerful in their own ecosystems. At the same time, they were condemned when their actions threatened humans' safety or economic interests, and thereby the hierarchy of nature (established both through religious texts, such as the Judeo-Christian creation myth, and scientifically; Aristotle's *Scala naturae* and Linnaeus' *Systema naturae;* Pui-lan 1992; Clutton-Brock 1995). This duality helps explain humans' continual "love-hate relationship with predators" ("Predators on Top" 2018). On the one hand, they have long been culled when they've posed any threat to human interests: consider, for instance, the US decision to slaughter wolves in the late 1800s to prevent livestock predation (Dunlap 1998). However, after such threats have been minimized, predators are valorized for their critical ecosystem roles and selected as charismatic targets for conservation and ecological restoration initiatives (Dunlap 1998; Macdonald et al. 2017).

2. Her perspective is unchanged thirty years later: "this contemptible bird everyone should know if for no better reason than to despise it … shirking as she does every motherly duty" (Blanchan 1927, 140-141).

This tension is visible, again, in the work of Blanchan (1898) who writes admiringly of "innocent birds of prey" (vii), whose "...entire structure indicates strength, ferocity, carnivorous appetite, and powerful flight, have, for their diagnostic features, strong, hooked bills..." (301) But her tone changes significantly when birds of prey threaten the anthropocentric hierarchy, writing that the chicken hawk "lives by devouring birds of so much greater value than itself that the law of the survival of the fittest should be enforced by lead until these villains, from being the commonest of their generally useful tribe, adorn museum cases only." (314-315)

5. Assumptions About Parasites: Two Case Studies

On its own, this brief survey of the history of the terms 'parasite' and 'predator' is suggestive: it would be surprising if the values associated with these terms (e.g., powerful/important vs. weak/unimportant) played no roles whatever in scientists' thinking about parasites and predators. Like the divergent societal values associated with sex and power that promulgated the reign of the "king bee," the divergent values associated with predators and parasites probably had some impact on scientists' appreciation of parasites' ecological significance. However, the impacts of these values are clearer when we consider specific assumptions about parasites. In what follows, we turn to two case studies: one about the assumption that parasites are ecologically insignificant; the other about parasites being unworthy of conservation. In each case, we argue that societal values played some role in explaining why earlier scientists opted not to explore hypotheses that framed parasites as powerful/important – and thus as ecosystem assets.

5.1. Parasites as Weak and Unimportant Dependents

> *From the 19th century birth of evolutionary biology until well into the 20th century, parasites were seen as biologically degenerate, ecologically marginal and evolutionarily anomalous… [This atmosphere] casts a pall over parasite evolution and affects the questions we tend to ask.* (Jackson 2015, S1)

Elton was the first to categorize trophic patterns in feeding relationships in his pyramid of numbers: "Eltonian pyramids," the ancestors of the more familiar trophic pyramids in ecological textbooks today (Sukhdeo 2010). Like many early 20th-century ecologists, Elton was influenced by the capitalism of his day, claiming that "the carnivores … live on capital and the [parasites] on income," where living "on capital and not on income [is] an almost ideal existence" (Elton 1927, 71, 138). Echoing centuries of associating powerful, wealthy men with carnivores, Elton's pyramid placed carnivores at the peak of the pyramid, mirroring "the philosophy that had prevailed in Washington since 1921 … [that] government was to provide prosperity for those who lived and worked at the top of the economic pyramid" (presidential speechwriter Samuel Rosenman, 1952, 62).

Elton himself recognized the limits of this model – acknowledging, for instance, that carnivore numbers are (at least partially) controlled by parasites. However, mere pages after acknowledging the similarity of predators and parasites, he still concluded (without providing evidence) that "many ectoparasites have no very important direct effects upon the food-cycle [and] it is for this reason that parasites can very often be ignored in practice" (Elton 1927, 81). While predators, much like those at the top of the economic pyramid, were considered too important to be ignored, parasites, much like the marginalized people with whom they were historically associated, could (and would) be neglected (Lafferty et al. 2006; Sukhdeo 2012).

As mentioned earlier, ecology's perspective on parasites began to shift due to a series of critical publications in the 1970s and 1980s. Modern trophic pyramids and food webs may

even place parasites at *the very top* (Rafaelli 2002; Sukhdeo 2010), and parasites are now known to serve many powerful roles in ecosystems: generating host population cycles (Dobson and Hudson 1992; Hudson et al. 1998), making prey vulnerable to predation (Hudson et al. 1992), affecting the structure or connectivity of food webs (Marcogliese and Cone 1997; Lafferty et al. 2006; Lafferty et al. 2008), direct or indirect ecosystem engineering (Thomas et al. 1999; Pascal et al. 2020), changing temporal ecosystem dynamics and biogeochemical cycling (Preston et al. 2016), initiating trophic cascades (Holdo et al. 2009; Buck and Ripple 2017; Monk et al. 2022), contributing to biomass and secondary productivity (sometimes more than the top predators; Kuris et al. 2008), and more (Price et al. 1986; Thomas et al. 2005b; Hudson et al. 2006; Hatcher and Dunn 2011; Hatcher et al. 2012).

In addition, parasites can be important players in evolutionary ecology. Contrary to the "traditional, but untested, assumption that anti-parasite responses are weak relative to anti-predator responses" (Rohr et al. 2009, 447), parasites drive numerous changes in host behavior through the evolution of anti-parasite responses (Bush and Clayton 2018) and through direct and indirect manipulation (Moore et al. 2005; Hughes et al. 2012). Indeed, parasite-induced changes in host behavior may be more numerous and frequent than anti-predator behaviors (Daversa et al. 2021). After decades of ignoring the possible powerful roles of parasites in natural selection (Vickerman 2009; often in favor of predators, Haldane 1949), recent research shows parasites drive speciation and diversity, mediate gene transfer among species, and may have played a role in the evolution of sex and sociality (Schmid-Hempel 1998; Poulin 2007; Jokela 2009; Auld et al. 2016; Brunner and Eizaguirre 2016; Yang et al. 2016; Turko et al. 2017; Poulin 2021).

The morphological simplicity of many animal parasites, and their physiological reliance on their hosts, generated assumptions of negatively-valenced dependency; parasites were positioned as 'having regressed' evolutionarily to a simplified and weak state (see quote by zoologist Lankester in supplementary table 1; Vickerman 2009), precluding a transition back to free-living lifestyles (Dollo 1893; Cruickshank and Paterson 2006). In a review of fifteen parasitology textbooks, "only four texts allowed the possibility that reversals of parasitism [back to a free-living state] might be possible, but all cautioned that it is unlikely to occur" for parasites (Cruickshank and Paterson 2006, 511). However, recent evidence has shown that parasites can become free-living species again and there are likely more examples than the few discovered so far (Siddal et al. 1993; Dorris et al. 2002; Klimov and O'Connor 2013; Xu et al. 2016). Parasites are also more complex than initially assumed, with highly specialized genetic and morphological adaptations for host manipulation and survival, suggesting parasites are not 'regressed' but rather innovative (Auld and Tinsley 2015; Hughes et al. 2012; Hurford and Day 2013; Jackson 2015; Jackson et al. 2016; Carvalho Cabral 2019; Yang 2019). Parasites are now known to shape ecosystems and exert powerful selective pressures on their hosts despite long-held assumptions to the contrary. It seems plausible, then, that our realizing these facts was hampered by a predisposition to view parasites as *definitionally* weak, unimportant, dependent, and heritably simplified.

5.2. Parasites as Categorically Threatening

> *Parasitism as a way of life is usually confounded with a status: a parasite, at any density, is automatically considered as a pest, because wildlife is a valuable resource for man.* (Pérez et al. 2006, 2034)

There has been a similar transition regarding the management of parasites. To be worthy of conservation – i.e., of status as a protected 'natural resource' or asset – the services an organism provides must outweigh the perceived burdens they impose on humans (Clutton-Brock 1995).

A large literature exists about how and when predators went from mostly 'threat' to mostly 'asset' over the course of the 20th century (Dunlap 1988; Kruuk 2002; Bergstrom 2017). Two factors appear to have been particularly important: first, the actual diminishing threat posed by predators to industrial settler-colonialist societies due to successful predator control and the industrialization of habitat; second, predators' role as a recreational and economic asset for powerful men (like United States President Theodore Roosevelt; Dunlap 1988; Johnson 2002).

By contrast, veterinary/medical parasitologists presented parasites as a substantial threat to health and comfort at home and abroad (Cox 1993; 2002; Morris 2011; Sarasohn 2021) leading to, for example, militarized tropical medicine (Lederman 2005; Keller 2006; Mitman and Erickson 2010). Parasites also posed major challenges to colonial projects, such as the construction of the Panama Canal where the threat of mosquito-borne parasites led to ecologically ruinous control strategies such as 'oiling' sources of standing water ("the greatest liberty man has ever taken with nature," according to Englishman James Bryce, quoted in Haskin 1913, 20; Moore 2017; Lindsay-Polard 2003).[3]

Conservation has never been an impartial enterprise, even when it has appealed to values that support such an orientation. Most 19th and early 20th century conservation efforts were directed toward species that had some easily discernible value for human beings (Stork and Lyal 1993; Singer 2009). Michael Soulé, the founding father of conservation biology, attempted to correct this by arguing that biodiversity ought to be valued in itself (1985). While this idea helped many species with no obvious value for humans, it did not seem to benefit parasites. Parasites were categorically either assumed to be unimportant (as previously described), and thus not worthy of consideration (completely absent from 42% of conservation textbooks), or represented as threats to human conservation interests (31% of all textbooks; Nichols and Gomez 2011). Only 15% of conservation textbooks in 2011 contained at least one sentence positively describing the conservation value of parasites (Nichols and Gómez 2011). This near-universal absence of positive perceptions of parasites in the conservation literature prevented "a paradigm shift in the perception and valuation of parasites … similar to that of apex predators in the mid-20th century" (Dougherty et al. 2016, 724).

Despite being more speciose than predators (Price 1980; Poulin and Morand 2004), and despite their enhanced vulnerability due to the threat of co-extinction with their hosts (Koh et al. 2004; Strona 2015; Thompson et al. 2017), parasites were 'missing' in conservation: neglected in studies of extinction and left out of reintroduction efforts, translocation considerations, and theoretical de-extinction conversations (Moir et al. 2012; Jørgensen 2015; Northover et al. 2018; Selbach et al. 2018). Humans have driven some parasites to extinction or endangered their intermediate hosts without conducting risk assessments, including during wildlife conservation efforts and in direct contradiction of taxonomically unbiased biodiversity goals (e.g., condor lice on California condors, about which more below; Gompper and Williams 1998; Kristensen and Brown 1999; Colwell et al. 2009; Dunn 2009; Pizzi et al. 2009; Mihalca et al. 2011; Pérez et al. 2013; MacKenzie and Pert 2018; Milotic et al. 2020).

Moreover, when parasite conservation began to gain traction among some researchers, it met resistance from many others who, in the absence of acknowledged ecological roles for parasites, latched on to the narratives of threat imported from medical/veterinary parasitology. Windsor (1995, 1) notes that "informing most people, even most biologists, that parasites are going extinct is sure to bring a response such as 'good riddance'… [E]ven those who specialize in the study of parasites tend to regard them with controlled disdain." Indeed, the uncertainty

3. Given the ample evidence of negative value associations with the term 'pest' (see, e.g., McWilliams 2008; Biehler 2013; Sarasohn 2021), our argument would only be strengthened by considering the tendency to classify parasites as pests. For the sake of space, however, we set this issue aside.

surrounding the actual threat level posed by most parasites led to a tendency to exaggerate the threat that all parasites pose to wildlife. For instance, among the IUCN endangered species reports that listed parasites/disease as a "major threat," approximately 70% provided no evidence to back up the claim (Smith et al. 2006). Stringer and Linklater (2014, 935) offer three historical examples of the "overestimation of the threat … of parasites within an ecological community," and McCallum (2012, 2829) states that "attributing prehistoric extinctions to infectious disease has become almost a cottage industry in the last two decades," before demonstrating that the evidence for such claims is rarely convincing.

Despite this magnified perception of their threat, parasites/disease are only listed as a contributing factor in 8% of endangered species cases, even including the 70% of cases with no supporting evidence (Smith et al. 2006). Parasites are estimated to contribute to the decline of less than 1–4% of species; moreover, they are rarely the sole threat (Wilcove et al. 1998; Yingming and Wilcove 2005; Smith et al. 2006; Heard et al. 2013). Instead, they usually act as the last straw for species on the edge of extinction, already threatened by habitat loss, invasive species, overexploitation, and climate change (Wilcove et al. 1998; Smith et al. 2006; Sodhi et al. 2009; Smith et al. 2009; Heard et al. 2013). Host-specific parasites may even be threatened with extinction more rapidly than their hosts, potentially serving as early indicators of biodiversity decline (Koh et al. 2004; Hechinger et al. 2007; Lafferty and Kuris 2009; but see Strona et al. 2013).

Of course, some parasites contribute significantly to local population declines, failed reintroductions, or even historical and current extinctions. The threat level posed by a specific parasite can be very high, especially when the parasite is non-native or the host population is genetically homogeneous (de Castro and Bolker 2005; Ewen et al. 2012; McCallum 2012; MacPhee and Greenwood 2013; Heard et al. 2013). But predators can also pose severe threats, and in similar cases (Doherty et al. 2015). It is thus crucial to find evidence to guide each species's categorization as 'asset' or 'threat' in its unique context (if these categorizations are determined to actually be helpful at all). In any case, changing the default "parasite = threat" assumption will prevent the mismanagement of parasite biodiversity – e.g., the use of broad-action anti-parasite treatments in wildlife communities (Pedersen and Fenton 2015).

Lingering assumptions of parasites as threats have been slowly revised over the past 15 years, allowing an increased focus on active parasite conservation that positions parasites as important and positive components of biodiversity in their own right. Estimates of parasite extinction rates are accumulating, global and specific conservation guidelines have been proposed (and in a few cases, implemented), calls are mounting for cataloging diversity, and there is research starting on the factors that make specific parasites more or less vulnerable to extinction and more or less threatening to host biodiversity (Dobson et al. 2008; Lafferty 2012; Gómez and Nichols 2013; IUCN/SSC 2013; Brown et al. 2017; Carlson et al. 2017; Cizauskas et al. 2017; Thompson et al. 2017; Wait et al. 2017; Okamura et al. 2018; Kwak et al. 2019, 2020; Carlson et al. 2020a, 2020b; Moir and Brennan 2020). However, absent the values that seem to have shaped thinking about parasites, these revisions to conservation strategies and priorities (and the extinction of some parasite species, such as the Condor louse) may never have been necessary.

6. The Importance of Attending to Values

> *Parasitology … has been forced to address a number of stereotypes, prejudices, and common misconceptions which surround the objects of its research … theories which at the time were considered indisputable, but which have long been disproved.* (Jajszczok 2015, 67)

We have argued that societal values associated with the terms 'predator' and 'parasite' were uncritically imported into ecology. We contend that these values partially explain both the appeal and durability of erroneous assumptions about parasites relative to predators, even though both are ecologically similar classes of consumer organisms. The values associated with predators made it easier to appreciate their ecological importance and conservation value; by contrast, the values associated with parasites made it harder to do the same.

Of course, it is not possible to quantify exactly how much harder these values made it for ecologists to appreciate the ecological importance and conservation value of parasites. In part, this is because there is no obvious metric by which to make the comparison. For instance, we can't show that these values set back appreciation of parasites by a specific number of years. However, we think a strong case can be made that the contributions of values associated with parasites were not entirely trivial. The first part of that case involves demonstrating that ecologists persisted in their beliefs about parasites long after ample evidence became available to contradict those beliefs. At that point, it becomes necessary to seek potential cultural explanations for belief persistence. One component of scientific culture is the values associated with the concepts that scientists employ. The rest of that case involves showing that a cultural explanation of the neglect of parasites would be inadequate were it *not* to cite the relevant value associations. Imagine, for example, a cultural explanation that just appealed to "within-paradigm" scientific conservatism as the mechanism for the neglect of parasites. Such an explanation would miss the mechanisms by which conservatism is implemented – e.g., particular ways of understanding parasites that are informed by values – as would other explanations that attempt to avoid this level of granularity.

In any case, insofar as the value associations hypothesis is correct, it raises two important questions. One of them concerns whether there were or are any other costs of having these values shaping parasite ecology. The second focuses on moving forward: are there ways to mitigate any impacts of negative values being associated with parasites?

6.1. Broader Costs

We've focused on one way that science can be set back when scientists aren't sufficiently critical about the way that social values inform theory. However, as has been well-documented in other contexts, the direction of influence can go the other way too: society pays costs when scientific theories lend themselves to misinterpretation and misuse. Here, we'll briefly consider some of the ways this has happened with parasites.

Prior to the scientific adoption of 'parasite' to describe an entire category of plants in the 17th century (Gullestad 2011), the invective was aimed exclusively at individual persons. Following the scientific adaption of the term for categorical usage, the social 'parasite' expanded to label whole categories of undesirable people (Musolff 2016). Conceptions of parasites' properties were also evolving. Before the advent of parasitology in the 19th century, biological parasites were believed to spontaneously generate within a host's body (Gullestad 2011). After the development of 19th and 20th-century medical and veterinary parasitology, new concepts became associated with both biological and social parasitism: contagiousness, physical invasion by a foreign entity, and bodily resource exploitation/host dependency. Moreover, the advent of medical/veterinary parasitology – and the race to eliminate numerous parasites across the globe in the late 19th to early 20th century – naturalized the idea that parasites were to be eliminated, all at a time when natural history and biological research were increasingly reaching the public (Musolff 2016; Inda 2000; Gullestad 2011; Osborne 2017).

Jointly, these developments made it natural to describe whole categories of humans as "para-

sites" – the downtrodden and oppressed. They too could then be framed as having "contagious" and socially undesirable traits, as foreign (at least in the sense of "not like us," though often literally of other nationalities), and as objectionably dependent. Minimally, such individuals are unimportant to the social order; worse, they are threats. And just as physical disgust is often directed toward animal parasites, moral disgust is often directed toward human "parasites," who can be understood as 'worthless' and 'depraved' (Haslam et al. 2011).

It's no surprise, therefore, that the label of 'parasite' is often used against already vulnerable people. Parasite metaphors are aimed at people of color, the poor, and the disabled, especially when these populations can be represented as invaders, weak, dependent, degenerate/impaired, or disgusting – as, e.g., in the case of immigrants (especially women), those who receive state welfare, transgender people, or disabled people (or intersectional identities that cross these numerous axes of oppression; Markel and Stern 2002; Musolff 2016; Waśniewska 2017; HoSang & Lowndes 2019). Sometimes, these metaphors have even been advanced casually by parasitologists (e.g., 'welfare state' in Stunkard 1954, 'illegal aliens' in Drisdelle 2010). All these groups have been described as 'parasites' or 'leeches' by hate groups, and even by politicians (Hogan and Haltinner 2015; Pring 2017; Brufke 2018, Gander 2018). This appears to be an effective strategy: one study found that participants exposed to the metaphor of "countries as bodies" were more concerned with the threat of physical contamination and had more negative attitudes towards immigrants (Landau et al. 2009). This language is used to legitimize discriminatory views, actions, and policies as both natural and necessary: after all, parasites are either (at best) unimportant or (at worst) threatening to the maintenance of a 'healthy' ecosystem or body; so, the relevant groups must be excluded or eradicated.

To be clear, we are not claiming that the choices of early ecologists are responsible for xenophobia, classism, or the systematic devaluation of the economically marginalized. Instead, we're making the modest point that scientific theories are not simply attempts to understand or make predictions about their ostensible subject matter: in addition, they create new metaphors using the natural world that society may use to make claims about the social world, whether for good or ill. And insofar as scientific theories are already informed by social values, this means that there is some risk of a vicious loop, where negative values shape science that shapes society that shapes science, and so on. With respect to the rhetorical utility of the language of parasitism, those looking to preserve key hierarchies and systems of oppression would, no doubt, find other ways to make their case. Still, the case was probably easier to make because that language invokes the aura of science and a supposed 'natural' order.

Put differently, every hegemonic dichotomy – e.g., citizen/alien, man/woman, human/animal – takes work to maintain. Scientific theories can help prop up these hegemonic structures when scientists fail to interrogate the values that those theories inherited from the societal context in which they were developed, thereby creating tools that lend themselves to the preservation of such orders. The contribution may be small, but it's a contribution nonetheless – one to which self-critical scientists have reason to attend.

6.2. Moving Forward

Suppose that we accept that societal values played some non-negligible role in the development of parasite ecology, with some effects lingering to the present day. One encouraging thought is that societal values are not destiny: ecology has made significant strides toward correcting the record on parasites without any major changes in the broader societal value associations with these animals. As ecologists developed increasingly powerful tools – theoretical, methodological, and physical – for understanding the roles and value of parasites, scientific thinking began

shifting, even if that change took time and is not yet complete.

Still, in managing societal values in science, we shouldn't rely entirely on somewhat chancy scientific developments as a strategy for self-correction. Better, we submit, to pursue two strategies: first, taking some preventive medicine in hopes of avoiding such risks in the future; second, considering how we might leverage other cultural values to counteract problematic cultural associations that are already in place.

On the preventive side, there may be value in considering frameworks that blur the lines between scientists, the societies in which they live, and the objects of their inquiries. The naturalcultural framework, for instance, proposes that "nature and culture are so tightly interwoven that they cannot be separated," implying that our understanding of even ostensibly objective phenomena, like ecological relationships, "are both biophysically and socially formed" (Malone and Ovenden 2017, 1; MacCormack and Strathern 1980). This approach invites us to be especially sensitive when our ostensibly objective descriptions of phenomena have served as natural metaphors for human behaviors and societies across cultures and millennia (Yamamoto 2000; Palmatier 1995; Talebinejad and Dastjerdi 2009; Haslam et al. 2011; Liu 2013; Urton 1985). Culture is visible in animal ecology in the way it lends itself to constructing both interspecific (human/animal) and intraspecific (human/human) divisions (MacCormack and Strathern 1980). This construction ultimately depends on the premise of a clean separation between the culturally-located human 'self' observing the naturally-located animal 'other'. Rejecting this separation means acknowledging that ecological research is not done by objective humans outside of and above nature, but rather subjective humans embedded within a unified natureculture.

In practice, this involves thinking carefully and critically about *why* certain terms seem useful for describing and theorizing about some phenomenon, why certain metaphors or particular turns of phrase seem so intuitive or insightful. What assumptions come along with that language, and how well do they fit with what the evidence actually supports? What are the costs of a given way of characterizing a particular role in an ecosystem, whatever the benefits may be? Asking these questions is the first step toward naming the influence of culture on the study of nature, bringing out the relationship between our positionality and the practice of science, from the questions we ask to the theories we construct.

Preventive measures aside, what can we do about existing values associated with parasites, such as the view that they aren't important enough to conserve? The proposal here is to identify positive societal values that can counteract any negative associations with parasites. We can appreciate the idea by revisiting an example that we mentioned earlier: namely, the case of *Colpocephalum californici* (Psocodea: Menoponidae), the California Condor's host-specific louse that was wiped out in the 1980s in an effort to save the condors. Barrett and Fischer (2023) explore the various dimensions of *C. californici*'s importance as a species, including the information it held about its host's ecology (Adler et al. 2011) and evolutionary history (Whiteman and Parker 2005), its contributions to biodiversity and ecosystem complexity (Norton 1988), its aesthetic value (Parsons 2007), its potential value to future generations, and its intrinsic value. Once we appreciate these dimensions of *C. californici*'s value, we have ways of resisting the assumption that delousing the California condor was a costless conservation action. By articulating and communicating such values, we may be able to undo some of the negative impacts these other values we have described have on ecological parasitology and the parasites themselves. And insofar as we can do this, the Condor louse example suggests a general blueprint for navigating negative cultural associations in science: first, explicitly identifying those negative values; second, highlighting the many implications of more positive values for the case in question.

7. Conclusion

It takes work to retrofit parasites into a century of ecological research that ignored them; in some cases, it is difficult enough that some researchers have argued that we must start anew (e.g. food web theory; Sukhdeo 2010). Moreover, when societal values are uncritically incorporated into scientific theories, they can lend themselves to unfortunate social uses. Credit is due to the many researchers who have questioned prevailing societal and cognitive biases about roles of parasites in ecological systems when confronted with contradictory evidence. However, it would have been far better – for researchers, for conservation, and for parasites themselves – had earlier generations of ecologists been more aware, more reflective, and more critical of the values that informed the way these organisms were viewed and studied.

Scientists have some responsibility to be critical of the concepts they borrow and question the values associated with them. This process can be facilitated by reconfiguring our conception of the relationship between the inquirer, society, and the object of inquiry (e.g., the naturalcultural framework). We can also search for other values that can counteract objectionable consequences of past theoretical choices. Via such strategies, progress can be maintained and accelerated into the future.

Literature cited

Allen, D. 2004. "Burning the fable of the bees: The incendiary authority of nature." In *The Moral Authority of Nature*, edited by L. Daston and F. Vidal, 74-99. Chicago: University of Chicago Press.

Allen, Q., and H. Metcalf. 2019. "Up to No Good: The Intersections of Race, Gender, and Fear of Black Men in US Society." In *Historicizing Fear: Ignorance, Vilification, and Othering*, edited by T. D. Boyce and W. M. Chunnu, 19-34. Louisville: University of Colorado Press.

Anker, P. 2001. *Imperial ecology: Environmental order in the British Empire, 1895-1945*. Cambridge, MA: Harvard University Press.

Anderson, R. M., and R. M. May. 1978. "Regulation and stability of host-parasite population interactions: I. Regulatory processes." *Journal of Animal Ecology* 47: 219–247.

Anderson, R. M., and R. M. May. 1979. "Population biology of infectious diseases: part I." *Nature* 280: 361–367.

Anderson, R. M., and R. M. May. 1981. "The population dynamics of microparasites and their invertebrate hosts." *Philosophical Transactions of the Royal Society of London B* 291: 451–524.

Andrew, N. R., M. J. Evans, L. Svejcar, K. Prendegast, L. Mata, H. Gibb, M. J. Stone, and P. S. Barton. 2021. "What's hot and what's not – Identifying publication trends in insect ecology." *Austral Ecology*. https://doi.org/10.1111/aec.13052.

Aristotle. 350 BCE. *History of Animals*. Translated by D. W. Thompson.

Auld, S. K. J. R., S. K. Tinkler, and M. C. Tinsley. 2016. "Sex as a strategy against rapidly evolving parasites." *Proceedings of the Royal Society B* 283: 20162226.

Bailie, H. 2011. "Blood ties: The vampire lover in the popular romance." *Journal of American Culture* 34: 141–148.

Bateson, M. 1899. *George Ashby's Poems. Ed from two 15th century mss. At Cambridge*. London: Paul, Trench, Trübner & Co.

Bein, A. 1964. "The Jewish parasite: Notes on the semantics of the Jewish problem, with special reference to Germany." *The Leo Baeck Institute Year Book* 9: 3–40.

Begon, M., and C. R. Townsend. 2020. *Ecology: From individuals to ecosystems* (5th ed). Hoboken, NJ: Wiley.

Bergstrom, B. J. 2017. "Carnivore conservation: shifting the paradigm from control to coexistence." *Journal of Mammalogy* 98: 1–6.

Biehler, D. 2013. *Pests in the city: Flies, bedbugs, cockroaches, and rats*. Seattle: University of Washington Press.

Blair, W. F. 1950. "Ecological factors in speciation of *Peromyscus*." *Evolution* 4: 253–275.

Blanchan, N. 1897. *Bird neighbors*. New York: Doubleday & McClure Co.

Blanchan, N. 1898. *Birds that hunt and are hunted*. New York: Doubleday & McClure Co.

Blanchan, N. 1927. *Birds* in "The Nature Library". New York: Doubleday, Page, & Co.

Bock, J., and M. Burkley. 2019. "On the prowl: Examining the impact of men-as-predators and women-as-prey metaphors on attitudes that perpetuate sexual violence." *Sex Roles* 80: 262–276.

Bogert, C., and L. Hancock. 2020. "Superpredator: The media myth that demonized a generation of Black youth." *The Marshall Project*, November 20. Accessed August 2025. https://www.themarshallproject.org/2020/11/20/superpredator-the-media-myth-that-demonized-a-generation-of-black-youth.

Bowman, D. D. 2006. "Successful and currently ongoing parasite eradication programs." *Veterinary Parasitology* 139: 293–307.

Bowman, W. D., and S. D. Hacker. 2020. *Ecology* (5th edition). Sunderland, MA: Sinauer Associates.

Braun, B. 2004. "Modalities of posthumanism." *Environment and Planning* 36: 1352–1355.

Brown, M. J. F., A. W. Sainsbury, R. J. Vaughan-Higgins, G. H. Measures, C. M. Jones, and N. Gammans. 2017. "Bringing back a healthy buzz? Invertebrate parasites and reintroductions: A case study in bumblebees." *EcoHealth* 14: S74–S83.

Brufke, J. 2018. "GOP rep in 2012 said 'parasites' on welfare 'substituted one plantation for another': report." *The Hill*, July 27. Accessed August 2025. https://thehill.com/homenews/house/399216-gop-rep-in-2012-said-parasites-on-welfare-substituted-one-plantation-for?rl=1.

Brunner, F. S., and C. Eizaguirre. 2016. "Can environmental change affect host/parasite-mediated speciation?" *Zoology* 119: 384–394.

Buck, J. C., and W. J. Ripple. 2017. "Infectious agents trigger trophic cascades." *Trends in Ecology and Evolution* 32: 681–694.

Bush, S. E., and D. H. Clayton. 2018. "Anti-parasite behaviour of birds." *Proceedings of the Royal Society B* 373: 20170196.

Butler, C. 1609. *The Feminin' Monarchie*. Oxford: Joseph Barnes.

Carlson, C. J., K. R. Burgio, E. R. Dougherty, A. J. Phillips, V. M. Bueno, C. F. Clements, G. Castaldo, et al. 2017. "Parasite biodiversity faces extinction and redistribution in a changing climate." *Science Advances* 3: e1602422.

Carlson, C. J., T. A. Dallas, L. W. Alexander, A. L. Phelan, and A. J. Phillips. 2020a. "What would it take to describe the global diversity of parasites?" *Proceedings of the Royal Society B* 287 (1939): 20201841.

Carlson, C. J., S. Hopkins, K. C. Bell, J. Doña, S. S. Godfrey, M. L. Kwak, ... C. L. Wood. 2020b. "A global plan for parasite conservation." *Biological Conservation* 250: 108596.

Carvalho Cabral, P., O. Martin, and C. Nicolas. 2019. "The complex interplay of parasites, their hosts, and circadian clocks." *Frontiers in Cellular and Infection Microbiology* 9: 425.

Chu, J. S. G., and J. A. Evans. 2021. "Slowed canonical progress in large fields of science." *PNAS* 118: e2021636118.

Cizauskas, C. A., C. S. Carlson, K. R. Burgio, C. F. Clements, E. R. Dougherty, N. C. Harris, and A. J. Phillips. 2017. "Parasite vulnerability to climate change: an evidence-based functional trait approach." *Royal Society Open Science* 4: 160535.

Clutton-Brock, J. 1995. "Aristotle, the scale of nature, and modern attitudes to animals." *Social Research* 62: 421–440.

Colwell, D. D., D. Otranto, and J. R. Stevens. 2009. "Oestrid flies: eradication and extinction versus biodiversity." *Trends in Parasitology* 25: 500–504.

Cotner, J. B., and B. A. Biddanda. 2002. "Small players, large role: Microbial influence on biogeochemical processes in pelagic aquatic ecosystems." *Ecosystems* 5: 105–121.

Courchamp, F., and C. J. A. Bradshaw. 2017. "100 articles every ecologist should read." *Nature Ecology and Evolution* 2: 395–401.

Cox, F. 2002. "History of human parasitology." *Clinical Microbiology Reviews* 15: 595–612.

Cox, F. 1993. *Modern Parasitology* (2nd edition). United Kingdom: Wiley.

Cruickshank, R. H., and A. M. Paterson. 2006. "The great escape: Do parasites break Dollo's law?" *Trends in Parasitology* 22: 509–515.

Darwin, C. 1859. *On the Origin of Species*. London: John Murray.

Daston, L. 2019. *Against Nature*. Cambridge, MA: Massachusetts Institute of Technology Press.

Daston, L., and F. Vidal. 2004. *The Moral Authority of Nature*. Chicago: University of Chicago Press.

Daversa, D. R., R. F. Hechinger, E. Madin, A. Fenton, A. I. Dell, E. G. Ritchie, H. Rohr, V. H. W. Rudolf, and K. D. Lafferty. 2021. "Broadening the ecology of fear: non-lethal effects arise from diverse responses to predation and parasitism." *Proceedings of the Royal Society B* 288: 20202966.

de Castro, F., and B. Bolker. 2005. "Mechanisms of disease-induced extinction." *Ecology Letters* 8: 117–126.

De Smet, I. A. R. 1996. *Menippean satire and the republic of letters, 1581-1655*. Geneva: Librairie Droz.

Devenson, E. 2016. "Parasites, politics and public science: the promotion of biological control in Western Australia, 1900-1910." *British Journal for the History of Science* 49: 231–258.

DiIulio, J. 1995. "The coming of the super-predators." *The Washington Examiner*, November 27. Accessed August 2025. https://www.washingtonexaminer.com/weekly-standard/the-coming-of-the-super-predators.

Dobson, A. P., and P. J. Hudson. 1992. "Regulation and stability of a free-living host-parasite system: *Trichostrongylus tenuis* in red grouse. II. Population models." *Journal of Animal Ecology* 61: 467–498.

Dobson, A. P., K. D. Lafferty, A. M. Kuris, R. F. Hechinger, and W. Jetz. 2008. "Homage to Linnaeus: how many parasites? How many hosts?" *Proceedings of the National Academy of Sciences* 105: 11482–11489.

Doherty, T. S., C. R. Dickman, D. G. Nimmo, and E. G. Ritchie. 2015. "Multiple threats or multiplying the threats? Interactions between invasive predators and other ecological disturbances." *Biological Conservation* 190: 60–68.

Dollo, L. 1893. "The laws of evolution." *Bulletin de la Société Belge de Géologie* 7: 164–166.

Donne, J. 1633. *The Flea*. London: John Marriot.

Dorris, M., M. E. Viney, and M. L. Blaxter. 2002. "Molecular phylogenetic analysis of the genus *Strongyloides* and related nematodes." *International Journal for Parasitology* 32: 1507–1517.

Dougherty, E. R., C. J. Carlson, V. M. Bueno, K. R. Burgio, C. A. Cizauskas, C. F. Clements, D. P. Seidel, and N. C. Harris. 2016. "Paradigms for parasite conservation." *Conservation Biology* 30: 724–733.

Douglas I, Goode D, Houck MC, Maddox D. 2011. *The Routledge Handbook of Urban Ecology.* Taylor & Francis.

Drisdelle, R. 2010. *Parasites: Tales of humanity's most unwelcome guests.* Berkeley: University of California Press.

Dunlap, T. R. 1988. *Saving America's Wildlife: Ecology and the American Mind, 1850–1990.* Princeton: Princeton University Press.

Dunn, R. R. 2009. "Coextinction: anecdotes, models, and speculation." In *Holocene Extinctions*, edited by S. T. Turvey, 167–180. Oxford: Oxford University Press.

Durand, F. 2016. "Nature, creation and morality: The case of parasites." *HTS Teologiese Studies/Theological Studies* 72 (4): a3841.

Dwyer, J. 2019. "The true story of how a city in fear brutalized the Central Park Five." *New York Times*, May 30. Accessed August 2025. https://www.nytimes.com/2019/05/30/arts/television/when-they-see-us-real-story.html.

Egerton, F. N. 2007. "A history of the ecological sciences, part 23: Linnaeus and the economy of nature." *Bulletin of the Ecological Society of America* 88: 72–88.

Egerton, F. N. 2010. "History of ecological sciences, part 34: A changing economy of nature." *Bulletin of the Ecological Society of America* 91: 21–41.

Egerton, F. N. 2013. "History of ecological sciences, part 47: Ernst Haeckel's ecology." *Bulletin of the Ecological Society of America* 94: 222–244.

Elton, C. 1927. *Animal Ecology.* London: Sidgwick & Jackson.

Englund, P. T. 2014. "A passion for parasites." *Journal of Biological Chemistry* 289: 33712–33729.

Errington, P. L. 1946. "Predation and vertebrate populations." *Quarterly Review of Biology* 21: 144–177.

Estes, J. A., and J. F. Palmisano. 1974. "Sea otters: Their roles in structuring nearshore communities." *Science* 185: 1058–1060.

Ewen, J. G., K. Acevedo-Whitehouse, M. R. Alley, C. Carraro, A. W. Sainsbury, K. Swinnerton, and R. Woodroffe. 2012. "Empirical considerations of parasite and health in reintroduction." In *Reintroduction biology: Integrating science and management*, edited by J. G. Ewen, D. P. Armstrong, K. A. Parker, and P. J. Seddon, 290-335. Hoboken, NJ: Wiley-Blackwell.

Farley, J. 2003. *Bilharzia: A History of Imperial Tropical Medicine.* Cambridge: Cambridge University Press.

Filo, G. 2019. "Gender, genre, and Donne's 'The Flea'." *Modern Philology* 117: 214–232.

Fisk, S. A. 2009. *When Words Take Lives: The Role of Language in the Dehumanization and Devastation of Jews in the Holocaust.* Master's thesis, University of Canterbury.

Gander, K. 2018. "Academic Says Trans Women Are Parasites for 'Occupying the Bodies of the Oppressed'." *Newsweek*, March 15. Accessed August 2025. https://www.newsweek.com/trans-women-are-parasites-occupying-bodies-oppressed-says-academic-846563.

Gingerich, O. 1993. *The Eye of Heaven: Ptolemy, Copernicus, Kepler.* New York: American Institute of Physics.

Gissler, C. F. 1884. "The crab parasite, *Sacculina*." *American Naturalist* 18: 226–229.

Goldberg, E. J. 2020. *In the Manner of the Franks: Hunting, Kingship, and Masculinity in Early Medieval Europe*. Philadelphia: University of Pennsylvania Press.

Gómez, A., and E. Nichols. 2013. "Neglected wild life: parasitic biodiversity as a conservation target." *International Journal for Parasitology: Parasites and Wildlife* 2: 222–227.

Gompper, M. E., and E. S. Williams. 1998. "Parasite conservation and the black-footed ferret recovery program." *Conservation Biology* 12: 730–732.

Grinnell, R. 2016. "Shakespeare's Keeping of Bees." *ISLE: Interdisciplinary Studies in Literature and Environment* 23: 835–854.

Gullestad, A. M. 2011. "Parasite." *Political Concepts: A Critical Lexicon* 1: Article 11.

Hairston, N. G., F. E. Smith, and L. B. Slobodkin. 1960. "Community structure, population control, and competition." *American Naturalist* 94: 421–425.

Haldane, J. B. S. 1949. "Disease and evolution." *La Ricerca Scientifica Suppl* A19: 325–334.

Haldane, J. B. S. 1955. "Review of Lack (1954)." *Ibis* 97: 375–377.

Hall, S. R., et al. 2008. "Is infectious disease just another type of predator-prey interaction?" In *Infectious Disease Ecology: The effects of ecosystems on disease and of disease on ecosystems*, edited by R. S. Ostfeld, F. Keesing, and V. T. Eviner, 223–241. Princeton: Princeton University Press.

Hamilton, W. D. 1980. "Sex versus non-sex versus parasite." *Oikos* 35: 282–290.

Hamilton, W. D., and M. Zuk. 1982. "Heritable true fitness and bright birds: A role for parasites?" *Science* 218: 384–386.

Haskin, F. J. 1913. *The Panama Canal.* Garden City, NY: Doubleday, Page & Company.

Haslam, N., S. Loughnan, and P. Sun. 2011. "Beastly: What makes animal metaphors offensive?" *Journal of Language and Social Psychology* 30: 311–325.

Hatcher, M. J., and A. M. Dunn. 2011. *Parasites in ecological communities: From interactions to ecosystems*. Cambridge: Cambridge University Press.

Hatcher, M. J., J. T. A. Dick, and A. M. Dunn. 2012. "Diverse effects of parasites in ecosystems: linking interdependent processes." *Frontiers in Ecology and the Environment* 10: 186–194.

Hayes, J. S. 2014. "Jupiter's legacy: The symbol of the eagle and thunderbolt in antiquity and their appropriation by revolutionary America and Nazi Germany." Vassar College Senior Capstone Project 261.

Heard, M. J., K. F. Smith, K. Ripp, M. Berger, J. Chen, J. Dittmeier, M. Goter, S. T. McGarvey, and E. Ryan. 2013. "The threat of disease increases as species move toward extinction." *Conservation Biology* 27: 1378–1388.

Hechinger, R. F., K. D. Lafferty, T. C. Huspeni, A. J. Brooks, and A. M. Kuris. 2007. "Can parasites be indicators of free-living diversity? Relationships between species richness and the abundance of larval trematodes and of local benthos and fishes?" *Oecologia* 151: 82–92.

Heesterbeek, J. A. P., and M. G. Roberts. 2015. "How mathematical epidemiology became a field of biology: A commentary on Anderson and May (1981) 'The population dynamics of microparasites and their invertebrate hosts'." *Philosophical Transactions of the Royal Society B* 370: 20140307.

Hogan, J., and K. Haltinner. 2015. "Floods, invaders, and parasites: Immigration threat narratives and right-wing populism in the USA, UK and Australia." *Journal of Intercultural Studies* 36: 520–543.

Holdo, R. M., A. R. E. Sinclair, A. P. Dobson, K. L. Metzger, B. M. Bolker, M. E. Ritchie, and R. D. Holt. 2009. "A disease-mediated trophic cascade in the Serengeti and its implications for

Ecosystem C." *PLoS Biology* 7: e1000210.

Holmes, J. C. 1996. "Parasites as threats to biodiversity in shrinking ecosystems." *Biodiversity and Conservation* 5: 977–983.

Holmes, M. 2020. "Legends, legions, and the Roman eagle." *Quaternary International* 543: 77–80.

Holmes, J. C., and P. W. Price. 1980. "Parasite communities: the roles of phylogeny and ecology." *Systematic Zoology* 29: 203–213.

Hopper, J. 2016. "Ted Cruz Says Not Having 'Bathroom Bill' Is 'Opening the Door for Predators'." *ABC News*, April 23. Accessed August 2025. https://abcnews.go.com/Politics/ted-cruz-bathroom-bill-opening-door-predators/story?id=38626340.

HoSang, D. M., and J. E. Lowndes. 2019. *Producers, parasites, and patriots: Race and the new right-wing politics of precarity*. Minneapolis: University of Minnesota Press.

Hudson, P. J. 2005. "Introduction – Parasites, diversity, and the ecosystem." In *Parasitism and Ecosystems*, edited by F. Thomas, F. Renaud, and J. F. Guégan, 1-12. Oxford: Oxford University Press.

Hudson, P. J., A. P. Dobson, and D. Newborn. 1992. "Do parasites make prey vulnerable to predation? Red grouse and parasites." *Journal of Animal Ecology* 61: 681–692.

Hudson, P. J., A. P. Dobson, and D. Newborn. 1998. "Prevention of population cycles by parasite removal." *Science* 282: 2256–2258.

Hudson, P. J., A. P. Dobson, and K. D. Lafferty. 2006. "Is a healthy ecosystem one that is rich in parasites?" *Trends in Ecology and Evolution* 21: 381–385.

Hughes, D. P., J. Brodeur, and F. Thomas. 2012. *Host manipulation by parasites*. Oxford: Oxford University Press.

Hünemörder, C. 2006. "Eagle." *Brill's New Pauly*. Brill Online.

Hurford, A., and T. Day. 2013. "Immune evasion and the evolution of molecular mimicry in parasites." *Evolution* 67: 2889–2904.

Hutchinson, G. E. 1957. "Concluding remarks." *Cold Spring Harbor Symposia on Quantitative Biology* 22: 415–427.

Hyll, T. 1579. *A profitable instruction of the perfite ordering of bees*. London: Henrie Bynneman. Project Gutenberg Ebook (2014).

Inda, J. X. 2000. "Foreign bodies: Migrants, parasites, and the pathological body politic." *Discourse* 22: 46–62.

IUCN/SSC (2013). Guidelines for Reintroductions and Other Conservation Translocations. Version 1.0. Gland, Switzerland: IUCN Species Survival Commission.

Jackson, A. P. 2015. "The evolution of parasite genomes and the origins of parasitism." *Parasitology* 142: S1–S5.

Jackson, A., T. Otto, M. Aslett, S. Armstrong, F. Bringaud, A. Schlacht, et al. 2016. "Kinetoplastid phylogenomics reveals the evolutionary innovations associated with the origins of parasitism." *Current Biology* 26: 161–172.

Jajszczok, J. 2015. "Cryptic origins: parasites and historical controversies." In *Cryptohistories*, edited by A. Bemben, R. Boryslawski, and J. Jajszczok, 67-76. Newcastle upon Tyne: Cambridge Scholars Publishing.

Janzen, D. H. 1970. "Herbivores and number of tree species in tropical forests." *American Naturalist* 104: 501–528.

Johnson, J. 2002. "Preserving the beasts of waste and desolation: Theodore Roosevelt and predator

control in Yellowstone." *Yellowstone Science*, 14–21.

Johnson, N. C., J. H. Graham, and F. A. Smith. 1997. "Functioning of mycorrhizal associations along the mutualism-parasitism continuum." *New Phytologist* 135: 575–585.

Jokela, J., M. F. Dybdahl, and C. M. Lively. 2009. "The maintenance of sex, clonal dynamics, and host-parasite coevolution in a mixed population of sexual and asexual snails." *American Naturalist* 174: S43–S53.

Jørgensen, D. 2015. "Conservation implications of parasite co-reintroduction." *Conservation Biology* 29: 602–604.

Jørgensen, S. 2012. *Introduction to systems ecology*. Boca Raton: CRC Press.

Julian, T. 2004. *The lions in our lives*. Victoria, BC: Trafford Publishing.

Keller, R. C. 2006. "Geographies of power, legacies of mistrust: Colonial medicine in the global present." *Historical Geography* 34: 26–48.

Kingsland, S. 2015. "Alfred J. Lotka and the origins of theoretical population ecology." *PNAS* 112: 9493–9495.

Klimov, P. B., and B. O'Connor. 2013. "Is permanent parasitism reversible? – critical evidence from early evolution of house dust mites." *Systematic Biology* 62: 411–423.

Koh, L. P., R. R. Dunn, N. S. Sodhi, R. K. Colwell, H. C. Proctor, and V. S. Smith. 2004. "Species co-extinctions and the biodiversity crisis." *Science* 305: 1632–1634.

Kristensen, T. K., and D. S. Brown. 1999. "Control of the intermediate host snails for parasitic diseases – a threat to biodiversity in African freshwaters?" *Malacologia* 41: 379–391.

Kruuk, H. 2002. *Hunter and hunted: Relationships between carnivores and people* (1st edition). Cambridge: Cambridge University Press.

Kuris, A. M., R. F. Hechinger, J. C. Shaw, K. L. Whitney, L. Aguirre-Macedo, C. A. Boch, A. P. Dobson, et al. 2008. "Ecosystem energetic implications of parasite and free-living biomass in three estuaries." *Nature* 454: 515–518.

Kwak, M. L., A. C. G. Heath, and P. Cardoso. 2020. "Methods for the assessment and conservation of threatened animal parasites." *Biological Conservation* 258: 108696.

Kwak, M. L., A. C. G. Heath, and R. L. Palma. 2019. "Saving the Manx Shearwater Flea *Ceratophyllus (Emmareus) fionnus* (Insecta: Siphonaptera): The Road to Developing a Recovery Plan for a Threatened Ectoparasite." *Acta Parasitologica* 64: 903–910.

Kwenti, T. E. 2017. "Biological Control of Parasites." In *Natural Remedies in the Fight Against Parasites*, edited by H. F. Khater, M. Govindarajan, and G. Benelli, 23-58. London: InTech Open.

Lack, D. 1954. *The natural regulation of animal numbers*. Oxford: Clarendon Press.

Lafferty, K. D. 2012. "Biodiversity loss decreases parasite diversity: Theory and patterns." *Philosophical Transactions of the Royal Society B* 367: 2814–2827.

Lafferty, K. D., and A. M. Kuris. 2002. "Trophic strategies, animal diversity and body size." *Trends in Ecology and Evolution* 17: 507–513.

Lafferty, K. D., and A. M. Kuris. 2009. "Parasites reduce food web robustness because they are sensitive to secondary extinction as illustrated by an invasive estuarine snail." *Philosophical Transactions of the Royal Society B* 364: 1659–1663.

Lafferty, K. D., S. Allesina, M. Arim, C. J. Briggs, G. De Leo, A. P. Dobson, J. A. Dunne, et al. 2008. "Parasites in food webs: The ultimate missing links." *Ecology Letters* 11: 533–546.

Lafferty, K. D., A. P. Dobson, and A. M. Kuris. 2006. "Parasites dominate food web links." *PNAS*

103: 11211–11216.

Lakoff, G., and M. Johnson. 1980. "The metaphorical structure of the human conceptual system." *Cognitive Science* 4: 195–208.

Landau, M. J., D. Sullivan, and J. Greenberg. 2009. "Evidence that self-relevant motives and metaphoric framing interact to influence political and social attitudes." *Psychological Science* 20: 1421–1427.

Larson, B. 2011. *Metaphors for Environmental Sustainability: Redefining Our Relationship with Nature*. New Haven: Yale University Press.

Latimer, J., and M. Miele. 2013. "Naturecultures? Science, affect, and the non-human." *Theory, Culture, & Society* 30: 5–31.

Lawton, Z., and P. Callister. 2010. "Older women-younger men relationships: The social phenomenon of 'Cougars'. A research note." *Institute of Policy Studies*, Victoria University of Wellington.

Lederman, E. 2005. "History of U.S. military contributions to the study of parasitic diseases." *Military Medicine* 170: 17–29.

Lewontin, R. C. 1992. *Biology as Ideology: The Doctrine of DNA*. New York: Harper Perennial.

Lima, S. L., and L. M. Dill. 1990. "Behavioral decisions made under the risk of predation: A review and prospectus." *Canadian Journal of Zoology* 68: 619–640.

Lindeman, R. L. 1942. "The trophic-dynamic aspect of ecology." *Ecology* 23: 399–417.

Lindsay-Poland, J. 2003. *Emperors in the Jungle: The Hidden History of the U.S. in Panama*. Durham: Duke University Press.

Linnæi, C. 1758. *Systema Naturæ* (10th edition). Stockholm: Laurentii Salvii.

Littlefield, J. 2010. "Men on the hunt: Ecofeminist insights into masculinity." *Marketing Theory* 10: 97–117.

Liu, J. 2013. "A comparative study of English and Chinese animal proverbs – From the perspective of metaphors." *Theory and Practice in Language Studies* 3: 1844–1849.

Lively, C. M., J. C. de Roode, M. A. Duffy, A. L. Graham, and B. Koskella. 2014. "Interesting open questions in disease ecology and evolution." *The American Naturalist* 184: S1–S8.

Livingston, J. 2021. "Predator or Prey: The Analysis of Gender and Race on the Perception of Black Men as Sexual Assault Victims." *Caravel Undergraduate Research Journal*, Spring 2021. https://sc.edu/about/offices_and_divisions/research/news_and_pubs/caravel/archive/2021_spring/2021_predator_prey.php.

Lloyd, E. A. 2006. *The Case of the Female Orgasm: Bias in the Science of Evolution*. Cambridge: Harvard University Press.

Loreau, M., J. Roy, and D. Tilman. 2005. "Linking ecosystem and parasite ecology." In *Parasitism and Ecosystems*, edited by F. Thomas, F. Renaud, and J.-F. Guégan. Oxford: Oxford University Press.

Lorenz, K. 1973. *The Waning of Humaneness*. London: Unwin Hyman.

Lotka, A. J. 1925. *Elements of Physical Biology*. Baltimore: Williams & Wilkins.

MacArthur, R. H., and E. R. Pianka. 1966. "On optimal use of a patchy environment." *The American Naturalist* 100: 603–609.

MacCormack, C. P., and M. Strathern, eds. 1980. *Nature, Culture and Gender*. Cambridge: Cambridge University Press.

MacKenzie, K., and C. Pert. 2018. "Evidence for the decline and possible extinction of a marine para-

site species caused by intensive fishing." *Fisheries Research* 198: 63–65.

MacPhee, R. D. E., and A. D. Greenwood. 2013. "Infectious disease, endangerment, and extinction." *International Journal of Evolutionary Biology* 2013: 571939.

Maderspacher, F. 2007. "All the queen's men." *Current Biology* 17: R191–R195.

Malone, N., and K. Ovendon. 2017. "Natureculture." In *The International Encyclopedia of Primatology*, edited by A. Fuentes. Hoboken, NJ: John Wiley & Sons.

Marcogliese, D. J., and D. K. Cone. 1997. "Food webs: A plea for parasites." *Trends in Ecology and Evolution* 12: 320–325.

Markel, H., and A. M. Stern. 2002. "The foreignness of germs: The persistent association of immigrants and disease in American society." *Milbank Quarterly* 80: 757–788.

Marlowe, C. 1592. *Doctor Faustus*.

May, R. M., and R. M. Anderson. 1978. "Regulation and stability of host-parasite population interactions. II. Destabilizing processes." *Journal of Animal Ecology* 47: 249–267.

May, R. M., and R. M. Anderson. 1979. "Population biology of infectious diseases: part II." *Nature* 280: 455–461.

MacArthur, R. H. 1958. "Population ecology of some warblers of northeastern coniferous forests." *Ecology* 39: 599–619.

Macdonald, E. A., A. Hinks, D. J. Weiss, A. Dickman, D. Burnham, C. J. Sandom, Y. Malhi, and D. W. Macdonald. 2017. "Identifying ambassador species for conservation marketing." *Global Ecology and Conservation* 12: 204–214.

McCallum, H. 2012. "Disease and the dynamics of extinction." *Philosophical Transactions of the Royal Society B* 367: 2828–2839.

McCallum, H., and A. Dobson. 1995. "Detecting disease and parasite threats to endangered species and ecosystems." *Trends in Ecology and Evolution* 10: 190–194.

McWilliams, J. 2008. *American Pests: The Losing War on Insects from Colonial Times to DDT*. New York: Columbia University Press.

Mihalca, A. D., C. M. Gherman, and V. Cozma. 2011. "Coendangered hard-ticks: Threatened or threatening?" *Parasites & Vectors* 4: 71.

Milaine, A. 2018. "Beyond the 'Cougar' stereotype: Women's experiences with age-hypogamous intimate relationships." PhD dissertation, McGill University Department of Sociology.

Milotic, M., A. Lymbery, A. Thompson, J. Doherty, and S. Godfrey. 2020. "Parasites are endangered by the conservation of their hosts: Meta-analyses of the effect of host captivity on the odds of parasite infection." *Biological Conservation* 248: 108702.

Mittelbach, G. G. 2005. "Parasites, communities, and ecosystems: conclusions and perspectives." In *Parasitism and Ecosystems*, edited by F. Thomas, F. Renaud, and J. Guégan. Oxford: Oxford University Press.

Mitman, G., and P. Erickson. 2010. "Latex and blood: Science, markets, and American empire." *Radical History Review* 107: 45–73.

Moir, M. L., and K. E. C. Brennan. 2020. "Incorporating coextinction in threat assessments and policy will rapidly improve the accuracy of threatened species lists." *Biological Conservation* 249: 108715.

Moir, M. L., P. A. Vesk, K. E. C. Brennan, R. Poulin, L. Hughes, D. A. Keith, M. A. McCarthy, and D. J. Coates. 2012. "Considering extinction of dependent species during translocations, ex situ conservation, and assisted migration of threatened hosts." *Conservation Biology* 26: 199–207.

Molles Jr., M. C., and A. S. Simon. 2019. *Ecology: Concepts and Applications* (8th ed.). New York: McGraw Hill.

Monk, J. D., J. A. Smith, E. Donadío, P. L. Perrig, R. D. Crego, M. Fileni, O. Bidder, S. A. Lambertucci, J. N. Pauli, O. J. Schmitz, and A. D. Middleton. 2022. "Cascading effects of a disease outbreak in a remote protected area." *Ecology Letters* 25: 1152–1163.

Montemurro, B., and J. M. Siefken. 2014. "Cougars on the prowl? New perceptions of older women's sexuality." *Journal of Aging Studies* 28: 35–43.

Moore, J., S. Adamo, and F. Thomas. 2005. "Manipulation: Expansion of the paradigm." *Behavioral Processes* 68: 283–287.

Moore, J. 2012. "A history of parasites and hosts: science and fashion." In *Host Manipulation by Parasites*, edited by D. P. Hughes, J. Brodeur, and F. Thomas. Oxford: Oxford University Press.

Moore, S. J. 2017. "Mosquitoes, Malaria, and Cold Butter: Discourses of Hygiene and Health in the Panama Canal Zone in the Early Twentieth Century." *Panorama: Journal of the Association of Historians of American Art* 3(2):1–27.

Morris, E. 2011. *Colonel Roosevelt*. New York: Random House Trade Paperbacks.

Musolff, A. 2014. "Metaphorical parasites and 'parasitic' metaphors: Semantic exchanges between political and scientific vocabularies." *Journal of Language and Politics* 13: 218–233.

Musolff, A. 2016. "Parasites, scrounging, and the question of deliberate metaphor." In *Political Metaphor Analysis: Discourse and Scenarios*. London: Bloomsbury.

Mylonas, G. E. 1946. "The Eagle of Zeus." *The Classical Journal* 41: 203–207.

Nichols, L., and A. Gómez. 2011. "Conservation education needs more parasites." *Biological Conservation* 144 (2): 937–941.

Oberholster, T. 2017. "The Fossil Record." *Art-Verse*, December 16. Accessed August 2025. https://art-verse.com/2017/12/16/ticks-fossil-record-spider-blood-sucking-vampire/.

Okamura, B., A. Hartigan, and J. Naldoni. 2018. "Extensive uncharted biodiversity: the parasite dimension." *Integrative Comparative Biology* 58: 1132–1145.

Ordiz, A., R. Bischof, and J. E. Swenson. 2013. "Saving large carnivores, but losing the apex predator?" *Biological Conservation* 168: 128–133.

Orme, N. 2011. *Fleas, Flies, and Friars: Children's Poetry from the Middle Ages*. Ithaca: Cornell University Press.

Osborne, M. A. 2017. "Parasitology, Zoology, and Society in France, ca. 1880-1920." In *Biological Individuality: Integrating Scientific, Philosophical, and Historical Perspectives*, edited by S. Lidgard and L. K. Nyhart. Chicago: University of Chicago Press.

Oswick, C. 2001. "The etymology of 'corporate predatorship': A critical commentary." *Tamara: Journal of Critical Postmodern Organization Science* 1: 21.

Oxford English Dictionary. 2021. "predator, n." *OED Online*. Oxford: Oxford University Press.

Paine, R. T. 1966. "Food web complexity and species diversity." *The American Naturalist* 100: 65–75.

Paine, R. T. 1969a. "A note on tropic complexity and community stability." *The American Naturalist* 103: 91–93.

Paine, R. T. 1969b. "The *Piaster-Tegula* interaction: prey patches, predator food preference, and intertidal community structure." *Ecology* 50: 950–961.

Paine, R. T. 1980. "Food webs: Linkage, interaction strength and community infrastructure." *Journal of Animal Ecology* 49: 667–685.

Palmatier, R. A. 1995. *Speaking of Animals: A Dictionary of Animal Metaphors*. Westport: Greenwood Press.

Parris, K. M. 2016. *Ecology of Urban Environments*. Hoboken, NJ: John Wiley & Sons.

Pascal, L., A. Grémare, X. de Montaudouin, B. Deflandre, A. Romero-Ramirez, and O. Maire. 2020. "Parasitism in ecosystem engineer species: A key factor controlling marine ecosystem functioning." *Journal of Animal Ecology* 89: 2192–2205.

Pérez, J. M., P. G. Meneguz, A. Dematteis, L. Rossi, and E. Serrano. 2006. "Parasites and conservation biology: the 'ibex-ecosystem'." *Biodiversity and Conservation* 15: 2033–2047. https://doi.org/10.1007/s10531-005-0773-9.

Pérez, J. M., I. Sánchez, and R. L. Palma. 2013. "The dilemma of conserving parasites: the case of *Felicola* (Lorisicola) *isidoroi* (Phthiraptera: Trichodectidae) and its host, the endangered Iberian lynx (*Lynx pardinus*)." *Insect Conservation and Diversity* 6: 680–686.

Pizzi, R. 2009. "Veterinarians and taxonomic chauvinism: The dilemma of parasite conservation." *Journal of Exotic Pet Medicine* 18: 279–282.

Porter, G. 2006. "Industrialization and the Rise of Big Business." In *The Gilded Age: Perspectives on the Origin of Modern America*, edited by C. W. Calhoun. Lanham: Rowman & Littlefield.

Poulin, R. 2007. *Evolutionary Ecology of Parasites* (2nd edition). Princeton: Princeton University Press.

Poulin, R. 2021. "The rise of ecological parasitology: twelve landmark advances that changed its history." *International Journal for Parasitology* 51 (13): 1073–1084. https://doi.org/10.1016/j.ijpara.2021.07.001.

Poulin, R., and S. Morand. 2004. *Parasite Biodiversity*. Washington: Smithsonian Institution Scholarly Press.

Power, M. E., D. Tilman, J. A. Estes, B. A. Menge, W. J. Bond, L. S. Mills, G. Daily, J. C. Castilla, J. Lubchenco, and R. T. Paine. 1996. "Challenges in the question for keystones: Identifying keystone species is difficult – but essential to understanding how loss of species will affect ecosystems." *BioScience* 46: 609–620.

Predators on top. 2018. *Nature Ecology and Evolution*, 2: 199.

Preston, D. L., J. A. Mischler, A. R. Townsend, and P. T. Johnson. 2016. "Disease ecology meets ecosystem science." *Ecosystems* 19: 717–748.

Price, P. W. 1980. *Evolutionary Biology of Parasites*. Princeton: Princeton University Press.

Price, P. W., M. Westoby, B. Rice, P. R. Atsatt, R. S. Fritz, J. N. Thompson, and K. Mobley. 1986. "Parasite mediation in ecological interactions." *Annual Review of Ecology and Systematics* 17: 487–505.

Pring, J. 2017. "Portraying disabled people as 'parasites' could lead to 'violence and killings', says UN chair." *Disability News Service*, September 14. Accessed August 2025. https://www.disabilitynewsservice.com/portraying-disabled-people-as-parasites-could-lead-to-violence-and-killings-says-un-chair/](https://www.disabilitynewsservice.com/portraying-disabled-people-as-parasites-could-lead-to-violence-and-killings-says-un-chair/).

Prystash, J. 2016. "Vectors of a flea: The convergence of species in Victorian animal autobiographies." *Mosaic: An Interdisciplinary Critical Journal* 49: 37–53.

Pui-lan, K. 1992. "Ecology and the recycling of Christianity." *The Ecumenical Review* 44: 304–307.

Raffaelli, D. 2002. "From Elton to mathematics and back again." *Science* 296: 239–247.

Raffel, T. R., L. B. Martin, and J. R. Rohr. 2008. "Parasites as predators: unifying natural enemy ecology." Trends in Ecology and Evolution 23: 610–618.

Rainolds W., Bruce R. 1593. *A treatise conteyning the true catholkie and apostolike faith of the holy sacrifice and Sacrament ordeyned by Christ at his last Supper.* Trognesius. Retrieved from: https://www.google.com/books/edition/A_treatise_conteyning_the_true_catholike/E3dmAAAAcAAJ?hl=en&gbpv=0.

Relyea, R. 2021. *Ecology: The Economy of Nature* (9th ed.). New York: W. H. Freeman & Company.

Reynolds, A. S. 2019. *The Third Lens: Metaphor and the Creation of Modern Cell Biology*. Chicago: University of Chicago Press.

Réale, D., M. Khelfaoui, P.-O. Montiglio, and Y. Gingras. 2020. "Mapping the dynamics of research networks in ecology and evolution using co-citation analysis (1975-2014)." *Scientometrics* 122: 1361–1385.

Ricklefs, R. E. 1987. "Community diversity: Relative roles of local and regional processes." *Science* 235: 167–171.

Rieppel, L. 2016. "Nature." *Political Concepts: A Critical Lexicon* 3.

Robinson, M. D., J. L. Bair, T. Liu, M. J. Scott, and I. B. Penzel. 2017. "Of tooth and claw: Predator self-identifications mediate gender differences in interpersonal arrogance." *Sex Roles* 77: 272–286.

Rocha, C. F. D., H. G. Bergalio, and E. B. Bitencourt. 2016. "More than just invisible inhabitants: Parasites are important but neglected components of the biodiversity." *Zoologia* 33: 03.

Rohr, J. R., A. Swan, T. R. Raffel, and P. J. Hudson. 2009. "Parasites, info-disruption, and the ecology of fear." *Oecologia* 159: 447–454.

Sarasohn, L. T. 2021. *Getting Under Our Skin: The Cultural and Social History of Vermin*. Baltimore: Johns Hopkins University Press.

Schmid-Hempel, P. 1998. *Parasites in Social Insects*. Princeton: Princeton University Press.

Selbach, C., P. J. Seddon, and R. Poulin. 2018. "Parasites lost: Neglecting a crucial element in de-extinction." *Trends in Parasitology* 34: 9–11.

Shakespeare, W. 1599. *The Life of King Henry V*.

Shepherd, S. A., and G. Edgar. 2014. *Ecology of Australian Temperate Reefs: The Unique South*. Clayton: CSIRO.

Siddall, M. E., D. R. Brooks, and S. S. Desser. 1993. "Phylogeny and the reversibility of parasitism." *Evolution* 47: 308–313.

Singer, P. 2009. "Speciesism and moral status." *Metaphilosophy* 40: 567–581.

Slobodkin, L. B., F. E. Smith, and N. G. Hairston. 1967. "Regulation in terrestrial ecosystems, and the implied balance of nature." *The American Naturalist* 101: 109–124.

Smith, K. F., D. F. Sax, and K. D. Lafferty. 2006. "Evidence for the role of infectious disease in species extinction and endangerment." *Conservation Biology* 20: 1349–1357.

Smith, K. F., K. Acevedo-Whitehouse, and A. B. Pedersen. 2009. "The role of infectious disease in biological conservation." *Animal Conservation* 12: 1–12.

Smith, T. M., and R. L. Smith. 2015. *Elements of Ecology* (9th ed.). Boston: Pearson.

Sodhi, N. S., B. W. Brook, and C. J. A. Bradshaw. 2009. "Causes and consequences of species extinctions." In *The Princeton Guide to Ecology*, edited by S. A. Levin, S. R. Carpenter, H. C. J. Godfray, et al. Princeton: Princeton University Press.

Soulé, M. E. 1985. "What is conservation biology?" *BioScience* 35: 727–734.

Sukhdeo, M. V. K. 2010. "Food webs for parasitologists: A review." *Journal of Parasitology* 96: 273–284.

Sukhdeo, M. V. K. 2012. "Where are the parasites in food webs?" *Parasites & Vectors* 5: 239.

Sukhdeo, M. V. K., and A. D. Hernandez. 2005. "Food web patterns and the parasite's perspective." In *Parasitism and Ecosystems*, edited by F. Thomas, F. Renaud, and J. Guégan. Oxford: Oxford University Press.

Steinmetz, K. 2016. "Why LGBT Advocates Say Bathroom 'Predators' Argument Is a Red Herring." *Time Magazine*. Accessed August 2025. https://time.com/4314896/transgender-bathroom-bill-male-predators-argument/.

Stork, N., and C. H. C. Lyal. 1993. "Extinction or 'co-extinction' rates?" *Nature* 366: 307.

Stringer, A. P., and W. Linklater. 2014. "Everything in moderation: Principles of parasite control for wildlife conservation." *BioScience* 64: 932–937.

Strona, G., P. Galli, and S. Fattorini. 2013. "Fish parasites resolve the paradox of missing coextinctions." *Nature Communications* 4: 1718.

Strona, G. 2015. "Past, present and future of host-parasite co-extinctions." *International Journal of Parasitology: Parasites and Wildlife* 4: 431–441.

Stunkard, H. W. 1954. "Freedom, bondage, and the welfare state." *Science* 121: 811–816.

Takacs, D. 1996. *The Idea of Biodiversity: Philosophies of Paradise*. Baltimore: Johns Hopkins University Press.

Talebinejad, M. R., and H. V. Dastjerdi. 2009. "A cross-cultural study of animal metaphors: When owls are not wise!" *Metaphor & Symbol* 20: 133–150.

Thomas, F. 2010. "The Alarming Proximity of Parasites." *PLoS Biology* 8: e1000526.

Thomas, F., R. Poulin, T. de Meeüs, J. Guégan, and F. Renaud. 1999. "Parasites and ecosystem engineering: What roles could they play?" *Oikos* 84: 167–171.

Thomas, F., M. B. Bonsall, and A. P. Dobson. 2005a. "Parasitism, biodiversity, and conservation." In *Parasitism and Ecosystems*, edited by F. Thomas, F. Renaud, and J. Guégan. Oxford: Oxford University Press.

Thomas, F., F. Renaud, and J. Guégan. 2005b. *Parasitism and Ecosystems*. Oxford: Oxford University Press.

Thompson, R. C. A., A. J. Lymbery, and S. S. Godfrey. 2017. "Parasites at risk – insights from an endangered marsupial." *Trends in Parasitology* 34: 12–22.

Timi, J. T., and R. Poulin. 2020. "Why ignoring parasites in fish ecology is a mistake." *International Journal for Parasitology* 50: 755–761.

Tschirhart, J. 2003. "Ecological transfers in non-human communities parallel economic markets in a general equilibrium ecosystem model." *Journal of Bioeconomics* 5: 193–214.

Turko, P., C. Tellenbach, E. Keller, N. Tardent, B. Keller, P. Spaak, and J. Wolinska. 2017. "Parasites driving host diversity: Incidence of disease correlated with *Daphnia* clonal turnover." *Evolution* 72: 619–629.

Urton, G., ed. 1985. *Animal Myths and Metaphors in South America*. Salt Lake City: University of Utah Press.

Van Valen, L. 1973a. "Body size and numbers of plants and animals." *Evolution* 27: 27–35.

Van Valen, L. 1973b. "A new evolutionary law." *Evolutionary Theory* 1: 1–30.

Vickerman, K. 2009. "'Not a very nice subject.' Changing views of parasites and parasitology in the twentieth century." *Parasitology* 136: 1395–1402.

Videen, H. 2016. "Bēo-mōder." *Old English Word Hord*, November 4. Accessed August 2025. https:

//oldenglishwordhord.com/2016/11/04/beo-moder/.

Volterra, V. 1926a. "Variazioni e fluttuazioni del numero d'individui in specie animali conventi." *Memorie della R. Accademia dei Lincei* 6: 31–113.

Volterra, V. 1926b. "Fluctuations in the abundance of a species considered mathematically." *Nature* 118: 558–560.

Wait, L. F. 2017. "A review of parasites in the Tasmanian devil (*Sarcophilus harrisii*)." *Biodiversity and Conservation* 26: 509–526.

Wásniewska, M. 2017. "The socio-parasite and bio-parasite metaphorical concepts in racist discourse." *Crossroads: A Journal of English Studies* 17: 46–61.

White, C. R., and D. D. Jenkins. 2017. "College students' acceptance of trans women and trans men in gendered spaces: The role of physical appearance." *Journal of Gay & Lesbian Social Services* 29: 41–67.

Whitford, W. G., and B. D. Duval. 2019. *Ecology of Desert Systems* (2nd ed.). London: Academic Press.

Wilcove, D. S., D. Rothstein, J. Dubow, A. Phillips, and E. Losos. 1998. "Quantifying threats to imperiled species in the United States." *BioScience* 48: 607–615.

Williams, F. X. 1931. *Handbook of the Insects and Other Invertebrates of Hawaiian Sugar Cane Fields*. Honolulu: Advertiser Publishing.

Wilson, B. 2014a. *The Hive: The Story of the Honeybee and Us*. New York: Thomas Dunne Books.

Wilson, E. O. 2014b. *The Meaning of Human Existence*. New York: Liveright.

Windsor, D. A. 1995. "Equal rights for parasites." *Conservation Biology* 9: 1–2.

Windsor, D. A. 2017. "Parasites' rights gaining ground." *Nature* 552: 334.

Windsor, D. A. 2021. "Conservation of parasites." *International Journal for Parasitology: Parasites and Wildlife* 14: 137.

Wolfe, P. 2006. "Settler colonialism and the elimination of the native." *Journal of Genocide Research* 8: 387–409.

Wood, C. L., and P. T. J. Johnson. 2015. "A world without parasites: Exploring the hidden ecology of infection." *Frontiers in Ecology and the Environment* 13: 425–434.

Worboys, M. 1983. "The Emergence and Early Development of Parasitology." In *Parasitology: A Global Perspective*, edited by K. S. Warren and J. Z. Bowers, 1–18. New York: Springer-Verlag.

Worster, D. 1994. *Nature's Economy: A History of Ecological Ideas*. Cambridge: Cambridge University Press.

Yamamoto, D. 2000. *The Boundaries of the Human in Medieval English Literature*. Oxford: Oxford University Press.

Yang, Z., Y. Zhang, E. K. Wafula, L. A. Honaas, P. E. Ralph, S. Jones, et al. 2016. "Horizontal gene transfer is more frequent with increased heterotrophy and contributes to parasite adaptation." *Proceedings of the National Academy of Sciences* 113: E7010–E7019.

Yang, Z., E. K. Wafula, G. Kim, S. Shahid, J. R. McNeal, P. E. Ralph, et al. 2019. "Convergent horizontal gene transfer and cross-talk of mobile nucleic acids in parasitic plants." *Nature Plants* 5: 991–1001.

Yingming, L., and D. S. Wilcove. 2005. "Threats to vertebrate species in China and the United States." *BioScience* 55: 147–153.

ISSN 2475-3025