The costs of too much cooperation

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June 26, 2023

Abstract

Cooperative behaviors within a group face the risk of being exploited by 'free-riders,' individuals that reap the benefits produced by cooperators without paying the costs of cooperating. Free-riders are often perceived as a burden to the group, since the group's survival depends on tasks performed by cooperators. However, this paper challenges this perspective, arguing that an excess of cooperators may actually lower the efficiency and persistence of groups. The perspective presented in this paper has ramifications to broader issues in philosophy, particularly the challenge of how to balance self-interest with the collective interests of the group. Ultimately, this paper seeks to highlight some of the subtle ways free-riders positively impact their groups, an aspect of free-riding that is often overlooked in discussions about cooperation.

Keywords: cooperation; free-riding; self-interest; redundancy; efficiency; persistence.

Free-riders have a shaky reputation. They are expected to burden the groups in which they reside because, by definition, they reap the benefits produced by cooperators without paying the costs of cooperating. Further, the group's survival often depends on goods and services cooperators provide, such as foraging

and sharing information. In fact, a wide range of disciplines have developed accounts of how groups of organisms can keep free-riders at bay, including philosophy, biology, psychology, political science, and economics (Birch, 2017; Sachs et al., 2004; Tomasello, 2009; Axelrod, 2006; Seabright, 2010). Despite this, this paper aims to challenge the assumption that free-riders are always detrimental to the group, and proposes that high levels of cooperation can actually harm the group.

In what follows, we look into how excessive levels of cooperation can induce a decline in group efficiency (Section 1) and compromise the group's long-term survival (Section 2). Yet, as we will see, free-riders only confer advantages to their groups under specific circumstances. After all, groups would fall apart if they lacked a sufficient number of cooperators. Understanding the precise contexts in which free-riders can confer advantages to their groups is the focus of the subsequent sections of this paper.

1 Cooperation and its opportunity costs

Organisms often live in close association with others, forming groups such as families, colonies, and brothers in arms. Within groups, cooperative behaviors confer benefits to the group even at the expense of the individual performing it. The presence of cooperators is crucial for group maintenance as they contribute various goods, including resources like food and services, such as alarm calls. However, studies conducted on microbes have shown that an excessive presence of cooperators can actually harm the group (García-Contreras and Loarca, 2021; MacLean et al., 2010). As we will see, these microbial experiments serve as a minimal model for understanding when elevated levels of cooperation can adversely impact the group.

1.1 Public good production among microbes

The production of 'public goods' is a common type of cooperative behavior. These goods are resources that are expensive to produce but are shared among group members, regardless of whether they cooperate or not. A group of public goods producers is vulnerable to the proliferation of free-riders, individuals that consume the public good without contributing to its production. Empirical research on microbial populations has extensively studied public good production and its relationship with cooperating and free-riding behaviors (West et al., 2007; Smith and Schuster, 2019). Because of this, such studies provide a valuable starting point for understanding how cooperating and free-riding affect public good production.

Microbes produce various types of public goods, including enzymes and signaling molecules (Crespi, 2001). Experiments with microbes indicate that the proliferation of free-riders can lead to a reduction in the production of public goods over time, ultimately resulting in a loss of the cooperative benefits for the entire population. A pertinent study by Rainey and Rainey (2003) offers a striking example of this phenomenon, examining the growth behavior of the bacterium *Pseudomonas fluorescens* in a glass of broth. These bacteria form a mat at the air-broth interface, which enhances their access to oxygen. In order to build this mat, a genetic variant of *P. fluorescens* has to produce a costly polymer that enables daughter cells to stick together after cell division. Interestingly, Rainey and Rainey observed an abrupt collapse of this mat when 'cheats'—bacteria that reap the benefits of mat living but that do not produce the polymer—were introduced. This study thus nicely illustrates the damage free-riders can inflict on their groups.

Yet, there are circumstances in which having too many public good producers harms the group. In particular, one study investigates how free-riders affect

their group's efficiency by growing yeast under laboratory conditions (MacLean et al., 2010). In this study, a cooperative strain of yeast produces and secretes a public good to the environment, the enzyme invertase. This enzyme plays a vital role in breaking down sugar, thereby providing benefits not just to the producer but also to the neighboring cells.[1] The free-riders in this study belong to a strain of yeast that benefit from the presence of the enzyme without paying for its production costs. After letting these two strains compete until all sugar was exhausted, the authors observed that the population size peaked when both cooperators and free-riders were present. This result is surprising because free-riders do not contribute to the break down of sugar in the environment. Moreover, game-theoretic models of invertase production predict that population fitness is maximal when free-riders are absent (Greig and Travisano, 2004; Gore et al., 2009).

In order to explain their unexpected result, MacLean et al. (2010) used a mathematical model to specify the conditions in which free-riders might benefit the group. One such conditions is that cell growth in yeast faces a 'rate-efficiency trade-off:' the higher the rate of resource uptake, the lower the number of cells created per unit of resource. As the proportion of cooperators increases, so does the concentration of invertase. This rise in invertase concentration causes an increase in resource uptake. However, the rate-efficiency trade-off dictates that an increase in resource uptake must be accompanied by a decline in efficiency. Consequently, a predominantly cooperative population exhibits rapid but inefficient growth. In contrast, a population with a mix of both cooperators and free-riders grows at a slower pace, but with greater efficiency.

Much like us, a vast array of life on Earth is comprised of 'heterotrophs,' organisms that derive their energy by consuming other organic matter. The

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[1]More specifically, the enzyme invertase breaks down sucrose, a disaccharide, into the monosaccharides fructose and glucose.

trade-off between rate and efficiency is an inevitable constraint of how heterotrophs obtain energy (Pfeiffer et al., 2001). In a nutshell, heterotrophs need to spend energy to boost the rate of energy production. As a result, organisms cannot ramp up the rate of energy production without a sacrifice in yield, the amount of energy obtained per resource unit. The rate-efficiency trade-off is thus a inescapable constraint for heterotrophs. This suggests that the enhanced efficiency due to the presence of free-riders, as observed by MacLean et al. (2010), is unlikely to be a result that is unique to their particular experimental conditions.

1.2   Cooperative benefits and their diminishing returns

The rate-efficiency trade-off underscores a broader constraint cooperative benefits run into: the principle of diminishing returns. As the number of cooperative individuals increases, the additional gains for the group, such as energy yield, start to diminish. Besides the rate-efficiency trade-off, a wide range of factors contribute to the observed diminishing returns from cooperation.

As a general rule, organisms tend to use resources less efficiently when they are abundant, with human food waste serving as a classic example (Hall et al., 2009).[2] And when resources are plentiful, other factors might take priority over efficiency. As an example, consider the hunting practice of North American tribes known as "buffalo jump," where entire buffalo herds were driven off cliffs. While seemingly inefficient, limiting the scale of the kill was likely impractical. As Jack Brink (2008) points out, buffalo jumps were fraught with peril. Hunters along the drive route could be trampled during failed jumps, and buffaloes that survived the fall probably became more aggressive. These risks were further

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[2]An intriguing hypothesis from ecology, known as the "paradox of enrichment," suggests that an excess of resources can actually drive populations to extinction. More specifically, this hypothesis states that augmenting the carrying capacity of a prey population can paradoxically lead to the extinction of both predator and prey populations. See Roy and Chattopadhyay (2007) for further details.

exacerbated by the limited effectiveness of darts and arrows against the thick hide of buffaloes.[3] Accordingly, when resources are abundant, organisms often prioritize factors that greatly impact their fitness over efficiency in resource utilization.

Moreover, as the number of individuals needed for group tasks such as hunting increases, the individual contribution of each participant becomes progressively diluted (Krause and Ruxton, 2002). For example, the success rate of hunting probably does not scale linearly with the quantity of hunters, leading to diminishing benefits for each additional participant (Scheel and Packer, 1991). And as cooperative groups become larger, the chance for internal conflict rises, and coordinating cooperators becomes more difficult (Tomasello, 2009). While cooperation brings considerable advantages to the group, the incremental benefits derived from each additional cooperator taper off.

All in all, the benefits derived from cooperation are bound to eventually face diminishing returns. As we will see, similar to the rate-efficiency trade-off, diminishing returns can cause highly cooperative groups to be inefficient under certain conditions. But in order to make this point, we first need to look into the limitations of analyzing social dilemmas in terms of competition between cooperators and free-riders.

1.3 Social dilemmas with partially aligned interests

Explanations for the evolution of cooperation often assume that the interests of cooperators and non-cooperators are diametrically opposed. According to the tragedy of the commons, for example, individuals who overuse resources are expected to proliferate because they reap the benefits of such overuse while

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[3]In addition to being impractical, Brink also suggests that the mass killing of buffaloes was rooted in tribal beliefs. It was believed that buffaloes could recognize and disseminate among themselves knowledge of human deception, thus thwarting the chances of successful hunts in the future. For a more comprehensive discussion, see Brink (2008, ch. 6).

bearing only a fraction of the associated costs (Hardin, 1968). Similarly, in the prisoner's dilemma, defecting is the dominant strategy as it yields the highest expected payoff, even though both players would be better off as a group had they cooperated. As such, multiple authors have proposed a variety of mechanisms for suppressing the evolution of selfish individuals, including genetic relatedness, punishment, and indirect reciprocity (Birch, 2017; Fehr and Gächter, 2002; Clutton-Brock and Parker, 1995; Nowak and Sigmund, 2005).

Yet, as the yeast study illustrates, cases of conflict often involve individuals with partly aligned interests. Although free-riders allocate their resources into reproducing instead of producing invertase, they still contribute to the group's overall growth. This is not a unique feature of yeast populations, as actual cases of social conflict tend to involve individuals whose interests are partly aligned with those of the group. Consider parent-offspring relationships, for example. Despite the genetic ties between parents and their offspring, an offspring might demand a larger share of parental investment than her fair share (Trivers, 1974). Similarly, in international relations, while every nation prioritizes its own security, a mutual interest persists in preventing conflicts (Schelling, 1980). More broadly, bargaining situations often position individuals at a crossroads, enticing them with mutual benefits while also instilling caution regarding the potential fallout from a failed agreement (Skyrms, 2004).

In situations where interests overlap, the degree of conflict within groups can fluctuate depending on the level of cooperation. Specifically, as cooperation intensifies, free-riders' interests might align more closely with those of the group due to diminishing returns associated with cooperative benefits. Specifically, once the level of cooperation reaches a certain threshold, the contributions of free-riders to the group might outweigh the incremental benefits derived from further cooperation. Thus, while cooperation is generally perceived as advan-

tageous, high levels of cooperation can actually breed inefficiencies in certain circumstances.

Like individuals, groups thus experience 'opportunity costs.' After all, when groups allocate their resources towards one particular objective, they inevitably forgo the potential benefits that could be derived from utilizing the same resources for alternative objectives.[4] Groups differ in how they allocate resources depending on their level of cooperation. Specifically, highly cooperative groups may over-allocate resources to one particular task (e.g., invertase production) while neglecting other tasks that free-riders could contribute to more effectively (e.g., growth). Conversely, groups also face opportunity costs when there is a shortage of cooperators. The opportunity costs for a group is thus a function of the group's cooperation level.

Here is an intentionally streamlined model, designed specifically to illustrate how cooperation can generate opportunity costs. Consider a group in which the total utility for the group (U) is the sum of the benefit produced by all cooperators (B) and the indirect benefits of all free-riders (I):

$$U(x) = B(x) + I(x),$$

where is x is the proportion of cooperators. As Figure 1 (top) illustrates, the benefits produced by cooperators B is a saturating function due to diminishing returns, and the indirect benefits of free-riders I decreases with the proportion of cooperators. As the bottom figure shows, once we make these assumptions,

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[4]The concept of opportunity costs is particularly valuable for identifying inefficiencies when resources are limited. Consider, for instance, a university committee tasked with allocating funds for campus development. If the members of this committee decide to build a new sports facility, they miss the opportunity of using the same resources for another potentially valuable project, such as expanding the library. If the opportunity costs associated with building a sports facility are significant, the university committee is allocating their resources inefficiently. Although he does not explicitly use the expression "opportunity costs," see Bastiat (1995) for an early discussion of the value of the concept of opportunity costs in the context of economic policy.
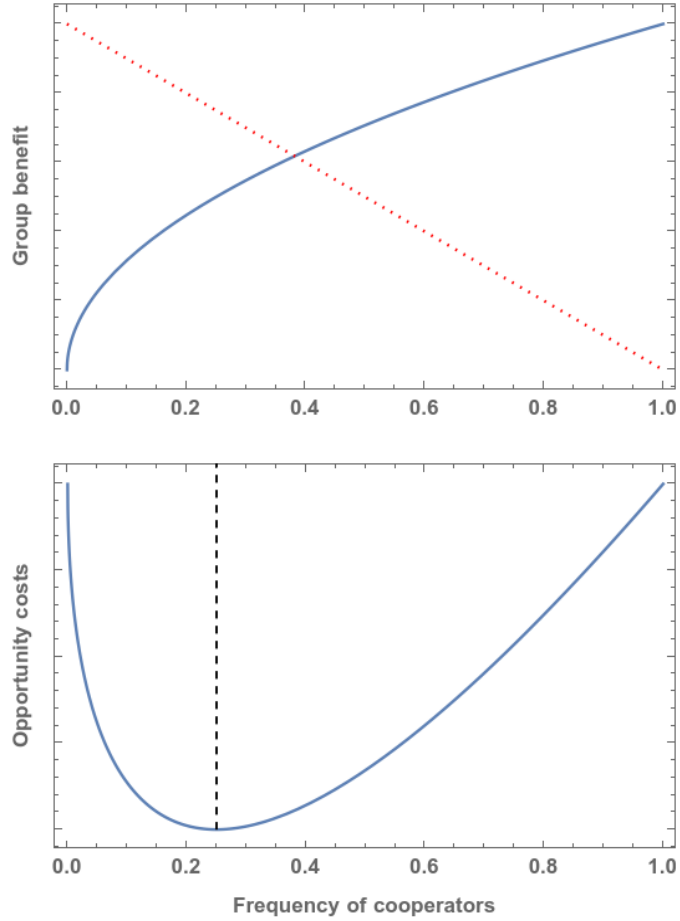
Figure 1: Visual representation of a model illustrating the potential negative impact of excessive cooperation on group efficiency. The top figure illustrates group benefits accrued by cooperators (blue line) and free-riders (dotted red line). The bottom figure, meanwhile, shows opportunity costs as a function of the proportion of cooperators. The vertical dashed line in the bottom plot marks the proportion of cooperators correlating with the lowest opportunity cost. To generate these plots, the following functions were used: $B(x) = \sqrt{x}$ to plot the benefits produced by cooperators, $I(x) = (1-x)$ to plot the indirect benefits of free-riders, and $\frac{U^* - U(x)}{U^*}$ to plot the opportunity costs, where U^* represents the maximal value for $U(x)$.

the total group utility is maximal when there is a mix of cooperators and free-riders.[5]

Our model requires two conditions for excessive cooperation to be detrimental to the group, conditions that are likely prevalent in nature. First, the incremental benefits of cooperation exhibit diminishing returns. This is expected as cooperation benefits often follow a saturation curve, where initial increases in cooperation yield substantial benefits, but the marginal benefits decrease over time. Second, the interests of free-riders and the group partially overlap. This condition is often satisfied because free-riders, unburdened by the costs of cooperation, are expected to reproduce at a higher rate than cooperators. Therefore, it is entirely plausible to encounter scenarios in which the group's efficiency is compromised due to the excessive levels of cooperation.

However, it is worth stressing that these two conditions alone—diminishing returns and overlapping interests—are not sufficient to cause free-riders to make their groups more efficient. Overwhelming cooperation may lead to inefficiencies, but insufficient cooperation risks fragmenting the group. Thus, free-riders become beneficial when the returns on cooperation start to diminish significantly, yet there is enough cooperation to maintain the group.

Free-riders are commonly defined as individuals that reap the rewards produced by cooperators without paying for the production costs. As we discussed, this definition does not preclude free-riders from enhancing the overall efficiency of their groups. A tempting reaction would be to stipulate that free-riders cannot enhance their group's efficiency. While this modification would automatically prevent free-riders from benefiting their groups, it would also obfuscate the surprising observation that the kind of self-interest exhibited by free-riders can enable groups to function more efficiently. By redefining the concept of

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[5]For more comprehensive models on how diminishing returns impact social interactions, see Foster (2004); Bach et al. (2006); Pacheco et al. (2009); Peña et al. (2014).

free-riding in this manner, we risk rendering the concept of free-riding inert. The fact that the common understanding of free-riding allows us to identify the trade-off between cooperation and efficiency should be seen as a feature, not a bug.

So far, we have focused on how social interactions among individuals, specifically free-riding and cooperation, shape how resources are allocated at a given moment. Yet, as we will see in the next section, the impact of free-riders extends beyond the immediate context, as they also affect the long-term persistence of their groups.

2 How free-riders increase their group's persistence

Groups of organisms tend to face a wide variety of unforeseen events, such as bouts of bad weather or the emergence of a novel parasite. To survive these disruptions, biological groups have developed a wide range of strategies to cope with them. For example, food taboos among hunter-gatherer societies incentivize meat sharing, which enables hunters to consistently obtain game despite streaks of bad luck (Henrich, 2015). Similarly, microbes form dense multicellular aggregates that are highly resilient to environmental stress, such as antimicrobial treatments (Hall-Stoodley et al., 2004). This section focuses on the question of how the level of cooperation within a group affects its ability to withstand unforeseen events.

2.1 Socializing under uncertainty

The struggle for survival coerces organisms into making decisions despite having imperfect information about their environments (Sterelny, 2003). Consider, for

example, the sentinel behavior of meerkats, who are tasked with alerting their group to impeding predators (Clutton-Brock et al., 1999). The sentinels operate under conditions of uncertainty, without comprehensive information about the predator's timing and direction of approach. Similarly, in the context of early human societies, encounters with strangers were fraught with uncertainty (Seabright, 2010). Without definite information regarding the intentions of these strangers, early humans were confronted with high-stakes decisions: they could either approach, potentially fostering alliances, confront, in a preemptive measure against threats, or evade, to sidestep any potential risk.

Uncertainty within an organism's environment often shapes how group members interact with each other. The previously discussed study on yeast nicely illustrates this phenomenon. Cooperative yeast cells produce invertase to break down sucrose in their surroundings. These cells exhibit imperfect information about sucrose concentration, as they produce invertase irrespective of the sucrose levels. However, if cooperators could adjust their invertase production rate based on the available amount of sucrose, free-riders would no longer enhance group efficiency (MacLean et al., 2010). This is because cooperators with perfect information could produce invertase only when needed, thus optimizing the group's efficiency without free-riders. Hence, the contribution of free-riders to group efficiency is partially due to cooperators having imperfect information about resource concentration.

Beyond having incomplete information about their current environment, organisms also face a deficit of information about future disruptions. These two types of environmental uncertainty suggest groups must strike a balance between immediate efficiency and long-term persistence. Groups may need to endure short-term inefficiencies to properly cope with unexpected events. Specifically, highly cooperative groups might be better equipped to cope with future per-

turbations than efficient groups. As an example, having extra cooperators may provide a safety net, ensuring the group retains a sufficient number of cooperators to bounce back from a mass mortality event (Pedroso, 2018). Yet, as I elaborate below, the presence of free-riders can similarly provide a safety net against future perturbations.

2.2 Two types of redundancy

Many pieces of technology are built with redundant components to enhance their reliability. For instance, computer server farms hosting critical data may rely on redundant components such as extra hard drives and power supplies to prevent data loss in case one or more components fail. Similarly, biological groups often rely on redundant members in order to properly cope with environmental uncertainty (Birch, 2012; Pedroso, 2022). For example, groups of vampire bats maintain a stable food source even in unpredictable situations partly because multiple bats hunt in parallel (Carter and Wilkinson, 2013). That is because groups of vampire bats might still obtain enough food if some of the bats fail to obtain blood during their feeding trips. In microbial systems, having extra public good producers might make their populations more resistant against drastic reductions in population density (Sanchez and Gore, 2013).

The redundant members do not have to be working in parallel, however. In some biological groups, the redundant members are only mobilized when needed, making them function as a 'reserve' workforce for the group. One intriguing example of this type of redundancy is the presence of inactive workers in insect colonies (Charbonneau et al., 2017; Birch, 2017). The presence of inactive workers enables groups to mitigate worker loss and take advantage of a novel resource, thereby enhancing the colony's resilience in changing environments. Similarly, the evolution of dormant cells within bacterial populations,

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Type of redundancy	Description and examples
Parallel	Redundant members perform the same task in parallel. E.g., foraging, public good production.
Latent	Redundant members remain inactive until needed. E.g., inactive workers, persister cells.

Table 1: Two types of biological redundancy.

known as 'persister cells,' enhances the resilience of infections due to their higher tolerance to antimicrobial treatments (Gollan et al., 2019).

As summarized in Table 1, we can identify two types of redundancy. Specifically, redundancy involves extra individuals performing the same function, either by working in parallel ('parallel redundancy') or by remaining inactive until needed ('latent redundancy').[6] Altogether, these types of redundancy illustrate different strategies biological systems deploy to ensure that critical tasks are still performed, even if the number of workers performing them has been reduced.

Having introduced the concept of redundancy, the next section returns to the question of how the level of cooperation affects persistence by focusing on latent redundancy.

2.3   Latent redundancy, free-riding, and persistence

In groups that display latent redundancy, active and inactive individuals have conflicting interests (Birch, 2017; Pedroso, 2021). Active members bear a higher risk of mortality and sacrifice their reproductive opportunities to enhance the group's survival against unexpected events. Meanwhile, inactive members benefit from the efforts of the active members without bearing equivalent costs,

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[6]Some authors distinguish another type of biological redundancy characterized by the ability of individuals to step into a novel role as needed. For example, in social insects such as ants, a worker might take on a new task if other workers are lost due to disease or predation, or if the colony needs to alter its task allocation in response to environmental changes. This type of redundancy is different from the other two types of redundancy discussed in this section, parallel and latent redundancy, because it does not require extra members. See Birch (2012) and Bourke and Franks (1995) for further details on this type of redundancy.

fitting the standard definition of 'free-riders.' Accordingly, latent redundancy nicely illustrates how some degree of free-riding can confer advantages to the group as a whole. Yet, the propensity to remain inactive, or free-ride, can differ among workers.

The likelihood of an inactive worker transitioning into an active state can vary, depending on its 'response threshold' to external stimuli (Charbonneau and Dornhaus, 2015). Specifically, some workers necessitate a stronger signal to start a task compared to others. This phenomenon is nicely illustrated by how bumble bees regulate the temperature of their nests (O'Donnell and Foster, 2001). Worker bumble bees cool their colonies by fanning their wings. While the fanning rate intensifies with rising temperature, not all bumble bee workers share the same minimum temperature threshold that triggers them to fan. A variability in response thresholds translates to varying propensities to free-ride, as workers with higher thresholds are more inclined to reap the benefits of others' efforts. However, this diversity in response thresholds can significantly augment a colony's persistence.

Colonies containing inactive workers with variable response thresholds are particularly flexible to environmental changes. This is because such colonies can match their workload with the current demands. For example, as the stimulus for a particular task increases (e.g., egg cleaning), variable response thresholds enable inactive workers to step in and replace active workers that have become fatigued (Hasegawa et al., 2016). In contrast, colonies with a uniform response threshold lack the same level of flexibility because all workers react similarly to a given stimulus, limiting their collective ability to adjust to varying demands.

While latent redundancy illustrates how free-riding can be advantageous for a group, it also highlights that not all forms of free-riding yield a group benefit. The capacity of free-riders to transition into an active state is a critical factor in

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latent redundancy. Furthermore, by hosting individuals with varying propensities to free-ride, groups may enhance their ability to changing environments.

Still, the reader might find it counterintuitive that inactive members are labeled as 'free-riders,' given their potential to become active contributors in the future. Some might even argue that free-riders should be defined based on their long-term fitness consequences, thereby excluding currently inactive members from being free-riders. However, adopting this narrower definition of free-riding obscures some of subtleties of latent redundancy. While the potential for future activity exists, it does not eliminate the existing social tension between currently active and inactive members. Depending on their response threshold, an individual might remain inactive, and thus free-ride, from brief spans to substantial fractions of their lifespan. During these periods of inactivity, they draw on group resources without direct contributions, which is the very essence of free-riding. What makes latent redundancy particularly intriguing is that individuals can act as free-riders while holding the potential to be essential for their group's resilience. By viewing latent redundancy in this light, we gain a more nuanced understanding of how the balance between cooperation and self-interest can contribute to the group persistence.

In sum, the phenomenon of latent redundancy challenges conventional perspectives on the role of free-riders within a group. The prevalent assumption portrays free-riders as a burden due to their reliance on others' efforts. Yet, this assumption neglects the potential benefits that a certain degree of free-riding can introduce. A group that tolerates some level of free-riding is able to build a reserve labor force, thus enhancing its persistence in the face of changing environments.

3 Conclusion

In this paper, we considered two kinds of benefits free-riders can confer to groups: efficiency (Section 1) and persistence (Section 2).[7] Altogether, these benefits underscore the same insight that, contrary to conventional wisdom, elevated levels of cooperation may inadvertently erode group performance. Indeed, groups may thrive when there is a balance between cooperative and free-riding behaviors.

The topics covered in this paper engage with broader issues not only from evolution, but also from the social sciences. In particular, one recurrent theme in this paper is that, when cooperation levels are sufficiently high, groups may fall into an overspecialization trap. This scenario arises when high levels of cooperation either compromise the group's adaptability to unforeseen circumstances or risk over-allocating resources to a particular task. In contrast, free-riders can inject necessary diversity by either establishing a reserve workforce or by offsetting opportunity costs. Accordingly, this overspecialization trap reflects the trade-off between generalists and specialists, a subject widely discussed by evolutionary biologists (Kassen, 2002), and also by authors in disciplines beyond the biological sciences (Epstein, 2019; Page, 2010).

Another topic of broader relevance discussed in this paper is the issue of how cooperation and self-interest should be balanced. Within philosophy and economics, this issue comes into play in arguments over the merits and drawbacks of market competition (Nozick, 1974; Sandel, 2012; Frank, 2014; Oreskes and Conway, 2023). Similarly, in environmental ethics, authors grapple with the tension between cooperation and self-interest when addressing the question

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[7]This paper did not cover all the ways free-riders can benefit their groups. For example, experiments with bacterial communities indicate that free-riders can facilitate the coexistence of different species (Leinweber et al., 2017). Additionally, Rainey and Kerr (2010) advance the hypothesis that 'cheats' might have played a significant role in the evolutionary transition from single cells to multicellularity. For a more comprehensive review on this subject, see García-Contreras and Loarca (2021).

of how we can avert the 'the tragedy of the commons' (Ostrom, 1990; Gardiner, 2006). In psychology, Barbara Oakley and others have taken a closer look at cases of cooperative behaviors going astray, concentrating on cases of 'pathological altruism' where individuals engage in self-destructive altruistic actions (Oakley et al., 2011; Oakley, 2013; Wilson, 2015). Altogether, these studies suggest that, contrary to first impressions, self-interest can be advantageous, even crucial, under certain conditions.

In conclusion, this paper challenges the common perception that free-riders are invariably harmful to their groups. Instead, it proposes that free-riders can actually be crucial for their groups' success. The proposed arguments in this paper tap into broader themes, especially the topic of how the balance between cooperation and self-interest impacts the collective good. Above all, this paper seeks to highlight the intricate dynamics of how free-riders impact their groups, a complexity that often goes unnoticed at first glance.

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