Gods, Games, and the Socioecological Landscape*

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Abstract

The social sciences have long recognized a relationship between religion and social ecology. Upon closer inspection, religious systems not only correspond to important features of a society's social ecology, but also appear to directly address these features. In this article, we examine the prospect that these salient features may be framed as game theoretical dilemmas and argue that contemporary approaches that emphasize cognition and/or social learning at the expense of social ecology are inadequate in accounting for cross-cultural variation in religious expression. Using ethnographic examples, we show that religions alleviate the costs of such dilemmas in a variety of ways by: 1) fostering beliefs that motivate and sustain beneficial practices; 2) incentivizing cooperative ventures; 3) encouraging ritual performances that minimize costly conflicts and bolster territorial conventions; 4) providing institutional forums to coordinate resource distributions; and 5) maintaining important resource and species diversity.

Keywords: religion, game theory, supernatural punishment, ritual, cooperation, coordination

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1. Introduction

Following others (Jensen, 2019; Tylor, 1920; Wallace, 1966), we theoretically define religions as practices done to engage with and alter the states and attitudes of spiritual agents. If we adhere to this definition and proceed to examine the cross-cultural variation in those practices and their associated beliefs (e.g., the objective costs, timing, and spatio-temporal distribution of ritual, or beliefs about what pleases and angers the gods), at least two things become clear. First, religion is a human universal. That is, although their forms and content may vary tremendously along a wide range of dimensions, all societies have practices conducted in relation to supernatural beings. A second fact—if perhaps less widely appreciated than the first—is that features of religious traditions evolve in ways that conform to communities’ socioecological conditions (Purzycki & Sosis, 2022). In this paper, we frame these socioecological conditions formally as cooperative dilemmas and closely examine ethnographic cases to illustrate this correspondence and how we might proceed with an evolutionary approach to religious variation. We also briefly discuss a general evolutionary process account by which religions achieve this correspondence.

Observing these patterns, many cultural anthropologists have appreciated that each of these elements interrelate in a kind of systemic cultural logic of meaning (Geertz, 1973; Rappaport, 1999; Spiro et al., 1987). Consistent with our other work (Alcorta & Sosis, 2005; Bendixen et al., in press; Lightner & Purzycki, n.d.; Purzycki & Sosis, 2022), we treat religions as systems of both information and energy, positing that their content and structure flexibly adjust to novel conditions, and that variation in religion is partly explained by these conditions. In order for religious systems to function as cohesive, adaptive systems, their elements must inform and respond to each other. By re-routing the allocation of resources into collective and other ritual acts with signaling functions, religions inhibit the kinds of selfishness that would otherwise plague social life. In light of systems’ constituent parts informing each other, simple accounts that appeal solely to cognition and/or social learning, for example, are

31 insufficient.

32 If there is a correspondence between religions and social ecologies, we should
33 expect the cultural evolution of religious traditions to be in certain respects dis-
34 similar to that of, say, linguistic accents, fashion trends, or ice cream preferences.
35 In such cases, historical contingency, social learning processes, and evolved cog-
36 nition explain the bulk of the variation. The evolution of religion, by contrast,
37 is more likely to resemble other cultural adaptations such as foraging strategies
38 and domicile constructions. Historical contingency, social learning, and cogni-
39 tion may explain some variance, but phenotypic design is largely a function of a
40 particular set of socioecological conditions (Bendixen et al., in press; Bendixen
41 & Purzycki, 2020; Purzycki & Sosis, 2022). In realtime, particular religious con-
42 texts might proximately trigger cognitive mechanisms such as agency detection
43 (Andersen, 2019; Guthrie, 1995) and corollary moral cognition (Boyer, 2000;
44 Purzycki et al., 2022). Enculturation and sharedness are also critical; we teach
45 each other when and where to engage these systems through religious thought
46 and practice. However, many of the important features of any social system
47 are also things that are not explicitly transmitted socially, such as the emergent
48 properties of such systems’ interacting components (Sosis, 2019) and the vari-
49 ation in payoff structures of different socioecological contexts. The ecological
50 inputs to cognitive-cultural systems are critical for accounting for the content
51 and form of religious traditions exhibited around the world.

52 To situate our discussion in a more formal evolutionary theory, we frame spe-
53 cific ethnographic examples using game theoretical payoff matrices. While clas-
54 sical economic game theory (Von Neumann & Morgenstern, 2007 [1944]) empha-
55 sizes the individual decision-making, evolutionary game theory (Maynard Smith,
56 1982) models the change in frequency of competing—and interacting—behavioral
57 strategies in social dilemmas. Formal theory suggests that cultural strategies
58 can evolve in response to different games (Bednar & Page, 2007), thus generating
59 relatively stable cooperative groups.

60 Many have appealed to and/or applied game theory and game theoretical
61 payoff structures to address various aspects of religion. Among these include:

62 theological questions (Brams, 2007, 2018; Hacking, 1972), the phylogeny of ani-
 63 mistic cognition (Guthrie, 1995), the relationships between religion and cooper-
 64 ation (Blum & Dudley, 2001; Bulbulia, 2004a,b; Bulbulia & Frean, 2010; Nesse,
 65 1999; Orbell et al., 1992; Pasquino, 2001; Schelling, 1968; Weingast, 1995), man-
 66 aging commons problems with religious appeals and practices (Atran et al.,
 67 1999; Lansing & Kremer, 1993; Lansing, 2006; le Guen et al., 2013; Sosis, 2003),
 68 and supernatural punishment more generally (Brams, 2007; Johnson & Krüger,
 69 2004). Building on this work, we wager that considerable variation in religious
 70 systems can be accounted for by virtue of their flexible adjustments to local
 71 problems.

72 To illustrate this, we examine specific ethnographic examples and show that
 73 in a variety of ways, important cross-cultural variation in religious systems can
 74 be accounted for in relation to the social ecologies in which they are embed-
 75 ded. The next section situates religious systems in four disparate socioecolog-
 76 ical contexts: 1) field-burning (Martu of Australia); 2) rice-terrace irrigation
 77 (farmers of Bali); 3) territoriality (Tyvans of southern Siberia); and 4) forest
 78 foraging (Batak of the Philippines; Itza' Maya of Guatemala). We frame these
 79 case studies in game-theoretical terms and point to how religious beliefs and
 80 practices influence how people interact in and with these games in a variety of
 81 ways.² We then turn to some brief examples of recent changes in the content
 82 and form of religious systems, discussing them in light of this framework. We
 83 conclude with prospects for future directions in the evolutionary, biocultural,
 84 and cognitive sciences of religion.

²Note that our analysis diverges from many discussions that emphasize the anonymity
 afforded by particular environments that might increase the temptation to defect (e.g., urban
 communities or widely disbursed communities) (see Johnson, 2005, 2016; Norenzayan, 2013).
 Here, we focus on the local socioecological problems among societies that have largely been
 underemphasized in the literature.

85 2. Gods, games, and socioecologies

86 2.1. *Martu field-burning*

87 The indigenous Martu of Western Australian burn fields in a controlled man-
88 ner. This practice has the effect of reducing the sizes of natural and less con-
89 trollable fires, such as from lightning strikes. It also enriches the soil, aiding
90 the growth of seed-producing plants upon which smaller animals feed and so
91 increases species diversity. These animals are prey for monitor lizards which, in
92 turn, the Martu hunt. In this system, controlled burning increases the availabil-
93 ity of resources for people over the long term. Bird et al. (2013) modeled this
94 system, as illustrated in Figure 1. Note that each arrow in the figure represents
95 a tractable, empirically testable relationship. Indeed, the authors subsequently
96 found that compared to otherwise untouched areas, hunting is more successful
97 where the Martu burn. Here, then, we have a system of niche construction
98 (Kendal et al., 2011; Laland et al., 2016) and foraging behaviors that co-vary
99 with measurable gains.

100 What about the role of religion? In our view, what qualifies Martu field burn-
101 ing as “religious” is that the Martu justify this practice with appeals to “the
102 dreaming” and the will of ancestors. According to the authors, such beliefs “are
103 the institutionalization of . . . histories of ecological practice” (Bird et al., 2013,
104 6), thus implying that these practices are maintained in part by religious ap-
105 peals. In other words, the Martu imbue these practices with religious meaning,
106 reducing energetic and informational uncertainty and thereby increasing effi-
107 ciency (North, 1990, 1991). Further bolstering the significance and predictabil-
108 ity of burning, some Martu hold that the stakes are quite high:

109 Critical to the perpetuation of life is the proper adherence to the
110 Law...[that] frames the importance of hunting and sharing within
111 the notion that ‘country must be used and appropriately burned’ if
112 life is to continue. As one elder put it, to stop using up resources, to
113 stop hunting and burning, would mean ‘the end of the world’ (Bird
114 et al., 2016, S71).

Figure 1: **Martu field burning system** (adapted from Bird et al. 2013). Solid lines are positive inputs and dashed lines are negative inputs.

115 And finally, successful hunting means successful sharing: “hunting is always
 116 embedded in a context of social exchange...the goal is not to eat more but to
 117 share more to other members” of the group (ibid.: S73). Successful hunting
 118 affords some status to the hunter, but it also facilitates the development of an
 119 individual’s cooperative network through trusting relationships (Bird & Power,
 120 2015). Burning fields to maintain the Law and the wills of ancestors clearly
 121 provides caloric gains for individuals and their communities. The collapse of
 122 this system, *ceteris paribus*, might very well entail the cessation of the Martu’s
 123 social ecology.

124 There are two things to note here. First, even though the ethnographic
 125 descriptions of Bliege Bird and colleagues (also see Tonkinson, 1991) suggest
 126 that field burning is religiously inspired and maintained, the role of religious
 127 cognition and beliefs in this system remains unclear and unmeasured. But if

we could toggle beliefs among the Martu, what would happen to field burning practices over time? Would the lack of divinely inspired motivations make the system appear impractical or unproductive (Johnson, 2005)? The collapse of the Tambaran cult among the Ilahita Arapesh of New Guinea, for example, transformed garden work, which had provided subsistence for the Arapesh and their ancestors, from a “meaningful endeavor into unredeemed drudgery” (Tuzin, 1997, 34), resulting in reduced work efforts and productivity. Would the Martu system suffer a similar fate if religious beliefs were altered or eliminated?

Imagining such scenarios raises an obvious question: why not instead make secular appeals—that is, appeals that do not point to a transcendent order—to maintain the Martu field burning system? Would it disintegrate sooner because secular rationales are easier to manipulate and alter, or because the authority of gods is generally perceived to be more powerful than human authority (Rappaport, 1999; Rossano & LeBlanc, 2017; Sosis & Bressler, 2003)? While ethnographers characterize Martu cosmological beliefs about field burning as institutionalized, which implies sharedness, researchers have not examined why the Martu have not institutionalized this system in a secular way (e.g., “we have always done this to get more lizards”).

The second thing to note is that while this system functions to extract more energy from the environment, and increasing resources might fuel more cooperation among individuals embedded in this system, Bliege Bird et al.’s model does not address the potential social dilemma(s) implicated in this process. Why burn at all? We might analyze the task of getting people to collectively participate in field burning as a coordination problem. Table 1 frames the payoffs involved in getting people to collectively burn as a “stag hunt” dilemma (Rousseau, 2016 [1755]; Skyrms, 2004; Bulbulia, 2011, 2012). In this dilemma, one has to choose between a smaller but more reliable payoff and a larger but less reliable one. More specifically, since it is costly to hunt, and bigger game (i.e., the stag) can only be captured with the assistance of a partner, it is better to hunt for big game only when your partner does. In other words, it pays to look for smaller game (e.g., a rabbit) on your own when others won’t contribute

159 to hunting larger game, even when hunting larger game would yield higher per
 160 capita net benefits.

	Burn	Don't Burn
Burn	b	0
Don't Burn	s	s

Table 1: **Payoff matrix for coordination in Martu field burning.** Payoffs are for player on left side of table.

161 In the case of the Martu, individuals in the model can choose to partic-
 162 ipate in collective burning or not. Here, the benefits of burning collectively,
 163 b , include the aforementioned lizards. Hypothetically, if a Martu chooses to
 164 burn without help, she is unable to control the fire and captures nothing. If
 165 she chooses to not burn, she accrues the benefits of slacking, s . What makes
 166 this a dilemma for individuals is the assumption that $b > s$; the individual net
 167 payoffs for collectively burning fields outweigh the individual net payoffs when
 168 fields are *not* burned. How can people work together to reap the larger benefits
 169 that require coordination? Does the threat of “the end of the world” motivate
 170 individuals to coordinate their actions? Beliefs about such costs might increase
 171 the likelihood of choosing to join in with field burning activities. In other words,
 172 collective pressure and religious appeals might motivate individuals to opt for
 173 the riskier—but more profitable—coordination strategy.

174 In this example, appeals to the spiritual realm and the end of the world
 175 might increase the likelihood of opting for the cooperative option of burning
 176 fields with your community. In contrast to our putative model of Martu field
 177 burning, our next example has been explicitly modeled as a social dilemma by
 178 ethnographers. There, the religious “solution” in the system is not beliefs, but
 179 an institutional mechanism that efficiently motivates and generates coordination
 180 between individuals.

181 *2.2. Water temples of Bali*

182 The Balinese water temple ecosystem has been extensively studied by Lans-
183 ing et al. (Lansing & Kremer, 1993; Lansing & Miller, 2005; Lansing, 2007;
184 Lansing et al., 2017). This research focuses on the inherent coordination prob-
185 lem faced by Balinese rice terrace farmers. Table 2 represents this problem in
186 the form of a payoff matrix that details the conflicts of interest between two
187 farmers (or farming groups). One lives upstream and one lives downstream.
188 They can choose between two different times to plant their rice. Water comes
189 down the mountain, ensuring that the upstream farmer can use the stream first,
190 depleting it by factor d . Therefore, if both farmers plant their rice at the same
191 time, there will be a loss for the downstream farmer since the water will be de-
192 pleted. Lansing and Miller (2005) assume that threat of pests is reduced if both
193 farmers plant simultaneously because pests can simply migrate from fallow to
194 nearby planted fields. By contrast, if all the fields in a given area are fallow at
195 the same time, pests will have nowhere to opportunistically migrate to and will
196 die off. So, if farmers plant in a staggered, step-wise fashion, both of their yields
197 are reduced by r , the pest-consumption factor. Therefore, it is always in the
198 upstream famer’s best interests to plant simultaneously with the downstream
199 farmer. However, it is only in the best interests of the downstream farmer to
200 coordinate planting when $r > d$; if the costs of water depletion are worse than
201 those associated with pests, then it makes sense to accept the costs of pests and
202 not coordinate.

	Simultaneous	Staggered
Simultaneous	$1, 1 - d$	$1 - r, 1 - r$
Staggered	$1 - r, 1 - r$	$1, 1 - d$

Table 2: **Payoff matrix for Balinese coordination problem (adapted from Lansing & Miller 2005).** First payoff in each cell is the payoff for the player on the left side of the table (the upstream player), second is for the player on the top of the table (the downstream player).

203 The practical question of how to maximize everyone’s yield, then, is: *how*

204 *can we get upstream farmers to give up some water so that the downstream*
 205 *farmers' crops improve to the point that they are willing to coordinate to reduce*
 206 *pests?* The answer, according to Lansing et al., is water temples: they function
 207 as structured, spiritually sanctioned forums for coordination and forging pacts
 208 sealed with ritually-induced bonds. Balinese farmers meet at temples with the
 209 desire to honor various deities, receiving small ceremonial distributions of "holy
 210 water" (not irrigation water) in return. As these temples exist in a much wider
 211 temple network, they have the capacity to maintain a remarkably complex coor-
 212 dination system over vast areas, timing and synchronizing planting on the basis
 213 of ritual performance and holy water distribution. Each temple coordinates the
 214 planting and harvesting cycles of the farms in its area, called a "subak." Here,
 215 the subak is not merely a set of beliefs or appeals that might induce coopera-
 216 tion. Rather, the subak is a community and the religious order facilitates the
 217 kind of coordination required to maximize everyone's yields rather than those
 218 conveniently located closer to water sources.

219 Lansing (2006) "wonders whether institutions like water temples exist else-
 220 where in the world, and if so, what form they might take. Perhaps, like the water
 221 temples, they are regarded as religious institutions that can be safely ignored
 222 by planners and engineers" (87). Indeed, like the Martu, the Balinese alter
 223 their physical landscape in coordinated ways to reap the benefits of collective
 224 action and mobilization. We suspect similar religious institutions do exist, and
 225 that evolutionary and cognitive scientists miss opportunities to observe them
 226 if they avoid rich ethnographic work along the lines of Lansing et al. (see also
 227 Sosis, 2009, for further discussion). In fact, the opportunity to explore such a
 228 possibility brought one of us to the field. In the following case, spirits function
 229 as mediators of human relationships and exploitable resources and ritual sites
 230 are strategically located on resources and territorial boundaries.

231 *2.3. Tyvan spirit-masters*

232 Local spirits, "spirit-masters," in the Tyva Republic of Siberia care about rit-
 233 uals and the preservation of natural resources such as game and water (Purzycki,

234 2011, 2016). The rituals that they care about take place on territorial borders,
 235 at mineral springs, and lakes (Purzycki, 2013b) and Tyvans encourage each
 236 other to keep these areas clean. Furthermore, in some regions considered to
 237 be the territories of the spirit-masters, hunting is strictly forbidden (Donahoe,
 238 2006, 120). In other words, behaviors associated with spirits and their behav-
 239 ioral corollaries are largely distributed near markers of negotiated territory and
 240 at other discrete exploitable resources. We illustrate these scenarios in Figure
 241 2.

242 In this illustration, there are two yurt encampments (1 and 2). By necessity,
 243 both are located by water sources. In addition to a river, one camp stands by
 244 a natural spring, marked with C. These two camps recognize their established
 245 territories, marked by a devotional cairn at B. One “territory” is the spirits’ land
 246 (marked by A) where hunting is forbidden. This illustration is a condensation
 247 and simplification of real, observed scenarios³: many Tyvans other Inner Asian
 248 ethnic groups are bound by a common, ancient religious system that entertains
 249 the possibility that spirit-masters inhabit the landscape. Individuals who fail to
 250 pay respect to the spirits in the locally appropriate manner risk misfortune. In
 251 other words, cognition about the moral interests (Boyer, 2000; Purzycki et al.,
 252 2022) and potential punishments (Johnson, 2005, 2016) of supernatural agents
 253 is contextually triggered, spatially distributed, and grounded in local rituals
 254 and resources. Indeed, as in the previous sections, we can model each of these
 255 scenarios as corresponding to a different social game.

256 We model Scenario A as a dilemma that revolves around over-exploitation,
 257 where it is tempting to hunt deer. In this territory, hunting is off-limits because
 258 this is the “spirits’ land,” but it is in individuals’ interests to hunt there any-
 259 way, especially considering the difficulty of monitoring others’ behavior (or of
 260 determining where gunshots are coming from, if they’re audible at all). Hardin’s
 261 (1968) “Tragedy of the Commons” famously offered a dismal portrait of how

³Purzycki has directly observed and reported on Scenarios B and C, while Scenario A is derived from stories, by implication, and reports by Donahoe (2006).

Figure 2: **Three scenarios on the relationship between spirit-masters, ritual, and resource in Tyva.**

262 such self-interested behavior can lead to the destruction of common-pool re-
 263 sources when top-down governance is absent (cf. Ostrom, 2015).

264 We use the Prisoner’s Dilemma to model this problem (Table 3). Players can
 265 either hunt or forgo hunting. One person could easily defect and continue killing
 266 deer, only to effectively wipe out the population⁴. Without restraint, two people
 267 hunting would wipe out the deer population even more quickly. However, if
 268 both people agree to not hunt there—possibly motivated by a territorial spirit’s
 269 threat of punishment—the land may ultimately have more reliable returns in the
 270 future (since deer migrate too). In other words, spiritual punishments can alter
 271 the payoff structure (Johnson & Krüger, 2004; Johnson, 2016) so that hunting
 272 appears to be more costly than forgoing the hunt.

273 Scenario B concerns territorializing land, which has long been recognized as
 274 an effective solution for reducing costly conflict between individuals or groups
 275 who have a clear interest in expansion (Dyson-Hudson & Smith, 1978; May-

⁴Formal models often include discount parameters that adjust the value of subsequent interactions, or some time constraint parameter that toggles the likelihood of interactions changing through time (Axelrod, 1984). Depending on one’s questions, the availability of a game might be represented with one of these parameters.

	Forgo	Hunt
Forgo	3	1
Hunt	4	2

Table 3: **Payoff matrix for Camp 1 in Scenario A: Tragedy of Commons as modelled as the Prisoner’s Dilemma from Romagny et al. 1997.** Payoffs are for Camp 1.

276 nard Smith, 1982, pp. 151-161). In this scenario, it is in both parties’ best
277 interests to expand their territory. Properly functioning borders can prevent or
278 limit expansion, but keeping territorial borders requires maintenance. A rich
279 literature (e.g., Heap et al., 2012; Mesterton-Gibbons & Adams, 2003) suggests
280 that landmarks can reduce costs associated with border maintenance among
281 non-human animals. That is, physical—but non-obstructive—indices of borders
282 can function as a reminder of territorial ownership and reduce the likelihood of
283 aggressive conflict. In the context of human territories where borders are not
284 always easy to monitor and therefore maintain, localizing the presence of a pow-
285 erful deity through ritual acts can be a strategic way of maintaining borders in
286 the absence of effective secular punishment.

	Relent	Fight
Relent	$\frac{v}{2}$	0
Fight	v	$\frac{v-c}{2}$

Table 4: **Payoff matrix for Camp 1 in Scenario B: Territory as Hawk-Dove Game.** Payoffs are for Camp 1.

287 As detailed in Table 4, we can model territorial conflict using the Hawk-Dove
288 game (Maynard Smith, 1982, 147-166; cf. Hare et al. 2016). Here, two agents
289 compete over a resource with a specific value, v . Camps 1 and 2 could both
290 fight, incurring the costs of fighting, c , but with only a 50% chance of winning.
291 One who relents to an aggressor acquires nothing, and the aggressor gets ev-
292 erything. If both camps choose to relent, they divide the land by half. In this
293 scenario, the only conditions under which Relenters can outcompete Fighters

are when the costs of fighting outweigh the value of the resources ($v < c$). In the case of Tyva, placing a spiritual marker on a territorial border might reduce the temptation to engage in risky territorial expansion, turning potential Fighters into Relenters (at least proximately and psychologically). Indeed, when Tyvans are directly asked, spirit-masters are treated as knowledgeable, punitive, and interested in both the ritual and general moral behavior of individuals in their vicinity (Purzycki, 2011, 2013b). Fear of supernatural punishment may therefore increase the perceived costs of aggressive expansion (which entails violating the sacred boundary cairn rites) and therefore facilitate the proliferation of Relenters. Tyvans perceive ritual participants to be more broadly trustworthy than those who don't participate (Purzycki & Arakchaa, 2013). If disrespecting the spirits is tantamount to disrespecting communities and their rules (Rappaport, 1999), it would make sense to convey and adopt the idea that such disrespect would bring misfortune. Indeed, Tyvans believe that bad luck strikes travelers who fail to stop and leave a token of their presence when they encounter cairns.

The related scenario C echoes any system where outsiders are expected to pay their respects to spirits before extracting others' renewable resources (e.g., Jordan, 2003; Watanabe, 1972). In this scenario, Camp 2's water supply is temporarily depleted, so water must be acquired elsewhere. When local rivers get dirty, people might collect water at neighboring mineral springs. Thus, Camp 2 must travel to someone else's territory to get water. Prior to extracting the water, Camp 2 will perform rites at the mineral spring to pay their respects to the spirit-master of the spring. Camp 2 must convey that they do not have exploitative or aggressive intentions and that they are in Camp 1, where they should not be, simply for water. Conveying deference to spirits implies the likelihood of deference to other local rules, and thus there is no reason for hostility, especially since water is readily available in Camp 1. In this way, a small gesture of respect to the local spirits may decrease the chances of inflaming social tensions between camps.

Spirit-master concepts, evident in all three of these scenarios, are bundled together with corollary processes such as mentalizing (Andersen, 2019; Guthrie,

1980), punishment (Johnson & Bering, 2006), and moralizing (Boyer, 2000; Purzycki, 2011, 2013a; Purzycki et al., 2022). In Tyva, strategically distributed indices trigger these bundles, as well as behavioral expressions of commitment. In other words, the coupling of religious beliefs and practices (Purzycki & Sosis, 2013) systemically conforms to particular social dilemmas. With the expertise and inspiration of shamans and other religious experts, communities collectively and ritualistically sanctify and re-sanctify these indices regularly and therefore reinforce the relationships between cognition, cultural beliefs, motivations, and behaviors, and the relative harmony offered by sustained cooperation. Considerable work shows that a variety of mechanisms, such as supernatural punishment (Johnson, 2005; Lang et al., 2019; Shariff & Norenzayan, 2007) and ritual (Power, 2017; Sosis & Bressler, 2003; Soler, 2012; Xygalatas et al., 2013), can induce the cooperative options in these dilemmas, contribute to their proliferation, and increase the chances that individuals transmit and retain the kinds of information required to profitably engage in social institutions.

Such mechanisms are manifest in Tyva. With respect to Scenarios B and C, there is evidence that Tyvan beliefs and practices co-vary with social behavior; rituals have been shown to convey trustworthiness to observers (Purzycki & Arakchaa, 2013), and the more people claim spirit-masters know, the more they give to local community members—at the expense of distant co-religionists—in experimental games (Purzycki & Kulundary, 2018). However, it remains to be seen whether or not Scenario A, where individuals might forgo hunting because of spiritual sanctions, is adequately accounted for by spiritual sanctions. Indeed, a longstanding debate continues to rage about the so-called “ecologically noble savage” and whether or not traditional religions somehow contribute to the preservation of nature (Hames, 1991, 2007; Smith & Wishnie, 2000).

Yet, there is considerable experimental research showing that religiosity is related to self-restraint and self-control (Morgan, 2019; Ruffle & Sosis, 2020; Sasaki & Kim, 2021; Sosis & Ruffle, 2003; Tian et al., 2018). This suggests that it is plausible that Tyvans are more likely to forgo hunting when the injunction against it is associated with spirit-masters. Unfortunately, we have no data

beyond anecdotes.⁵ Nevertheless, there are general proscriptions against hunting in particular areas. Whether or not these proscriptions actually encourage hunters to restrain themselves and whether or not this affects the deer populations in any systematic way remains to be established with more specified theoretical models and focused empirical assessments. In summary, there are many reasons both direct and implied to suspect religious taboos would decrease overexploitation, but subsequent work is required to more rigorously assess this possibility. There are, however, at least two other case studies that reveal that religious beliefs are associated with the active maintenance of resources, namely, the forest spirit beliefs of the Batak from Palawan Island and the Itza' Maya.

2.4. *Forest spirits of the Batak and Itza' Maya*

Another ethnographic case study on spiritually-sanctioned resource management comes from Eder's (1997; 1999) work with the Batak people of Palawan Island, the Philippines. While, traditionally, the Batak lived in isolated and mobile family groups subsisting as hunter-gatherers, contact with the greater Philippine society and migrant farmers has dramatically changed their social environment. Yet, parts of the traditional Batak lifeway persist. One sustained set of traditional beliefs and practices pertains to the Batak's perceived connection with their natural surroundings. As in many traditional foraging societies (e.g., Bird-David, 1999; Rossano, 2007), the Batak possess intricate knowledge about the local ecology and view themselves in close reciprocal relationships with the forest, its plants, animals, and spirits. Importantly, the forest spirits

⁵Some anecdotes suggest that while the relationship between spiritual punishment and overhunting is explicit, beliefs and their underlying motivations variably moderate behavior. For example, one elderly man laments that "Taiga gives to you and taiga takes it away. I am blind now, it's my fault. I often hunted, sometimes too much, a passion seized me. I took a lot from taiga, now I have been paying for my bad attitude to taiga. The female master punished me for this" (Arakchaa, 2009, 50). Though it's left to the imagination what would have happened in the absence of this taboo against hunting too much, the taboo did not appear to work very well in this individual's case.

are regarded as “caretakers” of the forest and can assume both benevolent and malevolent forms. The spirits are usually permissive about letting the Batak forage in the forest; however, if forest resources are collected in excessive amounts, not fully utilized, or otherwise go to waste, the spirits get upset and punish the transgressor. Indeed, simply making fun of animals or disrespecting the forest in other ways will attract the wrath of the spirits. Since the threshold of violation as well as the form of the punishment itself are vague, almost any kind of malady and misfortune can be interpreted as spiritual retribution (Eder, 1997, 10-11). Note, too, that punishing misbehavior is strictly the responsibility of the spirit, in that there are otherwise no formal institutions or social sanctioning in place to deter exploitation (Eder, 1997, 11, 28).

Honey and wild pig meat are central to Batak subsistence. Interestingly, the Batak conceive of specific spirits dedicated to the protection and proliferation of honeybees and pig populations. For instance, if honey is wasted or a hive is disturbed or destroyed (regardless of intent), the relevant spirit will punish the responsible forager with illness, accidents, or even death. The spirit might also send the bees away, making honey unavailable for a time. In that case, a “honey ritual” is required, which involves more than two weeks of collective “good behavior” where interpersonal qualms and conflicts are avoided, and people are mandated to only “think cleanly” about their neighbors (Eder, 1997, 16-17). Similar spiritual sanctions and appeasing rituals ensue if pigs are killed but not properly respected and fully utilized (18). Eder (ibid.) argues that these spiritual beliefs directly contribute to the sustainability of the Batak lifeways. The Batak way of life stands in contrast to Filipino migrants who view the forest not as an agent to be respected but as a resource to be exploited and, as a result, engage in resource-depleting foraging and farming.

While one must remain careful not to romanticize indigenous people’s ways of life when evaluating such ethnographic reports (Angsongna et al., 2016; Hartberg et al., 2016, see Willerslev (2007) for an example of spirits *condoning* over-exploitation; see also Alvard 1994; Smith & Wishnie 2000), the ethnographic record is brimming with similar instances of spiritually sanctioned conservation

409 systems, at least hinting at causal implications to be tested in future research.

410 Indeed, a strikingly similar case to the Batak can be found in Atran et al.’s
411 (2002) work among three neighboring rain forest groups in the Maya lowlands
412 of Guatemala. As with the Batak, the indigenous Itza’ Maya, have few formal
413 institutions to appeal to but practices the most sustainable agroforestry (e.g., in
414 terms of tree cover and biodiversity) among the three groups, the other two being
415 migrant groups in the area. Importantly, only the Itza’ perceive themselves to
416 be in a fully reciprocal relationship with the forest and view the forest spirits
417 as punitive of exploitation and disrespect toward the local ecology.

418 The Batak and Itza’ cases lend themselves to game theoretic analysis. In-
419 deed, Atran et al. (2002) explicitly make this point. Imagine a very simple
420 set of payoffs where people can either exploit forest resources indefinitely for
421 a high benefit, B , or self-regulate for a lesser benefit, b , and that there is no
422 sanctioning either way (recall that neither the Batak nor the Itza’ rely on sec-
423 ular alternatives for deterring forest exploitation; punishing over-exploitation
424 is solely the domain of the spirits). This idealized payoff matrix—let us call
425 it the “Forest/Other people Game”—poses no dilemma in the short-term; as
426 game strategies, Exploit will always outcompete Self-regulation until resources
427 run out.

428 Imagine now a different permutation, the “Forest Spirit Game,” where in-
429 stead of playing against the forest or other people, the Batak/Itza’ now play
430 against punitive forest spirits (cf. Atran et al., 2002, 440). As shown in Table
431 5, spirits might Punish preemptively, $-c$, even when people Self-regulate, but
432 Punish more severely if people Exploit the forest, $-K$.⁶ Assuming widespread
433 belief in spiritual sanctions and no outside competition for land or resources (but
434 see discussion below), the perceived threat of spiritual punishment presents an
435 alternative set of payoffs, $B - K < b - c$, where the Batak/Itza’ are now better

⁶Our assumption that $K > c$ is reasonable because perceived supernatural retribution, K , involves costly ritual appeasement *in addition to* the serious illnesses, accidents, and deaths that might be linked to c .

off Self-regulating instead of Exploiting.

	No Punishment	Punishment
Self-regulate	b	$b - c$
Exploit	B	$B - K$

Table 5: **Payoff matrix for the “Forest Spirit Game”**. Payoffs are for the Batak/Itza’. See Brams 2007, 137-141 for example of a similar “punishment” game.

Taken together, the Batak and Itza’ Maya cases complement the other case studies discussed herein by illustrating how appeals to, beliefs about, and rituals devoted toward punitive and watchful spirits can shift cultural attitudes from short-term exploitation of common resources to long-term sustainable life-ways. The game theoretic analysis also makes explicit the conditions under which Self-regulation is predicted to outcompete Exploiting, namely when the perceived cost of Punishment for Exploiting outweighs the perceived cost of Self-regulating, even taking into account the greater benefit from Exploiting compared to Self-regulating. At least among the Itza’ (but see also Eder 1997, 10-11), these conditions appear to hold:

A plausible hypothesis is that spirit preferences represent a synthesis of experience accumulated over generations. Violations of spirit preferences can lead to accidents, falling ill, or worse. *It matters little if the supernatural threat is real or not: if people believe in it, the threat of punishment becomes a real deterrent.* Our research team has witnessed Itza’ who have been bitten by deadly pit vipers refuse to be taken for anti-coagulant treatments that could save their limbs or lives, unless they first had a chance to venture into the forest to ask the spirits for guidance or forgiveness (Le Guen et al., 2013, 781, our emphasis).

Finally, both the Batak and Itza’ case studies allow for comparisons between the focal cultural groups—the Batak and the Itza’, respectively—and migrant

groups living in the same environments but who lack the relevant beliefs, appeals, and rituals toward the local ecology and the spirits. In both cases, the Batak and Itza’ religious systems contribute to sustainable agroforestry, indicating that, at least under certain circumstances, beliefs about gods’ concerns can have tractable psychological, social, behavioral, material, and ecological consequences (Bendixen et al., in press; McNamara & Purzycki, 2020).

3. Religious Systems Evolving

3.1. Summary

These ethnographic examples—Martu field burning, Balinese water temples, Tyvan rituals, and the religious conservation values and practices of the Tyvans, Batak, and Itza’—each illustrate that religious beliefs and practices can, at the very least, reflect locally important socioecological dilemmas. However, they also show that those same beliefs and practices can actively *restructure* the payoffs of these dilemmas, by altering perceived costs of selfishness and/or providing a forum required to achieve cooperative solutions. Religions can be useful, in other words, for sustaining lifeways that would not be readily available otherwise.

As we have illustrated, religious systems around the world interact with locally salient games in notably different ways. First, religious systems can improve the chances that people will cooperatively sustain a common resource, for example, by increasing the perceived costs of selfish strategies. This increase in perceived cost, which might be invoked by threats of bad luck or supernatural monitoring and punishment, is sufficient to shift even a minimally risk-averse decision policy away from potentially costly behaviors (McKay et al. 2017). Second, as demonstrated by the Tyvans, Batak, and Itza’, we see that various dilemmas attract religious solutions, such as beliefs that motivate a preservation of natural resources. Third, beliefs and practices can also provide the currency (e.g., lizards among the Martu) and context (e.g., territory among Tyvans) to harness the trust-enhancing capabilities of ritual or ritualized obligations. In the

case of the Martu, associating field burning with spirits and cosmic order may motivate field burning and, in turn, fuel reciprocal commitments. And finally, specific problems may recruit institutional solutions. Among the Balinese, both theory and evidence suggest that religious institutions function to coordinate people in ways that resolve individually costly conflicts of interest.

Together, these examples also show that religious traditions can evolve in ways that are not satisfactorily reducible to individual cognition or transmission processes alone (Purzycki & Sosis, 2022, cf. Buskell et al. (2019) for more formal treatment of cultural systems' evolution). More general models that formally ignore behavioral payoffs in a given context miss the factors that maintain systems both synchronically and diachronically. Simple game-theoretic models nicely frame and clarify how religion might nudge individual adherents toward opting for cooperative strategies either directly (e.g., through spiritual punishment) or indirectly (e.g., through social institutions). But different societies face different cooperative games, some of which emerge from persistent ecological problems that are associated with the way people acquire resources. Focusing on the transmission of religious concepts and practices without attending to these contextual relations might have heuristic value, but doing so may overlook essential—but more complicated—factors involved in the persistence and evolution of religion.

3.2. *Accounting for change*

If our general approach has merit, religious systems' elements (Sosis, 2019, 2020) will correspondingly change when the payoff structures of extant problems change and when costly new problems arise. In Figure 3, religious beliefs and behaviors are dynamically related to the specific kinds of social dilemmas and conflicts communities endure. These problems would recruit the use of novel religious beliefs and practices that can serve as solutions (Bendixen & Purzycki, 2020; Bendixen et al., in press). The diagram in Figure 3 is a crude and oversimplified depiction of how deeper individual-level mental processes co-inform individual beliefs and behaviors, which in turn contribute to shared (group) be-

518 beliefs and behaviors that then feed back into individual-level cognitive processes
 519 once more. Individuals' deeper cognitive processes might generate, constrain,
 520 and modify beliefs and behaviors, but those cognitive processes also receive this
 521 information as feedback, channeled through locally relevant social and ecological
 522 pathways.

Figure 3: **Religion evolving with feedback from social ecology, represented here by payoff matrices.** Adapted from Purzycki & Sosis (2022).

523 One general prediction of this model is that the cost of social engagement,
 524 often experienced as risk of exploitation, affects the content of religious beliefs.
 525 As the costs of being exploited increase, we anticipate an increase in religious
 526 appeals—that is, appeals to powerful spiritual agents—in a strategic attempt
 527 to raise the perceived costs of selfishness (Bendixen et al., in press; Fitouchi &
 528 Singh, 2022; Purzycki & McNamara, 2016). We similarly expect a proliferation
 529 or intensification of religious appeals when communities face novel environmen-
 530 tal threats. Accordingly, natural experiments across varying socioecological con-
 531 texts show an increase in religious expression and commitment—often among
 532 relatively non-religious individuals—during times of stress (Henrich et al., 2019;
 533 Sibley & Bulbulia, 2012; Sosis, 2007; Sosis & Handwerker, 2011; Vardy & Atkin-
 534 son, 2019, cf. Jong et al. 2012; Jong & Halberstadt 2016 for discussion of
 535 the complicated relationship between death anxiety and religiosity). Moreover,

536 controlled experiments demonstrate that breaches in mutually beneficial trust-
 537 reliant interactions can alter the content of believers' models of what angers
 538 God in predictable ways (Purzycki et al., 2020).

539 We also expect that when the costs of interacting with non-cooperators in
 540 newly introduced games (i.e., novel conditions) outweigh the corresponding costs
 541 of a currently “played” game, religious appeals will increasingly include content
 542 that corresponds to the newly introduced problem, especially when the problem
 543 is salient in individual minds. To illustrate, interviews reveal that some Tyvans
 544 claim that spirit-masters (Purzycki, 2016) and Buddha (Purzycki & Holland,
 545 2019) are angered by the alcohol use and abuse that have become a devastating
 546 problem in the Tyva Republic. Like the other cases we discussed above, we can
 547 frame this particular dilemma in terms of its benefits and costs. The leftmost
 548 matrix in Table 6 provides the payoff cells for the general dilemma of whether
 549 or not to drink socially. We can model these payoffs primarily in terms of
 550 their impact on relative social standing; if drinking entails a social benefit (e.g.,
 551 the respect that is gained from having a drinking companion), and refusing to
 552 drink entails a loss of this social benefit, then $d > c > a > b$. An example of
 553 more concrete payoffs is in the middle matrix of Table 6. However, associating
 554 divine punishment with drinking behavior can render the costs of drinking much
 555 greater than the social costs of *not* drinking.⁷ Here, then, $d < c = b < a$
 556 (rightmost matrix in Table 6).

557 It is worth emphasizing that in Table 6, the shift from the middle matrix
 558 to the rightmost matrix is initiated by appeals to a supernatural punishment
 559 belief, but this initial nudge away from payoff cell d would be strengthened

⁷See Medicine (2006) for a discussion of drinking behavior among Lakota (Sioux) males where refusing to drink implies femininity and there is abundant peer pressure to imbibe (53-76). See, too, Shermer (2008) for a similar take on taking performance enhancing drugs in athletic competitions. Note that the Koranic source appealed to in discussions of alcohol consumption and gambling (Surah Al-Baqarah 2:219) states that “There is a great harm in both, although they have some benefit for men; but their harm is far greater than their benefit.”

	Refuse	Drink	Refuse	Drink	Refuse	Drink
Refuse	a	b	0	-1	0	-1
Drink	c	d	1	2	-1	-3

Table 6: **Payoff matrices for perceived costs and benefits of drinking. Left matrix is perceived payoffs of drinking; right is shifting costs to drinking and drinking socially.**

by a frequency-dependent shift from widespread approval of drinking toward widespread *disapproval* of drinking. At a population level, simply learning that a god will punish you for alcoholism is unlikely to curtail consumption. Rather, both changing the incentive structure as well as ensuring the presence of effective institutional and social support with access to resources are more likely to help. Religious appeals can certainly change the perception of the payoffs, then, but we anticipate that the development of fully-fledged religious institutions will be more effective in expediting and strengthening the kind of social support that contributes to abstinence and recovery.

Religions also adapt, adjusting their perceived payoffs, to advance extant meaningful ideologies. Take, for example, the Taiwanese goddess of the sea, Mazu, who became the patron saint of the anti-nuclear energy movement among a group of activists (Shih, 2012). Having found little support among the political parties in power and alienated by a system that failed to address a salient problem, activists consulted an oracle who “predicted” that if it was Mazu’s will, the development of another nuclear power plant would be halted. It was, and thus the activists were emboldened to adopt Mazu as their patron saint. Here, then, an already salient problem existed, a secular institution failed to address it, and through the oracular powers of a specialist, a deity was subsequently transformed into a patron saint of a contemporary movement. Believing that one’s actions will prevent environmental collapse is likely appreciated as an inequality between resistance and catastrophe. We also predict, therefore, that commitment to the idea that a deity supports one’s efforts should offset the perceived costs of engaging and resisting industry and the state.

584 A related example of religious evolution is the real and perceived expanding
585 association between environmental preservation and the Abrahamic faiths (see
586 Taylor et al., 2016; White, 1967). More specifically, while the Pope’s encyclical
587 *Laudato si’* likely increased Catholic perception that environmental conservation
588 is God’s will, it is much less likely such beliefs would have been adopted if so
589 many Catholics were not already aware and concerned about the environment.
590 In other words, religious change is not random. Had the Pope or the Mazu oracle
591 instead expressed concern about bunny-rabbit invaders from Mars, participation
592 in these religious institutions would likely have declined.

593 3.3. *Accounting for failure*

594 Religious systems fail for a host of reasons (Rappaport, 1999; Sosis, 2019;
595 Turpin & Lanman, 2022). While they can mitigate local challenges to coop-
596 eration and coordination, we stress that their benefits are conditional on the
597 system’s relationship to its context. In other words, they are not always opti-
598 mal and in fact appear to exacerbate problems as well. Consider again the Itza’
599 Maya. In a follow-up study, Le Guen et al. (2013) document how Itza’ beliefs
600 involving protective and punitive forest spirits are rapidly being undermined by
601 inter-generational change and external influences, in particular competition from
602 non-native immigrants with a more exploitative stance toward the environment.
603 Among younger Itza’, this resulted in shifts away from viewing themselves in a
604 reciprocal relationship with the forest and its resources and toward short-term
605 monetary incentives. Thus, according to Le Guen et al. 2013, the “Itza’ may be
606 subsidizing their own cultural extinction...to the demise of the forest commons”
607 (p. 789; for detailed discussion of a similar case study, see Eder 1997, p. 19-31).
608 Further, although traditional medicine practitioners in small-scale societies are
609 often shamans and religious healers (Winkelman, 2014), Western medicine prac-
610 titioners frequently outcompete them for first recourse for ailments (Blackwell,
611 2009; Lightner et al., 2021).

612 3.4. Conclusion

613 In conclusion, while the general content of religious appeals might partially
614 account for their dispersion (Fitouchi & Singh, 2022; Purzycki & Willard, 2016),
615 their transmission and retention are likely expedited due to their correspon-
616 dence to pressing and perceived costs that are already present; religious systems
617 draw attention to threats that already have a prior precedence in a community
618 (Bendixen & Purzycki, 2020; Bendixen et al., in press; Purzycki & McNamara,
619 2016). The adoption of novel beliefs is also constrained and facilitated by the
620 extant cultural milieu (Buskell et al., 2019) and corresponding psychologically
621 salient social dilemmas. But the spread of beliefs is not enough to make changes
622 in behavior, of course. Instead, beliefs must trigger, ontogenetically habituate,
623 and naturalize the motivation to behave in locally contingent, self-restrained
624 ways that facilitate cooperation.

625 As illustrated, features of religious behaviors also adjust to particular condi-
626 tions. To the extent that these mechanisms contribute to survival and reproduc-
627 tion, we can—by the most critical standards available—construe such systems
628 as adaptive. While the long-term evolution of any social system often escapes
629 precise description, and different evolutionary processes could have been behind
630 the convergent phenomena social scientists study (see issues of equifinality dis-
631 cussed in Barrett, 2019; Kandler & Powell, 2018; Von Bertalanffy, 1969), we
632 expect that actively assessing such systems will only enrich the field.

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637 References

638 Alcorta, C. S., & Sosis, R. (2005). Ritual, emotion, and sacred symbols. *Human*
639 *Nature*, 16, 323–359.

- 640 Alvard, M. S. (1994). Conservation by native peoples: Prey choice in a depleted
641 habitat. *Human nature*, 5, 127.
- 642 Andersen, M. (2019). Predictive coding in agency detection. *Religion, Brain &*
643 *Behavior*, 9, 65–84.
- 644 Angsongna, A., Ato Armah, F., Boamah, S., Hambati, H., Luginaah, I., Chuen-
645 pagdee, R., & Campbell, G. (2016). A systematic review of resource habitat
646 taboos and human health outcomes in the context of global environmental
647 change. *Global Bioethics*, 27, 91–111.
- 648 Arakchaa, T. (2009). *Household and Property Relations in Tuva*. Boise State
649 University.
- 650 Atran, S., Medin, D., Ross, N., Lynch, E., Coley, J., Ek', E. U., & Vapnarsky,
651 V. (1999). Folkeology and commons management in the Maya Lowlands.
652 *Proceedings of the National Academy of Sciences*, 96, 7598–7603. doi:10.
653 1073/pnas.96.13.7598.
- 654 Atran, S., Medin, D., Ross, N., Lynch, E., Vapnarsky, V., Ek', E. U., Coley, J.,
655 Timura, C., & Baran, M. (2002). Folkeology, Cultural Epidemiology, and
656 the Spirit of the Commons: A Garden Experiment in the Maya Lowlands,
657 19912001. *Current Anthropology*, 43, 421–450. doi:10.1086/339528.
- 658 Axelrod, R. (1984). *The Evolution of Cooperation*. New York: Basic Books.
- 659 Barrett, B. J. (2019). Equifinality in empirical studies of cultural transmission.
660 *Behavioural processes*, 161, 129–138.
- 661 Bednar, J., & Page, S. (2007). Can game (s) theory explain culture? the emer-
662 gence of cultural behavior within multiple games. *Rationality and Society*,
663 19, 65–97.
- 664 Bendixen, T., Apicella, C., Atkinson, Q., Cohen, E., Henrich, J., McNamara,
665 R. A., Norenzayan, A., Willard, A. K., Xygalatas, D., & Purzycki, B. G.
666 (in press). Appealing to the minds of gods: Religious beliefs and appeals

- correspond to features of local social ecologies. *Religion, Brain & Behavior*,
. doi:10.31234/osf.io/tjn3e.
- Bendixen, T., & Purzycki, B. G. (2020). Peering into the minds of gods: What
cross-cultural variation in gods' concerns can tell us about the evolution of
religion. *Journal for the Cognitive Science of Religion*, 5, 142–165. doi:10.
1558/jcsr.40951.
- Bird, D. W., Bird, R. B., Coddling, B. F., & Taylor, N. (2016). A landscape
architecture of fire: Cultural emergence and ecological pyrodiversity in aus-
tralia's western desert. *Current Anthropology*, 57, S65–S79.
- Bird, R. B., & Power, E. A. (2015). Prosocial signaling and cooperation among
martu hunters. *Evolution and Human Behavior*, 36, 389–397.
- Bird, R. B., Taylor, N., Coddling, B. F., & Bird, D. W. (2013). Niche construction
and dreaming logic: aboriginal patch mosaic burning and varanid lizards
(varanus gouldii) in australia. *Proceedings of the Royal Society B: Biological
Sciences*, 280, 20132297.
- Bird-David, N. (1999). “Animism” revisited: personhood, environment, and
relational epistemology. *Current Anthropology*, 40, S67–S91.
- Blackwell, A. D. (2009). *Life history trade-offs in growth and immune func-
tion: The behavioral and immunological ecology of the Shuar of Amazonian
Ecuador, an indigenous population in the midst of rapid economic and eco-
logical change*. University of Oregon.
- Blum, U., & Dudley, L. (2001). Religion and economic growth: was Weber
right? *Journal of Evolutionary Economics*, 11, 207–230.
- Boyer, P. (2000). Functional origins of religious concepts: ontological and strate-
gic selection in evolved minds. *Journal of the Royal Anthropological Institute*,
6, 195–214. doi:10.1111/1467-9655.00012.

- 693 Brams, S. (2007). *Superior Beings. If They Exist, How Would We Know?:*
694 *Game-Theoretic Implications of Omnipotence, Omniscience, Immortality,*
695 *and Incomprehensibility.* Springer.
- 696 Brams, S. J. (2018). *Divine games: Game theory and the undecidability of a*
697 *superior being.* MIT Press.
- 698 Bulbulia, J. (2004a). The cognitive and evolutionary psychology of religion.
699 *Biology and Philosophy, 19*, 655–686.
- 700 Bulbulia, J. (2004b). Religious costs as adaptations that signal altruistic inten-
701 tion. *Evolution and Cognition, 10*, 19–38.
- 702 Bulbulia, J. (2011). The hypnotic stag hunt. *Journal of Cognition and Culture,*
703 *11*, 353–365.
- 704 Bulbulia, J. (2012). Spreading order: religion, cooperative niche construction,
705 and risky coordination problems. *Biology & Philosophy, 27*, 1–27.
- 706 Bulbulia, J., & Freat, M. (2010). The evolution of charismatic cultures. *Method*
707 *& Theory in the Study of Religion, 22*, 254–271.
- 708 Buskell, A., Enquist, M., & Jansson, F. (2019). A systems approach to cultural
709 evolution. *Palgrave Communications, 5*, 1–15.
- 710 Donahoe, B. (2006). Who owns the Taiga?: inclusive vs. exclusive senses of
711 property among the Tozhu and Tofa of southern Siberia. *Sibirica, 5*, 87–116.
- 712 Dyson-Hudson, R., & Smith, E. A. (1978). Human territoriality: an ecological
713 reassessment. *American Anthropologist, 80*, 21–41.
- 714 Eder, J. F. (1997). *Batak resource management: belief, knowledge, and practice.*
715 IUCN.
- 716 Eder, J. F. (1999). Batak. In R. B. Lee, & R. Daly (Eds.), *The Cambridge*
717 *Encyclopedia of Hunters and Gatherers.* Cambridge University Press.

- 718 Fitouchi, L., & Singh, M. (2022). Supernatural punishment beliefs as cognitively
719 compelling tools of social control. *Current Opinion in Psychology*, 44, 252–
720 257. doi:<https://doi.org/10.1016/j.copsyc.2021.09.022>.
- 721 Geertz, C. (1973). *The interpretation of cultures*. Basic books.
- 722 le Guen, O., Iliev, R., Lois, X., Atran, S., & Medin, D. L. (2013). A garden
723 experiment revisited: Inter-generational change in environmental perception
724 and management of the Maya Lowlands, Guatemala: A garden experiment
725 revisited. *Journal of the Royal Anthropological Institute*, 19, 771–794. doi:10.
726 1111/1467-9655.12064.
- 727 Guthrie, S. E. (1980). A cognitive theory of religion. *Current Anthropology*, 21,
728 181–203. doi:10.1086/202429.
- 729 Guthrie, S. E. (1995). *Faces in the clouds: A new theory of religion*. New York:
730 Oxford University Press.
- 731 Hacking, I. (1972). The logic of Pascal’s wager. *American Philosophical Quar-*
732 *terly*, 9, 186–192.
- 733 Hames, R. (1991). Wildlife conservation in tribal societies. *Biodiversity: Cul-*
734 *ture, conservation, and ecodevelopment*, (pp. 172–199).
- 735 Hames, R. (2007). The ecologically noble savage debate. *Annu. Rev. Anthropol.*,
736 36, 177–190.
- 737 Hardin, G. (1968). The tragedy of the commons: the population problem has no
738 technical solution; it requires a fundamental extension in morality. *Science*,
739 162, 1243–1248.
- 740 Hare, D., Reeve, H. K., & Blossey, B. (2016). Evolutionary routes to stable
741 ownership. *Journal of Evolutionary Biology*, 29, 1178–1188.
- 742 Hartberg, Y., Cox, M., & Villamayor-Tomas, S. (2016). Supernatural moni-
743 toring and sanctioning in community-based resource management. *Religion,*
744 *Brain & Behavior*, 6, 95–111.

- 745 Heap, S., Byrne, P., & Stuart-Fox, D. (2012). The adoption of landmarks for
746 territorial boundaries. *Animal Behaviour*, 83, 871–878.
- 747 Henrich, J., Bauer, M., Cassar, A., Chytilová, J., & Purzycki, B. G. (2019).
748 War increases religiosity. *Nature Human Behaviour*, 3, 129–135.
- 749 Jensen, J. S. (2019). *What is religion?*. (2nd ed.). Routledge.
- 750 Johnson, D., & Bering, J. (2006). Hand of God, Mind of Man: Pun-
751 ishment and Cognition in the Evolution of Cooperation. *Evolution-*
752 *ary Psychology*, 4, 147470490600400119. URL: [https://doi.org/10.1177/](https://doi.org/10.1177/147470490600400119)
753 [147470490600400119](https://doi.org/10.1177/147470490600400119). doi:10.1177/147470490600400119.
- 754 Johnson, D., & Krüger, O. (2004). The good of wrath: Supernatural punishment
755 and the evolution of cooperation. *Political Theology*, 5, 159–176.
- 756 Johnson, D. D. P. (2005). God’s punishment and public goods. *Human Nature*,
757 16, 410–446.
- 758 Johnson, D. D. P. (2016). *God is watching you: How the fear of god makes us*
759 *human*. Oxford University Press, USA.
- 760 Jong, J., & Halberstadt, J. (2016). *Death Anxiety and Religious Belief: An*
761 *Existential Psychology of Religion*. London: Bloomsbury.
- 762 Jong, J., Halberstadt, J., & Bluemke, M. (2012). Foxhole atheism, revisited:
763 The effects of mortality salience on explicit and implicit religious belief. *Jour-*
764 *nal of Experimental Social Psychology*, 48, 983–989.
- 765 Jordan, P. (2003). *Material Culture and Sacred Landscape: The Anthropology*
766 *of the Siberian Khanty*. Walnut Creek, CA: AltaMira Pres.
- 767 Kandler, A., & Powell, A. (2018). Generative inference for cultural evolution.
768 *Philosophical Transactions of the Royal Society B: Biological Sciences*, 373,
769 20170056.

- 770 Kendal, J., Tehrani, J. J., & Odling-Smee, J. (2011). Human niche construction
771 in interdisciplinary focus. *Philosophical Transactions of the Royal Society B:
772 Biological Sciences*, 366, 785–792.
- 773 Laland, K., Matthews, B., & Feldman, M. W. (2016). An introduction to niche
774 construction theory. *Evolutionary ecology*, 30, 191–202.
- 775 Lang, M., Purzycki, B. G., Apicella, C. L., Atkinson, Q. D., Bolyanatz, A.,
776 Cohen, E., Handley, C., Kundtová Klocová, E., Lesorogol, C., Mathew, S.
777 et al. (2019). Moralizing gods, impartiality and religious parochialism across
778 15 societies. *Proceedings of the Royal Society B*, 286, 20190202.
- 779 Lansing, J. S. (2006). *Perfect Order: Recognizing Complexity in Bali*. Princeton:
780 Princeton University Press.
- 781 Lansing, J. S. (2007). *Priests and Programmers: Technologies of Power in the
782 Engineered Landscape of Bali*. Princeton University Press.
- 783 Lansing, J. S., & Kremer, J. N. (1993). Emergent Properties of Balinese Water
784 Temple Networks: Coadaptation on a Rugged Fitness Landscape. *American
785 Anthropologist*, 95, 97–114. URL: <http://www.jstor.org/stable/681181>.
- 786 Lansing, J. S., & Miller, J. (2005). Cooperation, games, and ecological feedback:
787 some insights from bali. *Current Anthropology*, 46, 328–334.
- 788 Lansing, J. S., Thurner, S., Chung, N. N., Coudurier-Curveur, A., Karakaş, ,
789 Fesenmyer, K. A., & Chew, L. Y. (2017). Adaptive self-organization of Bali’s
790 ancient rice terraces. *Proceedings of the National Academy of Sciences*, 114,
791 6504–6509. doi:10.1073/pnas.1605369114.
- 792 Le Guen, O., Iliev, R., Lois, X., Atran, S., & Medin, D. L. (2013). A garden
793 experiment revisited: inter-generational change in environmental perception
794 and management of the maya lowlands, guatemala. *Journal of the Royal
795 Anthropological Institute*, 19, 771–794.

- 796 Lightner, A. D., Heckelsmiller, C., & Hagen, E. H. (2021). Ethnomedical spe-
797 cialists and their supernatural theories of disease. *Review of Philosophy and*
798 *Psychology*, (pp. 1–36).
- 799 Lightner, A. D., & Purzycki, B. G. (n.d.). Game theoretical aspects of the minds
800 of gods. In B. G. Purzycki, & T. Bendixen (Eds.), *The Minds of Gods: New*
801 *Horizons in the Naturalistic Study of Religion*. Bloomsbury Publishing.
- 802 Maynard Smith, J. (1982). *Evolution and the Theory of Games*. Cambridge
803 university press.
- 804 McNamara, R. A., & Purzycki, B. G. (2020). Minds of gods and human cog-
805 nitive constraints: socio-ecological context shapes belief. *Religion, Brain &*
806 *Behavior*, 10, 223–238. doi:10.1080/2153599X.2019.1678510.
- 807 Medicine, B. (2006). *Drinking and sobriety among the Lakota Sioux*. Altamira
808 Press.
- 809 Mesterton-Gibbons, M., & Adams, E. S. (2003). Landmarks in territory par-
810 titioning: A strategically stable convention? *The American Naturalist*, 161,
811 685–697.
- 812 Morgan, J. R. (2019). *Religious engagement and varieties of self-regulation:*
813 *broadening beyond belief and restraint*. Ph.D. thesis Boston University.
- 814 Nesse, R. (1999). Evolution of commitment and the origins of religion. *Science*
815 *and Spirit*, 10, 32–33.
- 816 Norenzayan, A. (2013). *Big gods: How religion transformed cooperation and*
817 *conflict*. Princeton University Press.
- 818 North, D. C. (1990). *Institutions, Institutional Change and Economic Perfor-*
819 *mance*. Cambridge: Cambridge University Press. Google-Books-ID: oFn-
820 WbTqgNPYC.

- 821 North, D. C. (1991). Institutions. *Journal of Economic Perspectives*, 5, 97–
822 112. URL: <https://www.aeaweb.org/articles?id=10.1257/jep.5.1.97>.
823 doi:10.1257/jep.5.1.97.
- 824 Orbell, J., Goldman, M., Mulford, M., & Dawes, R. (1992). Religion, context,
825 and constraint toward strangers. *Rationality and Society*, 4, 291–307.
- 826 Ostrom, E. (2015). *Governing the commons: The evolution of institutions for*
827 *collective action*. Cambridge university press.
- 828 Pasquino, P. (2001). Hobbes, religion, and rational choice: Hobbes’s two
829 leviathans and the fool. *Pacific philosophical quarterly*, 82, 406–419.
- 830 Power, E. A. (2017). Discerning devotion: Testing the signaling theory of reli-
831 gion. *Evolution and Human Behavior*, 38, 82–91.
- 832 Purzycki, B. G. (2011). Tyvan *cher eezi* and the socioecological constraints of
833 supernatural agents’ minds. *Religion, Brain & Behavior*, 1, 31–45.
- 834 Purzycki, B. G. (2013a). The minds of gods: A comparative study of supernat-
835 ural agency. *Cognition*, 129, 163 – 179. doi:[http://dx.doi.org/10.1016/](http://dx.doi.org/10.1016/j.cognition.2013.06.010)
836 [j.cognition.2013.06.010](http://dx.doi.org/10.1016/j.cognition.2013.06.010).
- 837 Purzycki, B. G. (2013b). Toward a cognitive ecology of religious concepts: An
838 example from the tyva republic. *Journal for the Cognitive Science of Religion*,
839 1, 99–120.
- 840 Purzycki, B. G. (2016). The evolution of gods’ minds in the Tyva Republic.
841 *Current Anthropology*, 57, S88–S104. doi:10.1086/685729.
- 842 Purzycki, B. G., & Arakchaa, T. (2013). Ritual Behavior and Trust in the Tyva
843 Republic. *Current Anthropology*, 54, 381–388. doi:10.1086/670526.
- 844 Purzycki, B. G., & Holland, E. C. (2019). Buddha as a God: An Empirical
845 Assessment. *Method & Theory in the Study of Religion*, 31, 347–375. doi:10.
846 1163/15700682-12341453.

- 847 Purzycki, B. G., & Kulundary, V. (2018). Buddhism, identity, and class: fairness
848 and favoritism in the tyva republic. *Religion, Brain & Behavior*, 8, 205–226.
- 849 Purzycki, B. G., & McNamara, R. A. (2016). An ecological theory of gods'
850 minds. In H. De Cruz, & R. Nichols (Eds.), *Cognitive Science of Religion and*
851 *Its Philosophical Implications* (pp. 143–167). New York: Continuum.
- 852 Purzycki, B. G., & Sosis, R. (2013). The extended religious phenotype and the
853 adaptive coupling of ritual and belief. *Israel Journal of Ecology & Evolution*,
854 59, 99–108.
- 855 Purzycki, B. G., & Sosis, R. (2022). *Religion Evolving: The Dynamics of Cul-*
856 *ture, Cognition and Ecology*. Equinox.
- 857 Purzycki, B. G., Stagnaro, M. N., & Sasaki, J. (2020). Breaches of Trust Change
858 the Content and Structure of Religious Appeals. *Journal for the Study of*
859 *Religion, Nature and Culture*, 14, 71–94. doi:10.1558/jsrnc.38786.
- 860 Purzycki, B. G., & Willard, A. K. (2016). Mci theory: a critical discussion. *Reli-*
861 *gion, Brain & Behavior*, 6, 207–248. doi:10.1080/2153599X.2015.1024915.
- 862 Purzycki, B. G., Willard, A. K., Klocová, E. K., Apicella, C., Atkinson, Q.,
863 Bolyanatz, A., Cohen, E., Handley, C., Henrich, J., Lang, M., Lesorogol, C.,
864 Mathew, S., McNamara, R. A., Moya, C., Norenzayan, A., Placek, C., Soler,
865 M., Weigel, J., Xygalatas, D., & Ross, C. T. (2022). The Moralization Bias
866 of Gods' Minds: A Cross-Cultural Test. *Religion, Brain and Behavior*, 12,
867 38–60.
- 868 Rappaport, R. A. (1999). *Ritual and Religion in the Making of Humanity* vol-
869 ume 110. Cambridge University Press.
- 870 Romagny, B., Lobry, C., Canalis-Durand, M. et al. (1997). *Tragedy of the Com-*
871 *mons and Prisonner's Dilemma*. Technical Report Universite Aix-Marseille
872 III.

- 873 Rossano, M., & LeBlanc, A. (2017). Why add the supernatural? *Religion,*
874 *Brain & Behavior*, 7, 375–377.
- 875 Rossano, M. J. (2007). Supernaturalizing Social Life: Religion and the Evo-
876 lution of Human Cooperation. *Human Nature*, 18, 272–294. doi:10.1007/
877 s12110-007-9002-4.
- 878 Rousseau, J.-J. (2016 [1755]). *A Discourse on Inequality*. Open Road.
- 879 Ruffle, B. J., & Sosis, R. (2020). Do religious contexts elicit more trust and al-
880 truism? decision-making scenario experiments. *Journal of Economics, Man-*
881 *agement and Religion*, 1, 2050002.
- 882 Sasaki, J. Y., & Kim, H. S. (2021). The ego dampening influence of religion:
883 evidence from behavioral genetics and psychology. *Current Opinion in Psy-*
884 *chology*, 40, 24–28.
- 885 Schelling, T. C. (1968). Game theory and the study of ethical systems. *Journal*
886 *of Conflict Resolution*, 12, 34–44.
- 887 Shariff, A. F., & Norenzayan, A. (2007). God is watching you: Priming god
888 concepts increases prosocial behavior in an anonymous economic game. *Psy-*
889 *chological science*, 18, 803–809.
- 890 Shermer, M. (2008). The doping dilemma. *Scientific American*, 298, 82–89.
- 891 Shih, F.-L. (2012). Generating power in taiwan: Nuclear, political and religious
892 power. *Culture and Religion*, 13, 295–313.
- 893 Sibley, C. G., & Bulbulia, J. (2012). Faith after an earthquake: A longitudinal
894 study of religion and perceived health before and after the 2011 christchurch
895 new zealand earthquake. *PloS one*, 7, e49648.
- 896 Skyrms, B. (2004). *The stag hunt and the evolution of social structure*. Cam-
897 bridge University Press.

- 898 Smith, E. A., & Wishnie, M. (2000). Conservation and Subsistence in Small-
899 Scale Societies. *Annual Review of Anthropology*, 29, 493–524. doi:10.1146/
900 annurev.anthro.29.1.493.
- 901 Soler, M. (2012). Costly signaling, ritual and cooperation: evidence from can-
902 domblé, an afro-brazilian religion. *Evolution and Human Behavior*, 33, 346–
903 356.
- 904 Sosis, R. (2003). Why aren't we all hutterites? *Human Nature*, 14, 91–
905 127. URL: <https://doi.org/10.1007/s12110-003-1000-6>. doi:10.1007/
906 s12110-003-1000-6.
- 907 Sosis, R. (2007). Psalms for safety: Magico-religious responses to threats of
908 terror. *Current Anthropology*, 48, 903–911.
- 909 Sosis, R. (2009). The adaptationist-byproduct debate on the evolution of reli-
910 gion: Five misunderstandings of the adaptationist program. *Journal of Cog-
911 nition and Culture*, 9, 315–332.
- 912 Sosis, R. (2019). The building blocks of religious systems: Approaching religion
913 as a complex adaptive system. In *Evolution, Development and Complexity*
914 (pp. 421–449). Springer.
- 915 Sosis, R. (2020). Four advantages of a systemic approach to the study of religion.
916 *Archive for the Psychology of Religion*, 42, 142–157.
- 917 Sosis, R., & Bressler, E. R. (2003). Cooperation and commune longevity: A test
918 of the costly signaling theory of religion. *Cross-cultural research*, 37, 211–239.
- 919 Sosis, R., & Handwerker, W. P. (2011). Psalms and coping with uncertainty:
920 Religious israeli women's responses to the 2006 lebanon war. *American An-
921 thropologist*, 113, 40–55.
- 922 Sosis, R., & Ruffle, B. J. (2003). Religious ritual and cooperation: Testing for a
923 relationship on Israeli religious and secular kibbutzim. *Current Anthropology*,
924 44, 713–722. doi:10.1086/379260.

- 925 Spiro, M. E., Killborne, B., & Langness, L. L. L. (1987). *Culture and human*
926 *nature*. Transaction Publishers.
- 927 Taylor, B., Van Wieren, G., & Zaleha, B. (2016). The greening of religion
928 hypothesis (part two): Assessing the data from lynn white, jr, to pope francis.
929 *Journal for the Study of Religion, Nature and Culture*, 10, 306–378.
- 930 Tian, A. D., Schroeder, J., Häubl, G., Risen, J. L., Norton, M. I., & Gino, F.
931 (2018). Enacting rituals to improve self-control. *Journal of Personality and*
932 *Social Psychology*, 114, 851.
- 933 Tonkinson, R. (1991). *The Mardu Aborigines: Living the Dream in Australia's*
934 *Desert*. Fort Worth: Holt, Rinehard, and Winston.
- 935 Turpin, H., & Lanman, J. A. (2022). The failure of religious systems. *The*
936 *Oxford Handbook of the Cognitive Science of Religion*, (pp. 303–326).
- 937 Tuzin, D. (1997). *The cassowary's revenge: the life and death of masculinity in*
938 *a New Guinea society*. University of Chicago Press.
- 939 Tylor, E. B. (1920). *Primitive culture: Researches into the development of*
940 *mythology, philosophy, religion, language, art, and custom*. London: Murray.
- 941 Vardy, T., & Atkinson, Q. D. (2019). Property damage and exposure to other
942 people in distress differentially predict prosocial behavior after a natural dis-
943 aster. *Psychological Science*, 30, 563–575.
- 944 Von Bertalanffy, L. (1969). *General System Theory: Foundations, Development,*
945 *Applications*. George Braziller Inc.
- 946 Von Neumann, J., & Morgenstern, O. (2007 [1944]). *Theory of games and*
947 *economic behavior*. Princeton: Princeton University Press.
- 948 Wallace, A. (1966). *Religion: An anthropological view*. Random House.
- 949 Watanabe, H. (1972). The Ainu.

- 950 Weingast, B. R. (1995). A rational choice perspective on the role of ideas: Shared
 951 belief systems and state sovereignty in international cooperation. *Politics &*
 952 *Society*, 23, 449–464.
- 953 White, L. (1967). The Historical Roots of Our Ecologic Crisis. *Science*, 155,
 954 1203–1207. doi:10.1126/science.155.3767.1203.
- 955 Willerslev, R. (2007). *Soul hunters: Hunting, animism, and personhood among*
 956 *the Siberian Yukaghirs*. Berkeley: University of California Press.
- 957 Winkelman, M. (2014). Political and demographic-ecological determinants of
 958 institutionalised human sacrifice. *Anthropological Forum*, 24, 47–70. doi:10.
 959 1080/00664677.2014.860888.
- 960 Xygalatas, D., Mitkidis, P., Fischer, R., Reddish, P., Skewes, J., Geertz, A. W.,
 961 Roepstorff, A., & Bulbulia, J. (2013). Extreme rituals promote prosociality.
 962 *Psychological Science*, 24, 1602–1605.