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Review

Human-induced trait shifts reshape predator–prey interactions

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For millions of years, predators and their prey have been locked in an evolutionary arms race: adaptive changes in one favor compensatory adaptations in the other. Humans have also been powerful agents of selection, reshaping the distribution of traits in animal populations. These human-induced trait shifts can disrupt predator–prey interactions, with cascading effects on ecological communities and ecosystems. We synthesize emerging evidence demonstrating that anthropogenic pressures alter physical, behavioral, and social traits relevant to predator–prey dynamics. We provide a framework for predicting the outcomes of trait shifts and a roadmap for advancing this emerging field of research. Incorporating human-induced trait changes into interaction models is essential for forecasting and conserving ecological function in a rapidly changing world.

Highlights

In the Anthropocene, human disturbance is rapidly reshaping the traits that govern species interactions, with important implications for ecosystems worldwide.

Human-induced changes in the physical, behavioral, and social traits of predators or prey can affect the outcomes of existing interactions by conferring an advantage to one actor over the other and can also lead to novel interactions between species that did not previously interact.

Altered predator–prey interactions scale up to modify population and community dynamics, generate cascading ecological effects, and shape ecoevolutionary feedback loops between predators and prey.

As human disturbance transforms ecosystems around the world, trait-induced changes to predator–prey interactions represent an important and understudied aspect of novelty in the Anthropocene.

Predator–prey interactions and human-induced trait shifts

Predator–prey interactions are fundamental drivers of ecosystem structure and function [1,2]. Predators shape prey abundance and distribution by killing prey while modifying prey behavior through fear-driven, nonlethal effects [3,4]. Cumulatively, these effects cascade through ecosystems to influence vegetation communities, food web dynamics, and nutrient cycling [3,5]. Interactions between predators and prey are mediated by the traits of both species, including physical traits (e.g., morphology) [6,7], traits that govern behavior (e.g., personality and cognition) [8,9], and social traits (e.g., social learning and group dynamics) [10,11]. These traits not only determine which predators encounter which prey but also affect the timing, frequency, setting, and outcome of their encounters [12,13]. These traits have themselves been shaped by predator–prey interactions over evolutionary time scales, with selection honing predators into ever-more efficient hunters that, in turn, select for ever-more elusive prey [14]. Species traits are thus intrinsically linked to species interactions via ecoevolutionary feedbacks, which, in many cases, stabilize predator–prey interactions [15]. However, rapid shifts in species traits may instead have destabilizing consequences, and such shifts are increasingly common as humanity's role as an agent of selection and disturbance grows.

Human disturbance is reshaping animal phenotypes worldwide, shifting trait means and distributions via natural selection and phenotypic plasticity [16–19,48]. A range of anthropogenic mechanisms can alter traits that mediate predator–prey interactions (see [20] for an in-depth review of human-induced intraspecific trait shifts; Box 1), with important ecological and evolutionary consequences [49,50]. One potent mechanism is the harvest of wild animals (i.e., hunting and fishing); when acting as predators, humans exert strong, directional selection, particularly on morphological traits [21]. Other anthropogenic pressures—including habitat alteration, climate change, species introductions, and pollution—also drive trait shifts [17,23,50]. Trait distributions shift across

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generations through natural selection, as allele frequencies change with differential fitness, or through **phenotypic plasticity**, as individuals sharing a genotype express alternative phenotypes in response to novel conditions. Activational plasticity can lead to variable phenotypic trait expression over an individual's lifetime, while developmental plasticity can produce enduring phenotypic change when conditions during development alter trait expression [51]. Understanding how these shifting trait distributions alter ecological interactions is therefore essential to conserving biodiversity in the Anthropocene. (See Fig. 1.)

Here, we synthesize an emerging body of literature on how **human-induced trait shifts** alter predator–prey interactions. Previous work has established the **novelty** of predator–prey interactions in the Anthropocene [52–56]. We build on this work by demonstrating how shifts in individual traits can alter the outcomes of predator–prey interactions. Finally, we provide a framework and roadmap for predicting and studying the consequences of trait shifting in predator–prey interactions.

Linking trait shifts to predator–prey interactions

Changes in physical traits reshape interactions

Animal body size has a strong influence on predator–prey interactions, for instance, via physical mechanisms such as predator size relative to prey size [57,58]. Human-induced changes in either predator or prey body size can, hence, result in the loss of trophic interactions or the emergence of new ones. For example, by preferentially harvesting larger adults, humans may drive reductions in prey body size [27], potentially making these smaller-bodied individuals vulnerable to predators that were previously unable to hunt them [59]. In South Eastern Australian fish, just a 4% reduction in length over 50 years is predicted to drive a 50% increase in mortality by predation [60]. Size-selective fisheries often reduce the body size and age structure of predators, which may limit their prey size and result in higher temporal variability in food web structure [47]. Habitat loss and fragmentation can similarly disrupt predator–prey body size-mediated relationships, altering the nature of their interactions and driving shifts in food web structure [61]. Climate change is driving changes in body sizes across a range of taxa [17], which are likely to alter entire food webs in complex and unpredictable ways [62]. For instance, where climate change results in body size reductions in prey [17], predators may switch prey or increase rates of predation on previously nontarget species [63].

In addition to body size, other morphological traits determine which prey predators can capture and consume (e.g., gape size and beak length) and which prey can evade predation (e.g., wing morphology and limb length). Many morphological traits are also shifting in response to human disturbance. For example, when introduced island apple snails (*Pomacea maculata*) spread across Florida, USA, snail kites (*Rostrhamus sociabilis*) began hunting them during the decline of their native prey. This switch in prey selected for larger body and beak sizes in kites, driving an enduring dietary preference and decoupling interactions between snail kites and their historic prey [49] (Figure 2). In a different disturbance context, the introduction of toxic cane toads (*Rhinella marina*) in Australia drove a decrease in relative gape size and an increase in body length of red-bellied black snakes (*Pseudechis porphyriacus*) and common tree snakes (*Dendrelaphis punctulatus*) [50]. This selection occurred as individuals with gapes sufficiently large to consume toads died, while smaller-gaped snakes, unable to consume toads, were unaffected. This shift reduced the likelihood of fatal ingestion of toxic toads in these snakes and allowed them to persist in the presence of toads. An additional consequence is that a reduction in gape size may have left these snakes unable to consume prey at the larger end of their historic prey range, potentially altering predatory pressure on populations of large native frogs.

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Box 1. Human-induced animal trait shifts

Drivers of human-induced trait shifts: Humans exert selective pressures on wild animals [21], which can scale up to alter population-level variation in phenotypes (Figure I) [20,26]. Lethal human disturbances select strongly for adaptive phenotypes, driving rapid shifts in population-level trait distributions [27]. Other anthropogenic changes to the environment (e.g., habitat alteration, climate change, pollution, and species introduction) may also select for newly adaptive phenotypes through natural selection or induce phenotypic plasticity that allows animals to express adaptive traits [26]. Notably, novel disturbance may also induce the development of maladaptive traits, in the form of ecological traps. Habitat alterations such as urbanization and habitat clearing directly alter the environment, creating novel environments that individuals must navigate. Climate change alters the environment by altering factors such as ambient temperatures, abiotic qualities of water (e.g., pH), and the phenology of ecological processes (e.g., masting). Similarly, the widespread contamination of environments with pollution (e.g., chemical, noise, heat, and light) can drive trait shifts via both lethal and sublethal effects [19]. Species introductions reshape environments, as novel species ecological functions can sometimes be distinct from those of extant native species [28,29], and create novel ecological interactions [30,31]. Species introductions can thus drive trait shifts by selecting for newly adaptive phenotypes.

Physical traits: Human disturbance is driving widespread changes in animal body size. Fisheries have driven reduced body size in Pacific salmon (*Oncorhynchus* spp.), hampering reproductive capacities [32]. Species introductions may drive changes in animal body size as a result of new competitive or predatory selective pressures [28]. Other examples of trait shifts include the acceleration of metabolic rate by climate warming [25,33] and animals in urban areas having distinct body conditions [34] and color phenotypes [35].

Behavioral traits: Humans affect behavioral phenotypes that may reduce the risk of mortality via harvest [36] or mediate the exploitation or avoidance of anthropogenic environments [26,37,38]. Hyenas (*Crocuta crocuta*) are less innovative in urban environments, and animals are generally bolder in urban areas [23,39], although this pattern is not universal [18]. Climate change can alter cognitive development [40] and an individual's ability to process information [41]. Furthermore, exposure to environmentally realistic levels of the widespread anxiolytic drug pollutant oxazepam increases activity and boldness in European perch (*Perca fluviatilis*), while decreasing sociality [42].

Social traits: Human disturbance can also alter group structure and demography, changing the size and composition of animal social groups [43,44]. Novel animal cultures may emerge as animals exploit human resources and socially transmit these learned innovations [37] or, by contrast, existing animal cultural knowledge may erode through habitat alteration [45] or direct harvest [46,47].

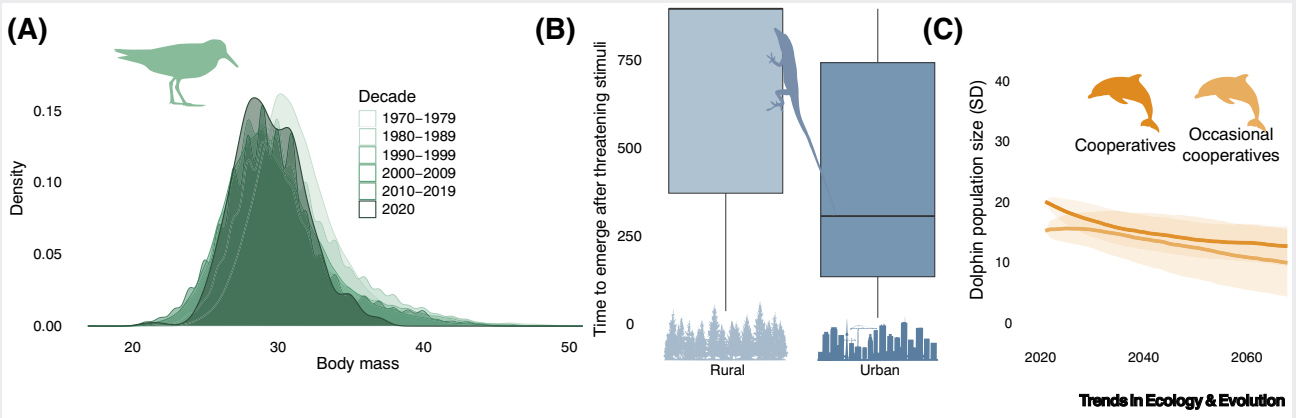

Figure I. Examples of human-induced trait shifts in the wild. (A) Body size: red-necked stints (*Calidris ruficollis*) have become smaller each decade since 1970. Their shrinking size has been linked to exposure to warmer temperatures [22]. (B) Personality: urban brown anoles (*Anolis sagrei*) are significantly bolder than their rural counterparts; they emerge more rapidly after exposure to threatening stimuli in urban compared to rural environments [23]. (C) Culture: in southern Brazil, some coastal populations of Lahille's bottlenose dolphins (*Tursiops truncatus gephyreus*) cooperate with artisanal human fishers to catch migratory mullet schools (*Mugil liza*), increasing the foraging success of both dolphins and fishers [10]. However, this practice is vulnerable to a combination of human-induced pressures—including changes in livelihoods, dolphin bycatch, and overfishing from industrial fisheries [24]—which could lead to the decline of this hunting mutualism [25] and, thereby, free prey from this joint top-down pressure [10].

In addition to altering morphological traits relevant to predator–prey interactions, human disturbance may also drive shifts in physiological traits. Increases in temperature driven by climate change tend to accelerate the rates of many biochemical reactions that constitute cellular metabolism [6]. The resulting rise in metabolic demand can drive organisms to consume more nutrients to fuel these processes [65]. In predators, increased metabolic rates can result in prey switching as individuals pivot to hunt smaller, more abundant species, ignoring larger, less abundant species, thereby narrowing predatory trophic niches as observed in Baltic fishes [33] (Figure 2). For prey, increased metabolic costs in a warmer world [66–68] likely make foraging and predator

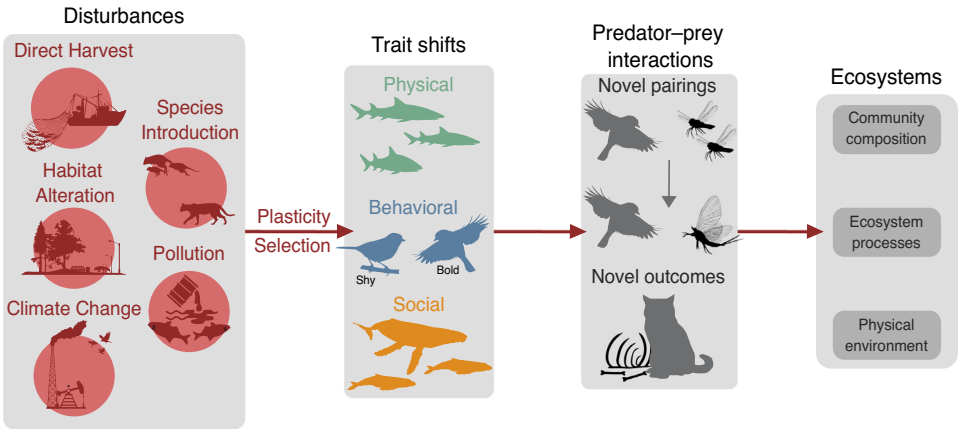

Figure 1. The diverse pathways through which human disturbance can influence the traits of predators and prey and cascade to shape ecosystems. Human disturbance induces changes in the physical, behavioral, and social traits of animals that can lead to novel predator–prey pairings and drive novel outcomes in historical predator–prey interactions. Shifts in the outcomes of predator–prey interactions and novel interactions are likely to alter the influence of predator–prey interactions on ecosystems.

Glossary

Animal personality: among-individual differences in animal behavior, which are consistent across time and contexts.
Cognition: the processes through which animals acquire, interpret, store, and act on information from the environment.
Human-induced trait shifts: human-driven changes in the mean (the position of a trait along a continuum), variance (spread of values around the mean), skew (the symmetry on either side of the mean), or kurtosis (prevalence of extreme values relative to a normal distribution) of a population's trait distribution.
Novelty: degree of dissimilarity between present or future conditions and historic conditions (usually relative to the Holocene or preindustrial baseline); can also refer to an individual's first encounter with an unfamiliar stimulus (e.g., cue, predator, and prey).
Phenotypic plasticity: the capacity of a given genotype to produce distinct phenotypes in response to environmental conditions or changes.

avoidance more costly [69]. Increased temperatures due to climate change are predicted to alter the biomechanics of animals by altering muscle [70] and neural function [41], limiting reactivity, as well as muscle and locomotive performance, for prey escape and predator hunting ability [70–72].

Changes in behavioral traits reshape predator–prey interactions

Human-induced changes to animal behavior have the potential to reshape predator–prey interactions through myriad pathways [52,53]. In this section, we focus on traits that shape multiple aspects of behavior—specifically, cognition and personality—rather than all behavioral phenotypes (e.g., movement, foraging, and vigilance). **Animal personality** [73] can mediate predator—prey interactions; for example, bolder or more active predators can hunt more efficiently [74,75], whereas shyer prey may better avoid predation [9]. Anthropogenic habitat alteration (particularly urbanization) biases populations toward bolder individuals, a widely reported pattern in vertebrates [23,39]. For example, brown anoles (*Anolis sagrei*) in urban South Florida, USA, are bolder than their forest-dwelling conspecifics, a behavioral shift that may increase their vulnerability to predators [23] (Figure 2). Different types of fishing activities (passive traps and active netting) can select for bold or shy behavior in fish, which can drive changes in hunting and avoidance behaviors [76,77]. Furthermore, environmentally relevant levels of the antidepressant drug pollutant fluoxetine drive increased activity and risk-taking behavior (boldness) in mosquitofish (*Gambusia holbrooki*) when in the presence of predators [42]. Such effects of pharmaceutical pollution on animal behavior are predicted to increase predation susceptibility in exposed fish populations in the wild, a prediction that was recently validated in migrating brown trout (*Salmo trutta*) tracked in a natural lake system [78]. Where humans alter the distribution of predator and/or prey behavioral phenotypes, such as biasing populations towards boldness, predators and prey may interact more frequently as predators are willing to take more risks to secure prey and prey are less likely to be cautious in the face of predation. It is worth noting that studies exploring how prey personality affects anti-predator behavior return conflicting results [9], but any human-induced shifts in predators or prey across the bold–shy continuum are likely to alter outcomes in predator–prey interactions.

Another key behavioral trait central to predator–prey interactions and vulnerable to human change is **cognition**, including perception, learning, and memory [8,79–82]. Enhanced cognition

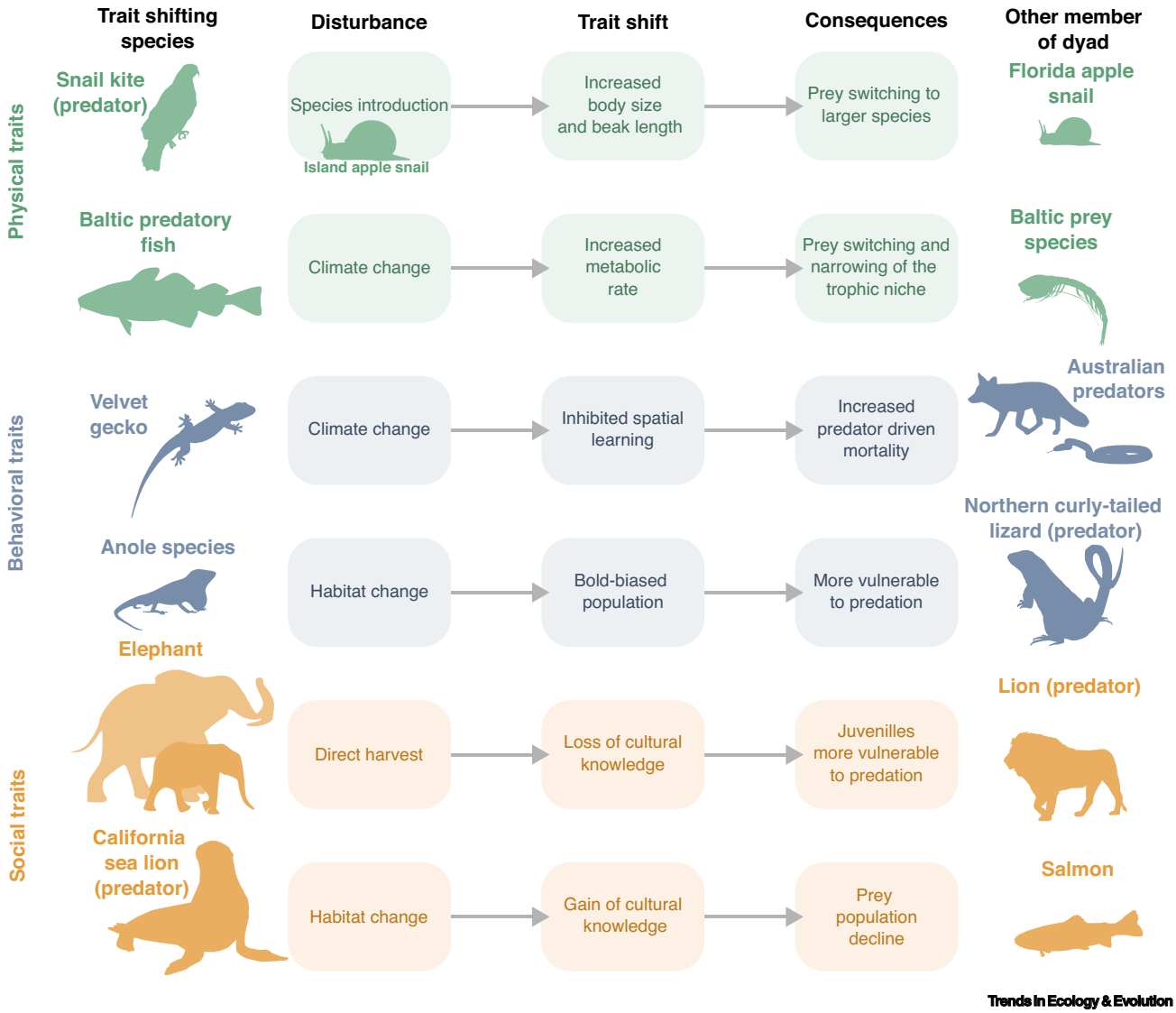

Figure 2. Human disturbance-induced trait shifts alter predator–prey interactions with consequences for individuals and populations. Human disturbances can induce trait shifts, which cascade to have individual- and population-level consequences for the species that has shifted or the other member of the predator–prey dyad. References and scientific species names—row 1 [49]: snail kites (*Rostrhamus sociabilis*), island apple snails (*Pomacea maculata*), and Florida apple snail (*Pomacea paludosa*); row 2 [33]: various predator fish and prey species in the Baltic sea; row 3 [40]: velvet gecko (*Amalosia lesueurii*),; row 4 [23]: various *Anolis* spp., northern curly tailed lizard (*Leiocephalus carinatus*); row 5 [64]: African elephants *(Loxodonta Africana*) and lion (*Pantera leo*); row 6 [11]: California sea lion (*Zalophus californianus*) and salmon (*Oncorhynchus spp*).

is widely predicted to allow prey species to better avoid predation and improve predator hunting success [8,83]. Thus, where humans alter the cognitive traits of animals, we may expect to see shifts in predator–prey interactions mediated via shifting learning and memory abilities. Increasing temperatures from climate change are predicted to inhibit cognitive performance [41]. Indeed, high temperatures inhibit associative learning performance in both male and female southern pied babblers (*Turdoides bicolor*) and inhibitory control in males [84], potentially limiting their ability to associate predators with their cues [8]. Further, high temperatures during incubation reduced spatial learning abilities in Lesueur's velvet geckos (*Amalosia lesueurii*), which was

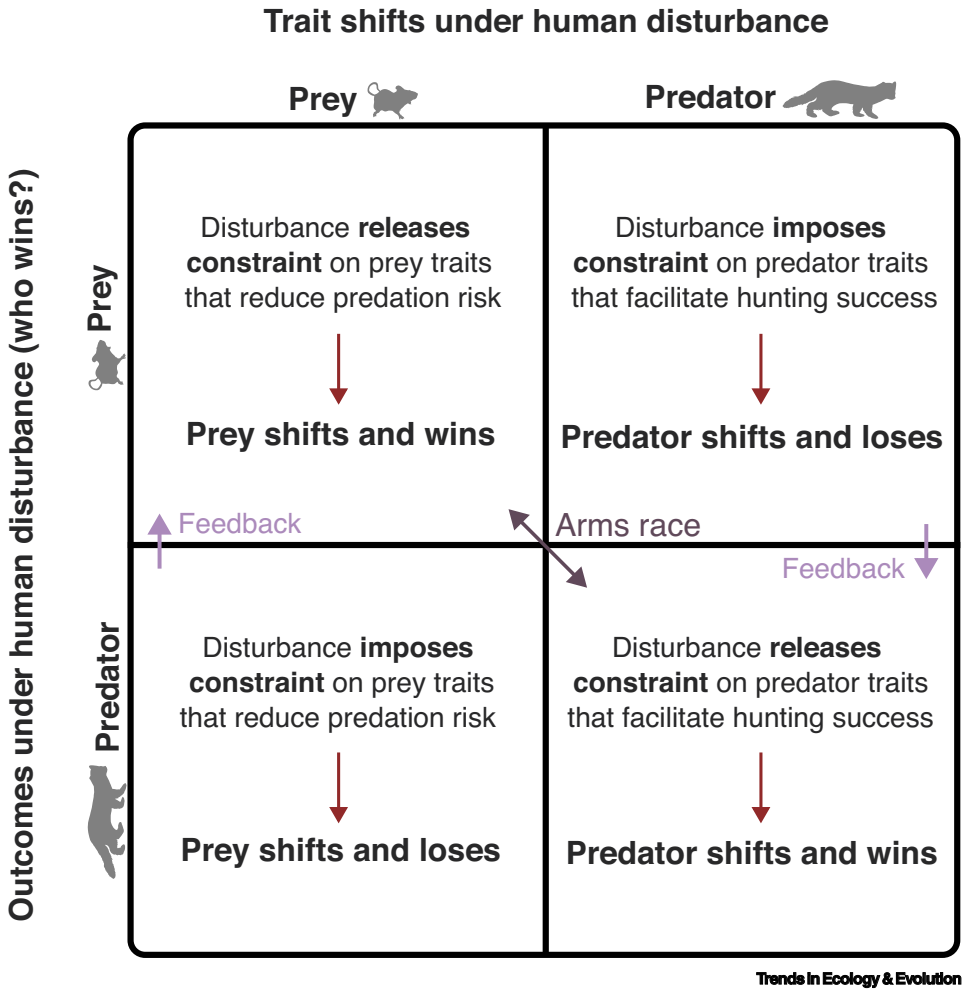

Figure 3. A framework for predicting the 'winners' and 'losers' in the predator–prey arms race under human-induced trait shifting. Human disturbance can impose novel selective pressures (constraints) on trait distributions, which may cause a predator or prey to 'lose' in the arms race. Less commonly, human disturbance can release species traits from ecological and evolutionary constraints, leading the predator or prey to 'win'. In turn, the predator–prey arms race should drive ecoevolutionary feedbacks, as both members of the dyad gain a selective advantage from 'winning'.

correlated with reduced survival in the wild, thought to be driven by an increased vulnerability to predators as geckos are unable to remember suitable refuges [40] (Figure 2).

Changes in social traits reshape predator–prey interactions

Animal cultures govern a range of behaviors key to predator–prey interactions, such as hunting techniques, predator recognition and alarm responses, diet composition, and spatiotemporal patterns of individuals and their social groups [85]. Human disturbance can result in the emergence or loss of animal cultures [45]. For example, the construction of a dam in California, USA, led to the aggregation of salmonids; social learning enabled California sea lions (*Zalophus californianus*) to exploit this prey aggregation, driving declines in at-risk salmonid populations [11]. Meerkats (*Suricata suricatta*) teach their pups to hunt scorpions, allowing pups to socially learn how to remove dangerous stingers before consumption. Human disturbance and climate

change are predicted to reduce meerkat population densities, in turn diminishing the number of helpers willing to assist with raising pups, potentially leading to the disruption of social knowledge transmission [86]. Additionally, social learning from elders is critical to golden lion tamarin (*Leontopithecus rosalia*) predator avoidance. Elder golden lion tamarins are the most vulnerable to human hunting, driving the near extinction of the species in the wild. Without elders, juvenile tamarins cannot socially learn to avoid predation [87]. Similarly, the social disruption of African savanna elephant (*Loxodonta africana*) cultural knowledge through hunting and habitat destruction leads to the erosion of cultural knowledge and makes juveniles more vulnerable to predation, as both juveniles and mothers lack appropriate behavioral responses to predators [46,64] (Figure 2).

Group size and composition structure predator–prey interactions, as many large predators pack-hunt large prey, and prey leverage large groups to dilute predation risk [88] and use group vigilance to detect threats at a low cost [89]. For example, the anxiolytic pollutant clobazam reduces shoal cohesion in Atlantic salmon (*Salmo salar*) in the presence of a predator, altering the risk of predation [90]. Human disturbance can alter the demography of animal groups, with consequences for both predators and prey. For example, dingoes (*Canis dingo*) have complex social lives: they live, hunt, and raise young cooperatively, and pack-hunting allows them to hunt prey much larger than themselves. When dingoes are hunted by humans, their social groups can fracture, limiting their ability to pack-hunt and altering the top-down pressure they exert on mesopredators and medium and large herbivores [54]. Similarly, high human infrastructure and presence reduce mountain gazelle (*Gazella gazella*) group size relative to low-disturbance areas. Mountain gazelle are also significantly more vigilant in high-disturbance areas [91]. Thus, human disturbance might increase the chances of prey spotting a predator, given their increased vigilance, while simultaneously reduced group sizes limit the dilution effect.

Predicting the ecological consequences of human-induced trait shifts

Predicting how human-induced trait shifts will shape future predator–prey interactions first necessitates predictions about which relevant traits are likely to shift under human disturbance. Trait shifts will be context and species dependent; for example, species with fast life histories and short generation times may experience rapid selection on morphological traits [28]. Alternatively, long-lived vertebrate species with slow life histories may experience shifts in culture in response to human disturbance, as culture is labile and can develop via individual and social learning within a lifetime [8]. Trait shifts will depend on the nature of the human disturbance and the selective pressures that it imposes. For example, anthropogenic resource subsidies may increase body size [18], while rising temperatures that speed up metabolic rates may decrease body size [63]. Enduring disturbances that favor bold [23] or problem-solving phenotypes are likely to select for these phenotypes, while disturbances that remove old animals from populations are likely to drive the loss of cultural knowledge [47].

Despite context-dependency, we can generalize about when predators or prey should 'win' or 'lose' the arms race under human disturbance (Figure 3). All else being equal, a predator 'loses' when trait shifts reduce their ability to hunt prey (e.g., a reduction in gape size, a loss of cultural hunting knowledge, or a reduction in brain size, limiting learning). Prey 'lose' when trait shifts increase their vulnerability to predators (e.g., selection for boldness, a decrease in body size, or a loss of cultural predator avoidance knowledge). In such cases, counterselection might limit the extent of these shifts—or even reverse them—unless the 'loser' suffers local extinction. One member of the predator–prey dyad 'losing' is likely to relax selection pressure on the other member of the dyad. Human disturbance may release constraints on traits that improve hunting success (in the case of predators) [11] or reduce predation risk (in the case of prey), allowing one party to 'win' the arms race. Reciprocal selection in the other may result in a renewed

arms race. However, cases where constraints are released may be rare, as human disturbance commonly acts as an agent of selection rather than a release of selective pressures [20].

Scaling up trait shifts

By altering predator–prey interactions, human-induced trait shifts can rewire food webs (Box 2). Trait shifts that make predators less effective at preying on a particular species (i.e., predators 'lose') can motivate predators to switch prey species [33]. Alternatively, trait shifts in predators may drive new prey preferences, as evidenced by a cultural trait shift in Californian sea lions leading to an increased reliance on salmonid prey relative to individuals without this cultural knowledge [11] (Figure 2). Where human-induced trait shifts in either predators or prey lead prey to 'win' the arms race, prey may be released from top-down pressures. This release could result in increases in prey abundance and range expansion and have cascading effects on lower trophic levels, including plant communities. In some cases, trait shifts can disrupt patterns of predator–prey interactions in such extreme ways that they lead to population decline and local extinction of one or both actors [92]. While not a human-induced trait shift, the development of socially learned stone tool use in long-tailed macaques (*Macaca fascicularis*) reduces the abundance and body size of shellfish prey, suggesting that novel trait shifts can both drive compensatory trait shifts and prey decline. Ultimately, changes in predator–prey interactions within food webs can drive extinction cascades, in which the loss of a single species drives the sequential extinction of other species [93]. Monitoring how trait shifts scale up to shape populations, communities, and ecosystems is an important next step to understanding the broader consequences of human disturbance.

Box 2. A roadmap for studying human-induced trait shifting in predator–prey ecology

Studying the role of human-induced trait shifts in predator–prey interactions requires the ability to first quantify trait variation in predator and prey populations (Figure IA) and link these traits to predator–prey interactions (Figure IB) [75]. Evaluating how predator and prey traits shape predator hunting success or functional responses or alter predation-driven mortality in prey—for example, via experiments or staged predator introductions [94]—offers the strongest evidence of how traits mediate predator–prey interactions. Observational studies of wild populations may also shed light on how the traits of predated individuals differ from those in the rest of the prey population or on the effects of predator traits on individual hunting success.

Once a particular trait has been linked to predator–prey interactions, the next step is to understand how human disturbance shapes variation in that trait (Figure IC) [49]. Ideally, studies would explore how plasticity and selection act in real time with spatially replicated, long-term studies or manipulative ecological experiments, facilitating the real-time observation of trait shifts and the isolation of causal mechanisms [49,99]. Less ideally, space-for-time comparisons can document how traits vary with spatial variation in human disturbance [18]. However, assigning an explanatory mechanism to differences in trait distributions is more speculative in such correlative studies.

Linking human-induced trait shifts to predator–prey interactions is inherently challenging. Understanding how human disturbance affects traits, and in turn predator–prey interactions, requires detailed monitoring of populations through space and time, and the use of methods like Structural Equation Models or Before-After Control-Impact (BACI) study designs to attribute causality (Figure ID). However, if the causal pathways between traits and predator–prey interactions (Figure IB) and between human disturbance and traits (Figure IC) have been independently established, trait shifts may be invoked to explain observed correlations between human disturbance and changes in predator–prey interactions, especially if trait shifts are also measured, and confounding factors are accounted for.

For well-studied populations, long-term monitoring of population trajectories and demography can shed light on the population-level consequences of trait-mediated changes in predator–prey interactions (Figure IE). In the absence of such monitoring, individual-based models that incorporate trait variation can generate predictions that can be compared with observed trends. At the community level, DNA metabarcoding or stable isotope analysis [99] and network analysis can be used to understand how trait-mediated changes in predator–prey interactions shape food webs (Figure IF) [100]. However, understanding these downstream consequences of altered predator–prey interactions for populations and ecosystems—and attributing causality to any observed changes—will remain a challenge, given the complexity of ecosystems and the many other pathways through which disturbance alters populations and food webs.

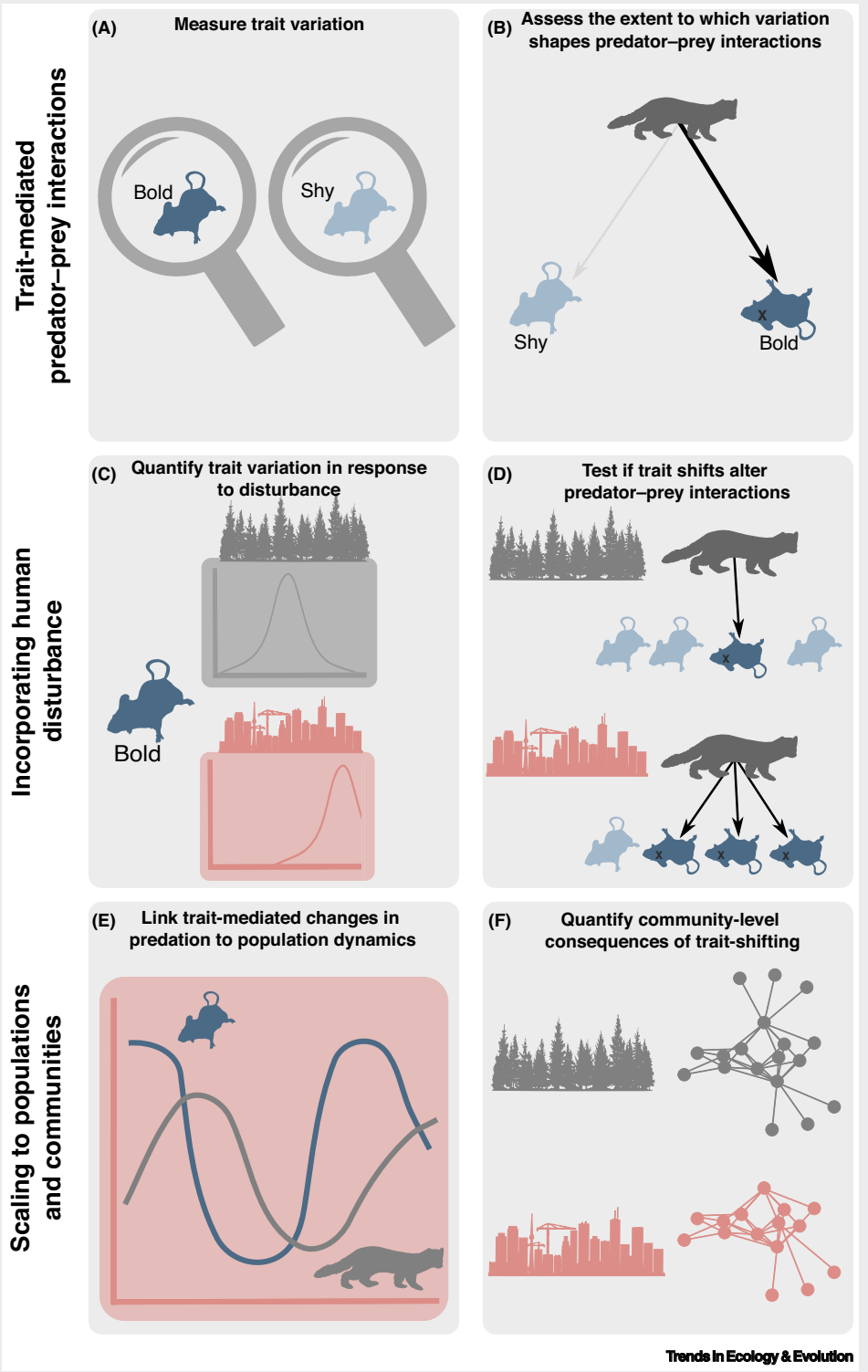

Figure I. A roadmap for studying trait-shifting in predator–prey ecology.

Human-induced trait shifts in predators or prey may also have ecoevolutionary feedbacks by altering the arms race between predators and prey. Trait changes in either can favor compensatory shifts in the other, leading to rapid and strong trait selection. There will be particularly strong selective pressure on naïve prey that experience predation from a novel predator. In these cases, prey may rapidly develop behavioral or morphological defenses via selection or phenotypic plasticity that allow them to evade predation [94]. Identifying how humans alter the evolutionary arms race between predators and prey is an important future research direction. Modeling approaches that allow for the incorporation and changes therein of individual traits are a promising avenue for exploring this arms race [95]. Additionally, technological advances in gene editing now offer a powerful tool for manipulating the phenotypic traits of animals to test their effects on predator–prey interactions (i.e., altering color phenotypes to test their fitness consequences) [96]. This means that the phenotypic traits of predators or prey can be manipulated through the editing of genes prior to experimentation or reintroduction, presenting new frontiers for both understanding how traits mediate predator–prey interactions and how human disturbance shifts and alters trait-mediated relationships.

Concluding remarks

The conservation of predator–prey interactions—and the functions and services they provide—is vital to planetary health and human well-being [1]. While human disturbances are increasingly ubiquitous, their impacts on predator and prey trait distributions can be ameliorated by diminishing the intensity of their selective pressure. For example, regulating direct harvest methods to reduce size- and age-based selection can limit morphological trait shifts [47]. Such policies could include the introduction of catch size limits, modification of fishing gear, restriction of trophy hunting, and exclusion of fishers and hunters from critical conservation areas, limiting selective pressures and allowing variation to re-emerge. Preventing trait shifts under habitat alteration, climate change, species introductions, and pollution is more challenging and largely rests on the prevention of the underlying disturbance. However, understanding how and why disturbances select for particular phenotypes can inform planning to mitigate these selective pressures and reduce the magnitude of trait shifts (see Outstanding questions). Yet, conservation in the Anthropocene requires an understanding that we live in novel times [97], and individuals, populations, and species will continually adjust and adapt to the world humans create.

Outstanding questions

How are human-induced shifts in morphology and behavior altering predator–prey interactions and their ecosystem-level consequences?

How do human-induced shifts in multiple traits (in one or more species) interact with one another to reshape predator–prey interactions?

How do human-induced shifts in predator and prey traits generate novel ecoevolutionary arms races?

Which anthropogenic selective pressures and predator–prey ecoevolutionary feedbacks lead to the stabilization or destabilization of trait distributions?

Under what circumstances do human-induced trait shifts drive predators to switch prey species, and what are the long-term consequences for food web dynamics?

How have trait shifts, driven by species introductions, altered existing predator–prey interactions?

How can shifting predator–prey interactions be managed and conserved to mitigate undesired effects on species and ecosystems?

Author contributions

E.I.F.W. developed the concept with input from K.M.G., D.G.N., A.J.R.C., C.J.J., and L.A.S. E.I.F.W. led the writing of the first draft with input from all authors. E.I.F.W., S.D.R., and K.M.G. designed and made the figures. All authors contributed substantially to the revisions and final text.

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Declaration of interests

The authors declare no competing interests.

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