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Anthropogenic Cues Create Evolutionary Novelty by Reshaping Attraction, Avoidance, Learning, and Ecological Traps in Insects

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ABSTRACT

Human-modified environments generate sensory conditions for which historically reliable insect responses may no longer predict beneficial outcomes. Artificial light, atmospheric pollution, pesticide residues, altered substrate properties, and other anthropogenic signals can modify cue identity, intensity, timing, spatial structure, or reliability. Yet behavioral responses to these changes are often compressed into simple labels such as attraction, avoidance, or disruption, obscuring distinctions among sensory detection, orientation, learning, habitat choice, realized fitness, and evolutionary change. This ecological perspective develops a proposed classification in which anthropogenic cue novelty is defined by where environmental modification enters the cue–response system and by the level at which its consequences are demonstrated. Novelty may arise because humans introduce an unfamiliar signal, alter a historically informative signal before reception, change the spatial or temporal architecture of information, or decouple a familiar cue from its former ecological outcome. Evidence from visual, olfactory, chemical, seasonal, and habitat-selection systems shows that attraction need not represent goal-directed approach, avoidance may be learned rather than innate, and experience cannot always compensate when the external cue itself is changing. Behavioral shifts can occur without demonstrated lifetime fitness effects, whereas altered chemical signals can disrupt pollination or sexual communication before population consequences are known. Ecological-trap inference therefore requires stronger evidence than behavioral preference alone. Anthropogenic cue responses should be interpreted through explicit boundaries separating observation from mechanism, behavior from fitness, community filtering from evolution, and plastic reassessment from heritable adaptation. These distinctions provide a basis for evaluating when altered cues create transient behavioral novelty, persistent maladaptation, candidate selection pressures, or potentially mitigable conservation problems without assuming that any one trajectory is universal.

Keywords: Sensory ecology, Artificial light at night, Olfactory pollution, Behavioral plasticity, Ecological traps, Evolutionary mismatch

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Introduction

Anthropogenic environmental change is commonly evaluated through mortality, habitat loss, resource limitation, toxicity, or climatic stress. For insects, however, environmental change also modifies the information used to locate resources, mates, refugia, hosts, developmental conditions, and seasonal transitions. Artificial light at night

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(ALAN) provides the most intensively studied example. Recent synthesis of moth research documents effects across behavior, reproduction, mobility, and community organization while also revealing strong concentration on adult stages and uneven taxonomic and geographic coverage [1]. This evidence makes anthropogenic information change difficult to treat as a peripheral consequence of environmental disturbance.

The central inferential problem is that a changed response to a cue does not identify the level at which biological harm, benefit, or evolutionary novelty occurs. A moth may approach a lamp, become disoriented without reaching it, reduce activity, alter feeding time, or experience developmental consequences through photoperiodic disturbance. These outcomes occupy different causal positions. Reviews of moth responses across the life cycle consequently support numerous behavioral and physiological pathways through which artificial lighting could contribute to decline, but population-scale causal attribution remains less secure than several component mechanisms [2]. The distinction is important because an immediate behavioral response is not itself evidence of a demographic effect, an ecological trap, or adaptation.

The same problem extends beyond light. Atmospheric pollutants can modify plant volatile production, transmission, persistence, or perception, thereby changing the chemical information available to pollinating insects [3]. Artificial nocturnal illumination can also disturb photoperiodic information used by insects to regulate diapause, converting a historically informative day-length environment into a potentially misleading seasonal signal [4]. Anthropogenic novelty is therefore not a single stimulus class. It can arise when a novel signal is added, when an established signal is chemically transformed, when its spatial or temporal structure changes, or when the relationship between a cue and its former consequence becomes unreliable.

This perspective argues that these routes should be separated before ecological or evolutionary meaning is assigned. The proposed synthesis distinguishes environmental cue modification, sensory acquisition, behavioral orientation, experience-dependent reassessment, cue–outcome reliability, demonstrated fitness consequence, population filtering, and evidence of heritable response. Such separation is needed because attraction may coexist with harm, avoidance may follow learning, apparent attraction may reflect disrupted orientation rather than preference, and behavioral novelty may occur without detectable fitness change. The objective is therefore not to define all anthropogenic responses as maladaptive, but to identify where evidence justifies moving from observed cue response toward stronger ecological or evolutionary inference.

Materials and Methods

Novel-cue classification

This perspective used a conceptual classification procedure rather than a new experiment or quantitative synthesis. Evidence was organized according to four questions: what aspect of the informational environment was altered; what insect response was directly measured; whether the proposed mechanism was observed or inferred; and how far the evidence extended from behavior toward ecological or evolutionary consequence. Taxon, life stage, sex, exposure setting, temporal scale, and laboratory-versus-field context were retained where they constrained interpretation.

The first classification axis concerns the physical architecture of the anthropogenic cue. Artificial light illustrates why the category “light pollution” is analytically insufficient. A field experiment manipulating four narrowband wavelengths across three intensities found that spectral responses differed among insect orders, while increasing intensity generally strengthened attraction [5]. Wavelength and intensity therefore represent distinct information dimensions rather than interchangeable descriptors of one exposure. Temporal structure, spatial geometry, background illumination, and exposure duration must likewise be considered separately when evidence indicates that insects can respond differently to them.

The second axis separates observable trajectory from sensory or sensorimotor mechanism. Three-dimensional tracking around artificial lights showed that some flight patterns conventionally described as attraction were consistent with insects maintaining a dorsal-light response inappropriate to a point source, generating orbiting, stalling, or inversion rather than direct steering toward the lamp [6]. Accordingly, an insect approaching or remaining near an anthropogenic stimulus should not automatically be classified as expressing a positively valued preference. The proposed classification treats trajectory, orientation mechanism, and habitat or resource choice as separate evidential states.

The third axis concerns where novelty is generated relative to the receiver. Anthropogenic change can transform an existing biological cue before the insect encounters it. Nocturnal atmospheric nitrate radicals degraded

components of floral scent and suppressed visitation by focal nocturnal pollinators, demonstrating that altered information can originate in the transmission environment rather than in the emitting plant or receiving insect [7]. In contrast, novelty may arise because an insect encounters an anthropogenic substrate whose sensory properties retain or acquire positive value despite potential hazard. Bumblebee queens selecting overwintering sites showed preference for some pesticide-contaminated soils rather than consistent avoidance [8]. These cases differ mechanistically even though both can produce apparently inappropriate behavior.

The resulting proposed novel-cue classification therefore uses three nonexclusive descriptors: cue modification, response state, and demonstrated consequence. Cue modification identifies whether information has been introduced, transformed, temporally displaced, spatially reorganized, or decoupled from its historical outcome. Response state distinguishes detection, orientation, attraction-like movement, avoidance, temporal reorganization, learning, and choice. Demonstrated consequence records the highest directly supported level—behavioral, physiological, interaction-level, fitness-related, population, community, or heritable evolutionary response. This final descriptor prevents evidence at one biological level from being silently promoted to another.

Results and Discussion

Attraction to anthropogenic cues is not a unitary behavioral state. Even within ALAN research, increased approach to light, prolonged occupancy around a light source, disrupted orientation, suppressed activity, and redistribution of movement can generate superficially similar trap or capture patterns. Multi-species experiments illustrate this distinction: exposure of 843 moths from 23 species to modern nocturnal lighting produced a large average reduction in night-time activity under white LEDs, with strong suppression also occurring under the tested amber lighting [9]. Reduced activity is clearly an ALAN response, but it is not equivalent to attraction.

Whole-flight tracking further weakens the assumption that ecological effects around lamps can be inferred from the number of insects reaching the source. Harmonic-radar trajectories of 95 moths showed that only a small minority terminated at the streetlight, while illumination altered flight tortuosity and could produce barrier-like movement effects extending beyond the lamp itself [10]. An anthropogenic cue can therefore reorganize movement even when terminal capture is uncommon. For dispersing insects, such altered trajectories could matter through movement costs or connectivity, but those downstream effects require direct testing rather than inference from flight geometry alone.

Temporal structure also modifies cue response. Pulsed artificial lighting altered moth flight behavior, demonstrating that the timing architecture of illumination can be biologically relevant independently of its mere presence [11]. Spatial engineering provides a corresponding intervention example: road-light designs that restricted and shielded illumination reduced attraction of nocturnal insects relative to conventional lighting arrangements [12]. These findings support treating cue geometry and temporal structure as manipulable components of exposure, while not establishing that a reduction in immediate attraction necessarily restores demographic performance.

Anthropogenic light can additionally create behavioral opportunities or disruptions that are poorly described by the attraction–avoidance dichotomy. Under semi-natural conditions, ALAN changed the temporal organization of activity and calling in male Gryllus bimaculatus, showing that an altered nocturnal cue can restructure behavior without requiring movement toward the source [13]. In the parasitoid Venturia canescens, nocturnal lighting enabled additional feeding and oviposition activity and altered aspects of senescence, yet lifetime reproductive success did not differ significantly among the tested lighting conditions [14]. Thus, even substantial behavioral exploitation of a novel temporal environment need not translate into a detectable change in the measured lifetime fitness endpoint.

These studies motivate a narrower use of “attraction.” In this article, attraction refers only to evidence of movement or choice toward an anthropogenic cue or cue-associated state. Activity suppression, temporal displacement, sensorimotor disorientation, or persistent occupancy are reported separately unless an experiment directly demonstrates directional preference. This distinction is necessary because evolutionary interpretation depends on what phenotype is actually exposed to selection.

Avoidance

Avoidance is equally heterogeneous. A negative response to an anthropogenic cue can reflect constitutive aversion, previous exposure, associative learning, impaired orientation, or altered motivation. These possibilities

differ in persistence and evolutionary meaning. Colorado potato beetles provide direct evidence for such heterogeneity: one tested strain showed active, experience-associated avoidance of systemically imidacloprid-treated host plants during oviposition decisions, whereas another strain did not express the same response [15]. Avoidance therefore cannot be assumed to be an intrinsic species-level property merely because it appears in one population or experimental history.

Sensory detection must also be separated from behavioral use. In Bombus terrestris, chronic exposure to an insecticide formulation altered aspects of chemosensory orientation while floral scent remained detectable in the measured sensory assays [16]. A receiver can therefore retain access to a signal yet fail to translate that signal into the same behavioral trajectory. This dissociation prevents altered orientation from being interpreted automatically as sensory loss and highlights the importance of measuring both perception-related and behavioral endpoints where mechanisms are claimed.

Experience can produce the opposite pattern: a previously neutral or tolerated chemical context can acquire negative behavioral value. Standardized assays with Aedes aegypti and Culex quinquefasciatus showed that a single sublethal exposure to compounds used in vector control could produce subsequent avoidance [17]. The result demonstrates behavioral updating after anthropogenic exposure but does not establish persistence under field conditions or heritable resistance.

The proposed classification therefore divides avoidance into pre-existing avoidance, experience-dependent avoidance, and apparent avoidance generated by disrupted cue use. The categories are evidential rather than taxonomic. Only the first two describe a directed negative behavioral response; the third records cases in which reduced approach may arise because perception, orientation, locomotion, or motivation is altered. Genetic adaptation constitutes a separate inference requiring evidence beyond behavioral avoidance itself.

Learned reassessment

Learning can reduce the cost of environmental novelty when experience improves subsequent decisions, but it does not guarantee successful compensation. Anthropogenic change may alter the cognitive processing of the cue, or it may alter the external signal faster than a learned association can remain reliable. Acute ozone exposure in honey bees impaired components of odor learning and memory and increased olfactory generalization, reducing the distinctiveness of learned floral information [18]. In this context, experience does not simply produce increasingly accurate reassessment because the sensory representation used for discrimination is itself altered.

A second failure mode occurs outside the nervous system. Experiments mapping ozone-driven changes in floral odor plumes showed that the chemical composition and recognizability of a previously learned odor could deteriorate with distance and near plume boundaries [19]. The insect may therefore possess a valid learned template for the original signal while encountering an anthropogenically transformed version that no longer matches it. Treating this as a memory deficit would assign the mechanism to the receiver when a major component of the mismatch lies in the transmission environment.

These observations support a proposed distinction between receiver updating and cue drift. Receiver updating describes changes in the insect's subsequent response following experience. Cue drift describes anthropogenic alteration of the signal after the association was formed. Successful learned reassessment requires sufficient stability on both sides: the insect must retain or update a useful association, and the environmental signal must remain recognizable enough for that association to guide behavior. Where either condition fails, learning can become ineffective or generate broader generalization rather than accurate correction.

This distinction also limits evolutionary interpretation. Rapid behavioral updating can buffer exposure and potentially reduce the consistency of selection on a cue response; alternatively, incomplete learning may leave persistent costs. The available evidence demonstrates learning and disrupted discrimination in particular taxa and exposure regimes, not a general rule that learning either accelerates or prevents adaptation to anthropogenic novelty.

Cue–fitness mismatch

A cue becomes evolutionarily consequential not because it is anthropogenic, but because its relationship with outcomes relevant to survival or reproduction has changed. The proposed term cue–fitness mismatch is used here for situations in which a cue-guided response retains behavioral influence while the association between that response and a fitness-relevant outcome becomes weakened, reversed, or uncertain. Importantly, the category

does not require that a fitness cost has already been demonstrated. Instead, it identifies where evidence must cross from altered information or behavior into measured ecological consequence before maladaptation can be claimed. Field pollution experiments show why this boundary matters. Exposure to diesel exhaust and ozone altered the activity or abundance of pollinators and parasitoids and reduced butterfly oviposition in the studied system, while responses differed among insect guilds [20]. These results show that anthropogenic chemical environments can propagate beyond sensory measurements into ecological interactions, but they do not imply that every observed response was produced by the same sensory pathway. Toxicity, resource modification, altered odor information, and behavioral avoidance can coexist. "Mismatch" should therefore identify a hypothesized information–outcome decoupling only when competing routes are acknowledged.

Highly specialized mutualisms offer stronger mechanistic resolution. In the Mediterranean fig–fig-wasp association, ozone altered the composition of the chemical signal used by the pollinator and disrupted attraction to the modified odor blend [21]. Here, novelty is generated between signal production and signal reception: the biological source continues to produce the cue, while atmospheric chemistry changes the information reaching the receiver. Such cases illustrate transmission-generated mismatch, in which the receiver's historically functional response encounters an environmentally transformed signal.

Sexual communication provides a distinct version of the same inferential structure. Ozone oxidized unsaturated pheromone compounds in drosophilids and altered courtship and sexual recognition [22]. The direct evidence concerns signal chemistry and mating behavior; it does not by itself establish population-level reproductive decline. This boundary is crucial because a disrupted interaction can be biologically important without demonstrating a reduction in realized lifetime fitness or population growth.

The parasitoid evidence described earlier provides the complementary null case: marked changes in nocturnal behavior under artificial light were not accompanied by a significant difference in the measured lifetime reproductive-success endpoint [14]. Cue–fitness mismatch therefore cannot be inferred from the magnitude of behavioral change alone. Conversely, absence of an effect on one fitness measure does not prove ecological neutrality across different environments, generations, or fitness components.

The manuscript consequently distinguishes four analytically different mismatch states. Transmission-generated mismatch occurs when anthropogenic chemistry or physics alters a biological signal before reception. Response–outcome decoupling occurs when a cue continues to elicit behavior but the associated ecological consequence has changed. Behavior-without-demonstrated-fitness-change describes strong behavioral novelty for which measured fitness consequences are absent or unresolved. Interaction-level mismatch records effects on pollination, oviposition, courtship, parasitism, or other ecological interactions before demographic consequences are established. These categories are proposed synthesis terms and should not be treated as mutually exclusive biological mechanisms.

Because prose cannot efficiently keep the location of cue alteration, the measured biological endpoint, and the permissible level of inference visible at once, the context–mechanism–outcome register below separates these dimensions without converting them into a numerical hierarchy.

Table 1. Cue–fitness mismatch states distinguished by where anthropogenic information change occurs and how far the evidence supports ecological consequence

Interpretation within its limit	Biological setting with observed basis	Discriminating check
Transmission-generated mismatch		
Proposed synthesis built from direct signal-transformation evidence		
Historically informative receiver responses encounter a chemically changed cue field	Floral odor systems used by nocturnal pollinators and specialized fig pollinators	Manipulate atmospheric transformation independently of emitter condition and receiver physiology
The relative contribution of cue transformation, direct pollutant effects, and altered resource condition can vary among systems	Atmospheric chemistry alters a signal between emission and reception, followed by reduced recognition or attraction	
Learned-template/cue-drift mismatch		
Proposed synthesis		

Learning may fail because the target signal moves rather than because memory itself is lost **Laboratory or wind-tunnel recognition does not establish field fitness consequence**	Pollinating insects using previously learned floral odors A learned odor template persists while the spatial plume becomes chemically less recognizable	Track learned individuals through realistic fluctuating odor fields while measuring resource acquisition
Response–outcome decoupling ***Proposed synthesis***		
Behavioral reliability cannot be equated with ecological benefit **Adverse outcomes may arise through toxicity or habitat degradation rather than informational mismatch**	Insects whose behavioral choices remain cue driven under anthropogenic exposure Direction, timing, or site selection changes while the historical relation between response and outcome is uncertain	Manipulate cue reliability and direct hazard separately
Behavior without demonstrated fitness change ***Evidence-defined boundary incorporated into proposed classification***		
Behavioral novelty does not automatically imply adaptation or maladaptation **Other fitness components, environments, or generations may respond differently**	Adult parasitoids exploiting artificial nocturnal light Large changes in activity, feeding, oviposition opportunity, or senescence occur without a detected difference in the measured lifetime reproductive endpoint	Couple behavioral assays to multiple lifetime and offspring-performance endpoints
Interaction-level mismatch ***Proposed synthesis***		
Ecological interactions can be disrupted before population effects are known **Interaction rate is not itself population growth or lifetime fitness**	Pollinators, parasitoids, herbivores, and mating insects Pollination-related activity, oviposition, attraction, courtship, or recognition changes under altered cue environments	Extend interaction measurements to recruitment, survival, reproduction, and population persistence
Social or sexual signal degradation ***Evidence-supported mechanism; higher-level consequence remains unresolved***		
Environmental chemistry can interrupt sender–receiver coupling without requiring a change in sender behavior **Population-level reproductive consequences remain unmeasured**	Drosophilid pheromone communication Anthropogenic oxidants chemically degrade communication molecules and alter courtship or recognition	Link signal chemistry and mating decisions to realized reproductive output under field-realistic exposure

Ecological traps

Ecological-trap inference requires more than anthropogenic attraction. A trap requires a cue-guided choice that favors a state yielding poorer fitness than an available alternative. Polarized-light pollution illustrates both mechanism and boundary: artificial surfaces can mimic water-associated polarization, yet strong preference occurred in only one of six aquatic-insect families tested [23]. Trap susceptibility therefore cannot be generalized across aquatic insects.

Adverse outcomes alone are also insufficient. Street lighting was associated with lower moth-caterpillar abundance in illuminated hedges and grass margins, while experimental exposure altered feeding and development [24]. These findings establish local biological costs but do not show that insects selected illumination because of a misleading cue. The proposed trap criterion therefore separates cue-driven choice, relative fitness consequence, and evidence that the consequence follows from that choice. Bumblebee-queen preference for pesticide-contaminated overwintering soil [8] similarly constitutes hazardous preference unless downstream fitness disadvantage is demonstrated.

Two further qualifications are necessary. First, cue quality is relational: the same anthropogenic signal can be misleading in one decision context yet neutral in another because the available alternatives, energetic state, reproductive condition, or life stage differ. Second, a trap diagnosis must specify the temporal window over which consequence is measured. Immediate mortality, failed reproduction, delayed development, and reduced

recruitment are not interchangeable endpoints. The proposed architecture therefore treats ecological-trap status as a claim about a defined decision–consequence pair rather than a permanent label attached to a stimulus.

Because this distinction is central, **Figure 1** makes attraction, hazardous preference, ecological-trap inference, and evolutionary interpretation visually non-equivalent.

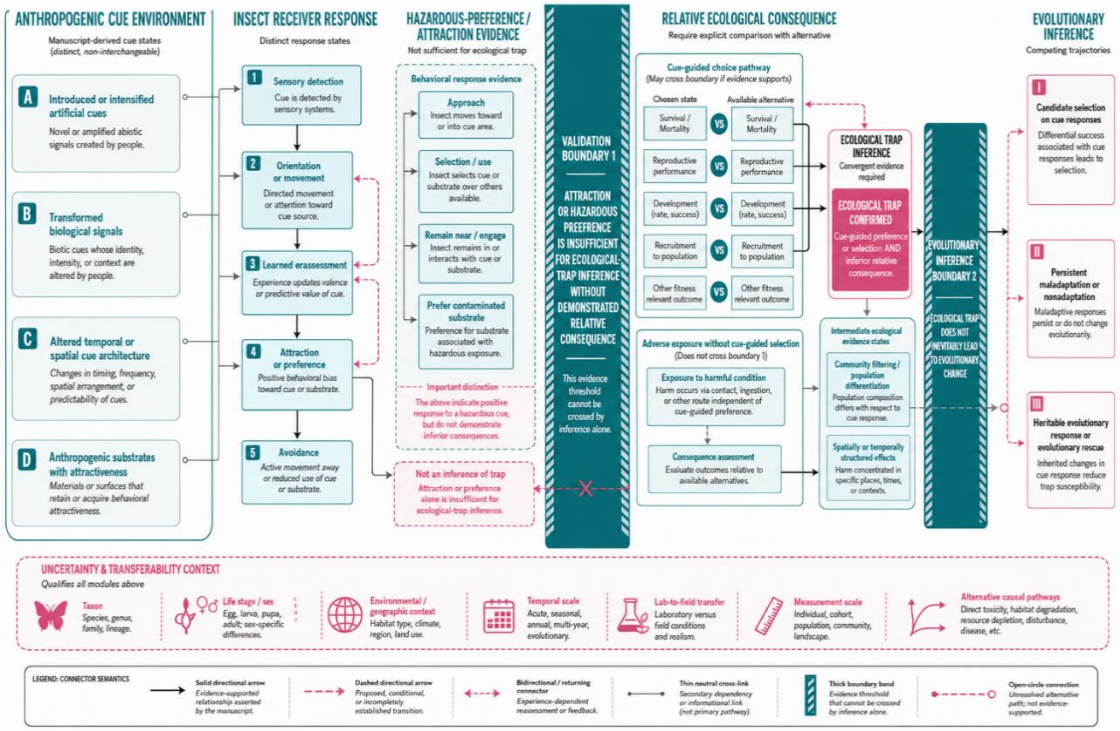


Figure 1. Evidence thresholds separating anthropogenic attraction from ecological-trap inference in insects.

Selection on cue responses

Selection requires phenotypic variation that covaries with fitness; behavioral divergence alone does not demonstrate it. Urban populations of Yponomeuta cagnagella with reduced flight-to-light responses also differed in mobility-related wing morphology [25]. This association is consistent with population divergence under urban conditions but does not establish genetic causation or selection by ALAN.

A direct counterpoint comes from Yponomeuta cagnagellus populations with different histories of nocturnal illumination. ALAN altered feeding and calling, yet the predicted local-adaptation pattern was not detected [26]. Chronic exposure can therefore coexist with plastic response and no demonstrated local adaptation in the measured traits.

Selection pressure may also be weakened when learning, avoidance, dispersal, or behavioral flexibility reduces exposure before reproduction. Conversely, repeated exposure could intensify selection if responses consistently direct individuals toward harmful states. The present evidence does not quantify either pathway generally. This is why the framework keeps plastic buffering, selective filtering, and inherited response change visually and conceptually separate rather than assuming a monotonic progression.

The distinction between evidence that motivates a selection hypothesis and evidence that establishes evolutionary response is compacted below.

Table 2. Evidence required to distinguish selection on anthropogenic cue responses from plasticity, sorting, and correlated divergence

Observable basis linked with test needed	Selection-related state with evidential standing	Permitted interpretation within its limit
Repeatable attraction, avoidance, timing, or learning change **Measure phenotype–fitness covariance**	Exposure-associated response Evidence-supported premise	Candidate phenotype Fitness covariance and heritability unknown

Consistent response differences among exposure histories **Common-garden and reciprocal-environment tests**	Population divergence Proposed inference category	Candidate differentiation Plasticity, drift, and migration remain alternatives
Cue response covaries with mobility-related morphology **Genetic tests linked to fitness**	Behavior–morphology covariance Evidence-supported association	Potential integrated phenotype Genetic covariance and causal selection unresolved
Cue changes behavior without predicted origin-by-environment pattern **Replicate across traits and generations**	Failed local-adaptation prediction Evidence-supported boundary	Trait-specific nonadaptation remains plausible Other traits may differ
Composition or trait distributions vary with cue environment **Couple community and population-genetic sampling**	Community filtering Evidence-supported ecological state	Species sorting or filtering Within-species evolution not demonstrated
Stable inherited response difference linked to fitness **Multigenerational inheritance and fitness tests**	Heritable response change Proposed validation requirement	Basis for evolutionary inference Sparse in the present evidence base

Evolutionary rescue versus persistent maladaptation

Direct streetlight and skyglow exposure alter moth-community abundance, diversity, composition, and trait structure [27]. These patterns demonstrate ecological filtering, not evolutionary rescue. Species sorting, migration, local extinction, plasticity, and habitat covariation can reorganize communities without heritable change.

The proposed synthesis therefore treats rescue, persistent maladaptation, plastic buffering, and demographic sorting as competing trajectories. Trap-like preference can be taxon specific [23]. Population divergence can be consistent with selection without proving it [25]. Long exposure can fail to produce detectable local adaptation [26]. Evolutionary rescue should be inferred only when heritable response and demographic improvement are jointly demonstrated.

Conservation implications

Conservation should target the information pathway supported by evidence. Spectrum and intensity alter attraction in taxon-dependent ways [5], while shielding and spatially restricting road lighting can reduce attraction [12]. These findings support manipulating cue architecture, but reduced attraction is not equivalent to population recovery.

Chemical cue pollution requires different interventions because signals may be transformed during transmission. Field pollution effects differ among insect guilds [20], while polarized-light susceptibility varies among aquatic taxa [23]. Cue modality, life stage, endpoint, and spatial scale should therefore be specified before intervention effectiveness is generalized.

The proposed framework treats anthropogenic novelty as an information problem with explicit inference boundaries. Measurement scale itself can alter interpretation: local illumination and skyglow were associated with different moth-community patterns across Colorado prairie sites [28]. A single scalar “light pollution” variable can therefore obscure distinct exposure structures.

Mechanistic heterogeneity reinforces this caution. Apparent lamp attraction may arise through disrupted orientation [6]. Marked behavioral change may occur without detected lifetime reproductive change [14]. Sensory detection may persist despite altered orientation [16]. Chronic exposure need not yield measurable local adaptation [26]. Together, these results argue against promoting behavioral evidence directly into fitness or evolutionary claims.

The framework remains limited by taxonomic, life-stage, geographic, and methodological concentration. Validation should connect measured cue properties to free behavior, realized choice, multiple fitness components, population trajectories, and heritable response within replicated field designs. Until then, the architecture is an inference discipline and hypothesis generator, not a validated predictive model.

Conclusion

Anthropogenic environments alter not only insect hazards and opportunities but also the information through which they are interpreted. Attraction, avoidance, learning, cue–fitness mismatch, ecological trapping, selection, and evolutionary rescue are therefore distinct response or inference states rather than inevitable stages of one process.

The proposed architecture requires each stronger claim to cross its relevant evidential boundary: behavior must be separated from fitness, hazardous preference from ecological trapping, population differentiation from selection, and community filtering from heritable evolutionary response. This preserves the ecological significance of anthropogenic sensory novelty without converting incomplete evidence into universal claims of maladaptation, adaptation, or rescue.

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