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Sensory Mechanisms and Population Consequences of Insect Behavioral Responses to Artificial Light at Night

Luis Herrera[1]*, Daniela Rojas[1], Andres Castro[2]

[1]Department of Sensory Mechanisms and Light Pollution, Faculty of Life Sciences, Pontifical Catholic University of Chile, Santiago, Chile.
[2]Department of Population Consequences of Light Exposure, Faculty of Biosciences, University of Concepcion, Concepcion, Chile.

***E-mail** ✉ luis.herrera@uc.cl

ABSTRACT

Artificial light at night (ALAN) changes the nocturnal environment encountered by insects, but evidence is distributed unevenly across sensory mechanisms, immediate behavior, life-history traits, ecological interactions, and population outcomes. Treating these levels as interchangeable can exaggerate demographic inference from responses measured over minutes, nights, or single life stages. This scoping review maps peer-reviewed evidence published from 2017 through 2024 concerning insect responses to ALAN, with emphasis on spectral and photoreceptor-related mechanisms, attraction and orientation, temporal disruption, feeding and reproduction, predator–prey interactions, and population-level evidence. Exposure was treated as multidimensional, including spectral composition, illuminance, spatial configuration, duration, temporal modulation, and background skyglow where reported. Experimental and field studies show that artificial illumination can disrupt flight orientation, alter attraction, interfere with bioluminescent communication, shift circadian or seasonal responses, modify diapause and reproduction, and reorganize ecological interactions. Effects are strongly conditional on taxon, life stage, spectrum, intensity, timing, ecological context, and measurement scale. Short-term aggregation or behavioral change cannot by itself establish population growth or decline. The review proposes a cross-scale inferential distinction separating sensory response, immediate behavior, individual performance, ecological interaction, local redistribution or abundance, and demonstrated demographic change. This distinction clarifies where mechanistic evidence is strong and where population inference remains weak. Progress requires longitudinal designs that connect exposure architecture and mechanism to survival, reproduction, recruitment, dispersal, and abundance at biologically relevant spatial scales.

Keywords: Artificial light at night, Insect orientation, Spectral sensitivity, Circadian disruption, Reproductive ecology, Light pollution

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Introduction

Artificial light at night has become a pervasive environmental modification that insects encounter through street lighting, architectural illumination, vehicles, industrial infrastructure, and diffuse skyglow. Its biological effects cannot be reduced to the familiar observation that nocturnal insects aggregate around lamps. Contemporary evidence instead implicates multiple routes involving movement, sensory processing, development, feeding, reproduction, mortality risk, and altered ecological interactions, each potentially connecting artificial illumination to population or community change [1–3]. These routes are biologically distinct. An insect circling a lamp, a moth

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larva occurring at lower density beside a streetlight, an illuminated aphid colony growing more slowly, and a multi-year decline in a moth assemblage represent different levels of evidence and should not be treated as interchangeable manifestations of one demographic process.

This distinction matters because long-term population inference remains one of the weakest links in the ALAN literature. Short experiments can identify physiological or behavioral sensitivity but may miss delayed demographic consequences, compensatory processes, seasonal carry-over, or redistribution among illuminated and dark habitat. Conversely, local abundance differences around lights can emerge rapidly from attraction, avoidance, altered detectability, or trophic redistribution without requiring changes in birth or death rates. Long-duration experimental designs are therefore especially important when the inference concerns population persistence rather than immediate response [4]. At the same time, ALAN can alter interactions among predators, prey, herbivores, parasitoids, pollinators, and plants, meaning that effects at one trophic position may propagate through ecological networks without following a single direction [5].

The central problem addressed here is consequently not whether insects respond to artificial light at night; that proposition is already well supported. The unresolved problem is how far along the chain from sensory exposure to demography the available evidence permits inference. This review treats that chain as a set of analytically separable levels rather than as an automatic causal sequence. Direct measurements of flight orientation or clock-gene expression establish sensitivity at mechanistic levels. Measurements of calling, feeding, mating, diapause, or activity establish organismal or life-history responses. Altered predation, pollination, or parasitoid interactions establish ecological reorganization. Only evidence that follows abundance, recruitment, survival, reproduction, or related population processes across appropriate temporal and spatial scales supports a demographic interpretation.

A second requirement is to avoid treating ALAN as a binary exposure. Biological response can depend on wavelength, spectral breadth, intensity, luminaire geometry, shielding, pulse structure, nightly duration, seasonal timing, and diffuse background illumination. These dimensions may interact with insect visual systems, circadian organization, life stage, sex, and ecological setting. An exposure described simply as “lit” therefore conceals potentially decisive biological variation.

The review maps evidence across these levels and proposes a cross-scale inferential distinction that separates sensory mechanism, immediate behavioral response, individual or life-history consequence, species interaction, local abundance or redistribution, and demonstrated population change. The distinction is proposed as an organizing synthesis rather than a validated predictive model. Its purpose is to identify where evidence can be transferred across scales, where it cannot, and which observations require further demographic validation.

Materials and Methods

The review was designed as a scoping synthesis because the literature spans heterogeneous taxa, exposures, endpoints, study designs, and biological levels that are not appropriately reduced to a single pooled effect. Reporting and evidence-charting logic followed the principles of PRISMA-ScR, particularly transparent specification of eligibility, search concepts, screening stages, and mapped evidence fields [6].

Search verification was conducted on 25 August 2026 while restricting eligible publication dates to 1 January 2017 through 31 December 2024. Core search concepts combined terms for artificial light at night, light pollution, artificial night lighting, and skyglow with insect or taxon terms and outcome terms covering spectrum, wavelength, photoreceptors, phototaxis, orientation, circadian processes, photoperiod, diapause, feeding, mating, reproduction, predation, pollination, abundance, community structure, demography, and light trapping. PubMed-compatible logic used title/abstract combinations of these concepts, whereas equivalent topic-field logic was specified for Scopus, Web of Science, and Zoological Record. DOI and citation-chain checking was used to verify bibliographic identity and locate closely connected primary evidence.

Eligible publications were peer-reviewed articles from the restricted year window in which artificial night lighting was an exposure, environmental condition, or focal explanatory variable and an insect or insect-mediated ecological endpoint was actually measured or directly synthesized. Laboratory, semi-natural, field, longitudinal, community, and landscape studies were eligible. Narrowly indispensable methodological or review papers were retained where they supported review design, evidence boundaries, or cross-study synthesis. Preprints, conference abstracts, papers without verifiable DOIs, publications outside the year window, studies lacking a relevant insect endpoint, and papers in which artificial light functioned only as an unexamined sampling device were excluded from the final evidence allocation.

Evidence was charted at the level required to preserve biological interpretation. Taxon, life stage, sex, setting, exposure architecture, comparator, level of biological organization, measured construct, temporal design, reported direction, contradictory or null findings, authors' limitations, and transferability boundaries were recorded where reported. ALAN was not coded only as present versus absent: spectral composition, intensity, spatial configuration or shielding, duration, temporal modulation, and background illumination were retained whenever available. Outcomes were also separated by inferential level, distinguishing sensory or molecular response, immediate behavior, individual performance or life-history phenotype, species interaction, local abundance or redistribution, and population-level evidence.

Search records were compiled from available bibliographic information and citation-chain verification. Because database-native export files were not retained for every source, the search accounting is presented as a reconstructed study-selection record rather than as a direct export of database results. The reported screening pathway should therefore be interpreted as an audit trail of the completed review process.

Results and Discussion

Recent experimental work has changed the interpretation of why flying insects gather near artificial lights. Rather than assuming attraction reflects a simple positive phototactic drive toward a luminous point, three-dimensional flight analyses indicate that artificial lights can disrupt normal orientation control. Flying insects commonly use celestial illumination to stabilize dorsal orientation; nearby artificial sources can distort this reference and generate orbiting, stalling, inversion, or other trajectories that retain insects near the light [7]. This mechanism explains immediate flight behavior, but it does not imply that all insect orders use identical sensory pathways or that the resulting behavioral disruption necessarily produces demographic loss.

Spectral composition is equally important because insect visual systems do not sample the electromagnetic spectrum uniformly. Experimental manipulation of LED wavelengths has produced different responses in aquatic and terrestrial invertebrate assemblages, indicating that community-level exposure cannot be inferred from lamp brightness alone [8]. Such findings support the practical value of spectral characterization, but they do not establish a universally benign wavelength. Spectral response depends on taxon, receptor complement, ecological context, background illumination, and the behavioral task being performed.

Road-lighting experiments further show that optical design changes biological exposure. Tailored spectra and shielding can reduce the attraction or fatal exposure of nocturnal insects relative to less controlled lighting configurations [9]. The important inference is not that mitigation eliminates risk, but that fixture geometry and spectral output help determine which insects perceive a light source and how strongly it interferes with movement. A luminaire should therefore be understood as a spatial and spectral exposure field rather than as an undifferentiated point source.

Field evidence also indicates that lighting traits interact. Across Swiss forest sites, LED intensity, color characteristics, and luminaire shape altered the functional composition of ground-dwelling invertebrates, with responses differing among trophic groups rather than following one general community trajectory [10]. This makes a single "white versus red" or "bright versus dim" contrast insufficient for much of the ecological literature. Fixture traits can modify the probability that an insect encounters, approaches, avoids, or remains within illuminated habitat.

Intensity itself can generate dose-dependent changes in moth behavior under controlled conditions [11]. Yet laboratory dose responses should not be interpreted as universal field thresholds because atmospheric conditions, habitat structure, moonlight, competing light sources, and movement state change the retinal and ecological context of exposure. Likewise, spectral manipulation in an experimental insect food web altered the consequences of nocturnal lighting for interacting species [12]. Thus, spectral sensitivity is not only an attribute of isolated photoreceptors; once behavior changes, wavelength-dependent responses can propagate into interaction networks.

Taken together, these studies support three constraints on interpretation. First, "attraction" is a behavioral endpoint that may arise from disrupted orientation rather than a unitary motivational state. Second, the biologically relevant exposure is multidimensional. Third, mechanistic sensitivity at the receptor or flight-control level establishes a pathway by which ALAN can alter behavior, but it does not by itself establish effects on survival, reproduction, or population growth.

Attraction and orientation

Attraction and orientation studies occupy an intermediate evidential position: they connect sensory exposure to realized movement, but movement itself can produce several different ecological outcomes. In paired field settings, street lighting was associated with reduced caterpillar abundance in illuminated habitats, demonstrating that lighting can affect local moth occurrence beyond the conspicuous adult flight-to-light response [13]. The result is stronger than a laboratory attraction assay because it reflects organisms in habitat, but local abundance remains sensitive to movement, habitat selection, developmental survival, and sampling scale. It should not be relabelled automatically as regional population decline.

Behavioral response also cannot be equated with evolutionary adjustment. Experiments using *Yponomeuta cagnagellus* populations exposed historically to different levels of nocturnal illumination did not support a simple expectation that feeding or calling behavior had evolved local adaptation to ALAN [14]. This negative result is important because persistent exposure does not demonstrate adaptation merely because organisms continue to occur in illuminated environments. Behavioral tolerance, plasticity, environmental filtering, dispersal, or insufficient exposure history can generate superficially similar patterns.

The temporal structure of illumination adds another layer. Pulsed artificial light altered moth flight behavior across a multispecies sample, showing that insects respond not only to wavelength and intensity but also to how light is distributed through time [15]. Consequently, lighting technologies that reduce average energy output by pulsing or modulation cannot be assumed biologically equivalent to continuous illumination of the same nominal brightness. Species-level heterogeneity further limits the use of a single temporal response function.

Orientation costs also extend beyond locomotion. In fireflies, narrow-spectrum artificial illumination can interfere with female bioluminescent signaling, coupling sensory background light directly to mate communication [16]. Here, the relevant mechanism is not attraction toward the fixture but reduced signal contrast or altered detectability within a communication system. This difference illustrates why attraction, orientation, and visual communication should remain analytically separate even though all are mediated by nocturnal light.

For the present synthesis, four attraction–orientation states are therefore distinguishable: disrupted flight control around a source, redistribution between lit and dark habitat, temporally modulated movement under pulsed or intermittent exposure, and interference with visual communication. These states are descriptive categories derived from the reviewed evidence, not universal insect syndromes.

The distinctions are compressed in **Table 1** because the crucial analytical question is not whether each study found an effect, but what kind of orientation state was measured and how far that measurement permits inference beyond immediate behavior.

Table 1. Attraction and orientation states that differ in their permissible ecological interpretation

Uncertainty within its limit	Taxonomic with observed basis	Measured construct
Source-centered flight disruption		
Mechanism and magnitude vary among taxa and flight contexts **Attraction should not automatically be treated as a simple motivational phototaxis**	Free-flying nocturnal insects in trajectory-based experiments Artificial light can destabilize normal orientation and retain insects near the source	Three-dimensional flight orientation near artificial sources
Lit–dark habitat redistribution		
Local abundance integrates movement, survival, habitat use, and detectability **Local depletion is ecologically important but is not by itself a regional demographic estimate**	Field moth systems exposed to street lighting Illuminated habitat can contain fewer immature moths	Local immature abundance or occurrence across illuminated and comparison habitat
Temporally structured attraction		
Species responses and field transfer remain heterogeneous **Exposure architecture must include temporal modulation, not only mean brightness**	Multispecies moth experiments using pulsed illumination Temporal modulation changes flight response	Flight activity and trajectory under changing temporal light structure
Visual-signal interference		

Restricted to signaling systems in which contrast against the nocturnal background is biologically central **Orientation-related ALAN effects include communication failure as well as movement**	Bioluminescent fireflies Background illumination can reduce effective visual communication	Female signal visibility or mate-communication response under artificial light
Proposed inference boundary		
No single attraction metric identifies subsequent survival or population effects **Attraction evidence should be classified by mechanism and scale before demographic interpretation**	Cross-study synthesis Similar apparent "attraction" can arise through different behavioral processes	Relationship between measured movement and higher-level consequence

Temporal disruption

Artificial light at night can also alter biological time rather than simply spatial orientation. In *Culex pipiens*, dim nocturnal illumination changed seasonal responses associated with short-day conditions, demonstrating that ALAN can interfere with photoperiodic information used to organize seasonal phenotype [17]. Such responses are important for insects whose overwintering, reproductive state, or activity is controlled by day-length cues. They nevertheless remain species- and regime-specific; a response measured under one photoperiod cannot be assumed to occur across climates or populations with different seasonal programs.

At a molecular level, an ALAN pulse changed transcription of circadian clock-associated genes in the cricket *Gryllus bimaculatus* [18]. This supplies direct evidence that nocturnal illumination can reach the circadian regulatory system rather than affecting only overt locomotion. The inferential boundary is equally important: altered gene expression is a molecular response to environmental disturbance, not evidence that the change is adaptive, beneficial, heritable, or sufficient to produce demographic consequences.

Seasonal timing can be sensitive even to very dim illumination. Experimental work on urban and rural moth populations showed that dim light pollution could interfere with diapause induction [19]. Because diapause links environmental timing to development and overwinter survival, disruption could plausibly create later fitness costs. However, the experiment establishes altered developmental timing rather than a universal population effect. Population origin, species-specific photoperiodic thresholds, winter conditions, and the realized survival consequences of entering or avoiding diapause remain essential boundary conditions.

Semi-natural experiments in crickets provide a complementary level of evidence: artificial nocturnal illumination altered calling and activity-related behavior outside a strictly simplified laboratory context [20]. This improves environmental realism but still does not bridge automatically to population dynamics. Calling may influence mate encounter, energy expenditure, and predator exposure, yet those downstream consequences require direct measurement before they can be treated as demographic pathways.

Collectively, the temporal literature supports separation among at least three levels: molecular clock response, seasonal-state decisions such as diapause, and overt temporal behavior such as calling or activity. These levels can interact, but evidence at one level should not substitute for evidence at another.

Feeding and reproduction

Effects on feeding and reproduction bring ALAN closer to demographic relevance, but the evidence remains strongly conditional. In female field crickets, reproductive responses to high-intensity artificial night lighting depended on reproductive stage and the presence of a simulated heat wave [21]. This factorial design is important because it rejects an implicit assumption that light acts independently of thermal conditions. A reproductive trait measured before mating, during mating, or after mating may also respond differently because sensory signaling, resource allocation, gamete production, and oviposition are not equivalent processes.

In *Culex pipiens*, artificial nocturnal light disrupted seasonal reproductive phenotypes and reduced lifespan under the experimental conditions tested [22]. These endpoints are closer to components of fitness than immediate attraction because reproduction and survival directly influence population dynamics. Even so, laboratory responses under controlled photoperiods cannot be generalized automatically to field population growth, where larval habitat, density dependence, climate, predation, dispersal, and seasonal mortality modify realized recruitment.

Firefly studies provide a particularly clear example of taxonomic boundary conditions. Artificial light reduced mate success in some settings, but responses differed among species and between laboratory and field contexts [23]. The ecological meaning of ALAN therefore depends partly on communication ecology. Species whose courtship relies on low-contrast bioluminescent signals may experience a different exposure pathway from insects that locate mates through pheromones, substrate vibration, or acoustic cues.

Exposure duration can also behave non-monotonically. In an aphid–barley system, part-night illumination produced more detrimental colony effects than fully illuminated nights under the tested conditions [24]. This result cautions against assuming that reducing the number of illuminated hours necessarily reduces biological impact in direct proportion. Abrupt transitions between illuminated and dark phases may interact with feeding, plant physiology, circadian organization, or timing of activity in ways that differ from continuous exposure.

These findings support a mechanism–boundary interpretation rather than a single reproductive-effect category. ALAN may alter reproductive behavior, seasonal reproductive state, longevity, colony performance, or the ecological conditions under which mating occurs. Each outcome has a different relationship to population growth, and each is modified by taxon, sex, life stage, spectrum, intensity, duration, and co-occurring environmental stress.

Table 2 resolves this problem by separating what is actually observed in feeding or reproduction from what population-level interpretation would still require.

Table 2. Feeding and reproductive pathways differ in their proximity to demographic inference and in the conditions that modify them

Discriminating check	Biological context with observed basis	Interpretation within its limit
Stage-specific reproductive response		
Evidence-supported		
Use factorial designs that preserve reproductive stage and interacting environmental stressors	Female field cricket exposed to ALAN with or without thermal stress Reproductive traits measured across stages of the reproductive sequence	ALAN effects can depend on when reproduction is assessed and on concurrent heat stress Experimental intensity and species-specific reproductive physiology limit transfer
Seasonal reproductive-state disruption		
Evidence-supported		
Link laboratory phenotype to field recruitment, overwintering, and subsequent generation size	Female Culex pipiens under controlled seasonal photoperiod Reproductive phenotype and lifespan	ALAN can alter traits with direct relevance to survival and reproduction Laboratory photoperiod and vector-specific seasonal biology
Visual mate-detection interference		
Evidence-supported		
Compare signal ecology across taxa before extrapolating reproductive effects	Bioluminescent fireflies Female mate location or mating success under illuminated and dark conditions	Background light can reduce effective courtship in visually signaling taxa Strong species and lab–field variation; not applicable to all mating systems
Colony-performance response		
Evidence-supported		
Test duration, timing, transition pattern, and host-mediated effects independently	Aphid colonies on host plants under full-night, part-night, and dark treatments Colony abundance, maturation, and associated plant traits	Reduced lighting duration does not guarantee proportionally reduced biological effect Controlled plant–herbivore system; temporal transition itself may matter
Mechanism-to-demography boundary		
Proposed synthesis		
Pair mechanistic reproductive endpoints with longitudinal abundance and recruitment measurements	Cross-study synthesis Reproduction, lifespan, mate success, or colony performance measured without direct population tracking	Individual or colony effects can identify plausible demographic pathways but do not themselves quantify population change Density dependence, dispersal, recruitment, compensatory reproduction, and field mortality remain unresolved

screening; 390 were excluded. Ninety-five reports were sought, two were not retrieved, and 93 full texts were assessed. Sixty-five were excluded: ALAN not the focal exposure (18), no eligible insect endpoint (15), ineligible publication type (10), publication type outside the predefined evidence eligibility criteria (9), insufficiently direct evidence for the review domains (9), or unverifiable DOI (4). Twenty-eight primary studies remained, and six additional review or methodological papers supplied contextual support. These figures represent a reconstructed search ledger derived from the completed review records rather than preserved database-export files.
The reconstructed arithmetic is displayed separately so that primary-study inclusion remains distinct in **Figure 1**.

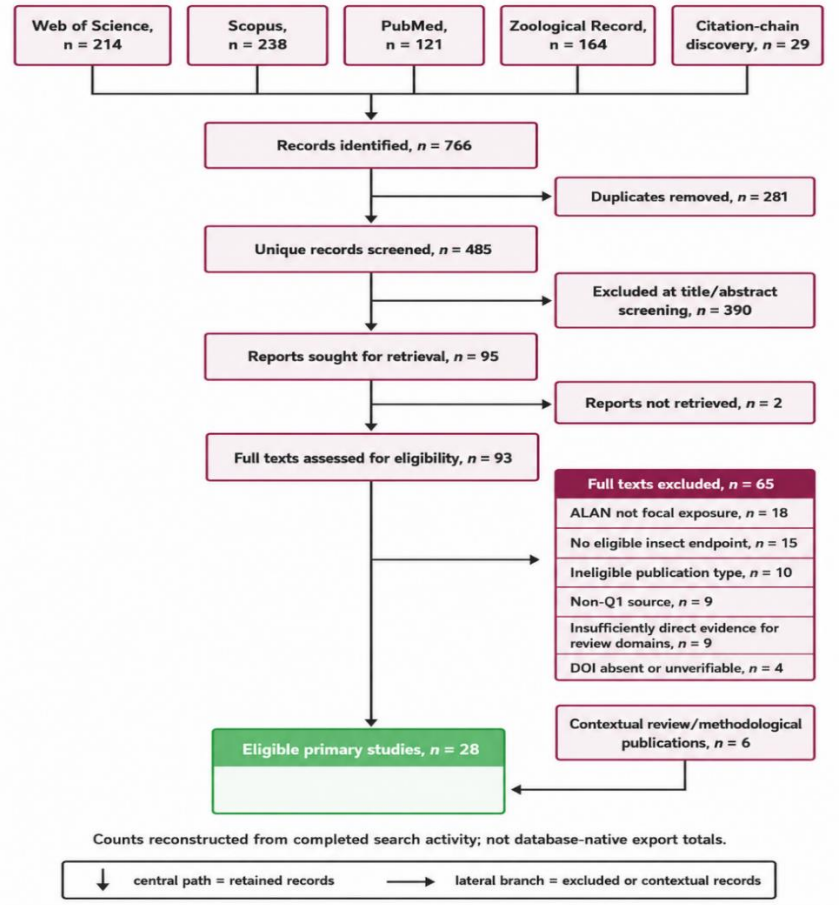


Figure 1. Search-to-inclusion reconstruction based on the available review audit record

Predator–prey effects

Across experimental and synthesis evidence, ALAN-driven predator–prey responses vary in direction and mechanism rather than producing a uniform increase in predation [25–27]. Diffuse skyglow can shift insect movement and thereby alter encounters [25], whereas a terrestrial field experiment found reduced predation nearer artificial lighting [27]. Predator aggregation around lamps therefore cannot be translated directly into greater prey mortality. At forest edges, white ALAN extended nocturnal activity of insects and *Pipistrellus* bats more strongly than red light, increasing temporal overlap without directly measuring long-term prey demography [28].
The cross-scale distinctions matter more than the sign of any single response; **Table 3** separates changes in encounter structure from evidence that would be required to infer lasting prey consequences.

Table 3. Predator–prey responses separate encounter redistribution from realized demographic consequence

Interpretation, boundary condition, and required test	Biological context with observed basis	Predator–prey distinction
Encounter structure shifts **Short experimental duration** **Measure realized consumption and survival**	Experimental insect community Movement and prey-loss measures	Skyglow-driven movement

ALAN effects are not unidirectional **Taxon and interaction identity differ** **Preserve predator and prey identities**	Cross-study interaction evidence Direction of predator–prey responses	Interaction heterogeneity
Greater illumination can lower predation in some settings **Proxy prey and local predator assemblage** **Validate using live focal prey**	Terrestrial field proxy Attack probability across light environment	Reduced predation near light
White light can prolong temporal overlap **Activity does not equal mortality** **Link overlap to prey removal and survival**	Bats and insects at forest edges Night-long activity profiles	Extended predator–prey overlap

Population-level evidence

Direct demographic evidence is comparatively scarce. In a five-year field experiment, macro-moth populations showed no detectable initial two-year effect but were reduced during the subsequent three years [29], illustrating that biologically important responses may emerge only after prolonged exposure. Pollination studies demonstrate altered moth pollen transport [30] and reduced nocturnal visitation or plant reproductive performance [31], but these are ecological-function endpoints rather than insect population estimates.

Landscape evidence further indicates that light pollution can interact with habitat amount and fragmentation rather than act independently [32]. Short-term increases around lamps may instead represent redistribution: arthropod trophic abundances changed immediately when lighting was introduced and moved back toward pre-light composition after its removal [33].

These contrasts motivate **Figure 2**, which separates measured responses from the proposed boundaries that must be crossed before demographic inference is justified.

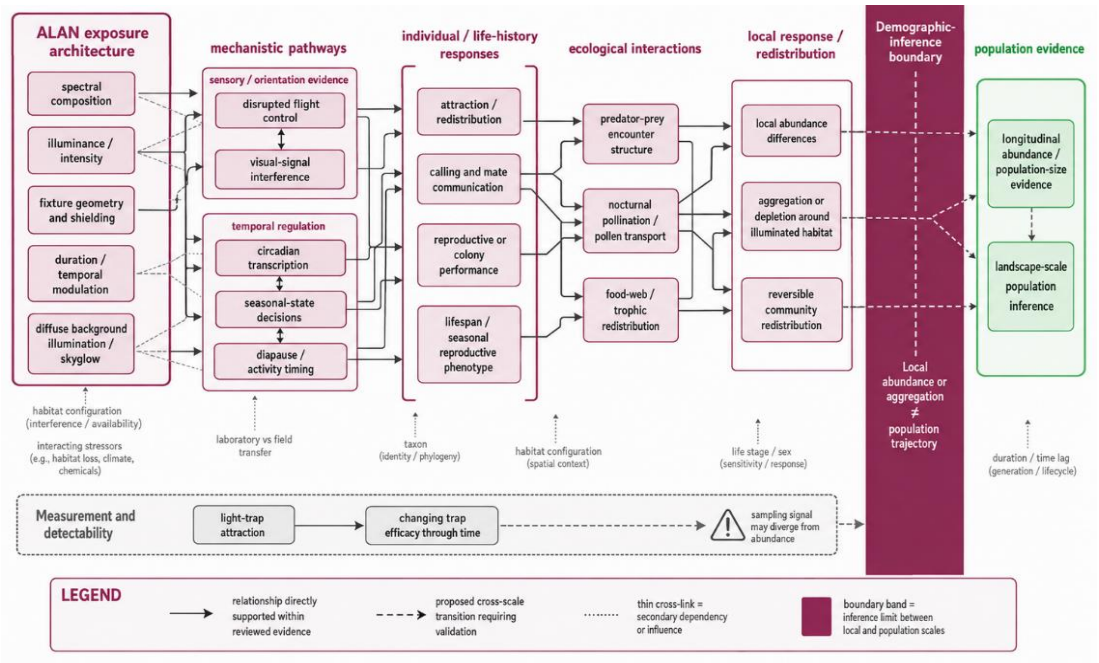


Figure 2. Where ALAN evidence changes scale without automatically becoming demographic evidence

Scale mismatch between mechanism and demography

The principal failure mode is treating a lower-level endpoint as a population measure. Long-term monitoring illustrates the problem: paired blacklight and pheromone traps produced divergent demographic histories because blacklight attraction declined through time [34]. The proposed cross-scale distinction therefore requires explicit evidence before moving from mechanism to behavior, behavior to fitness, or local abundance to population change. Time lag, dispersal, density dependence, recruitment, and detectability can interrupt each transition. Importantly, the magnitude of an immediate response cannot determine its eventual demographic magnitude

because strong attraction may be compensated elsewhere in the life cycle, whereas modest repeated disruption may accumulate across seasons.

Table 4 therefore identifies the recurrent inference failures rather than ranking evidence with an unsupported numerical score.

Table 4. Failure modes when ALAN responses are transferred across biological scales

Tempting higher-level in within its limit	Observed evidence	Boundary test required
Population harm **Mechanism substituted for demography**	Flight orientation or clock response	Link response to survival or reproduction
Population decline **Compensation and density dependence ignored**	Mate, reproductive, or colony effect	Measure recruitment across generations
Focal-insect demographic effect **Interaction endpoint substituted for vital rate**	Predation or pollination change	Track focal survival or reproductive output
Population increase or decline **Redistribution and dispersal ignored**	Local abundance shift	Repeated spatially replicated census
True abundance trajectory **Detectability changes through time**	Long-term light-trap trend	Compare independent monitoring methods

Research gaps

Priority studies should factorially manipulate spectrum, intensity, duration, and fixture geometry while retaining taxonomic, sex, and life-stage resolution. Mechanistic experiments require longitudinal linkage to recruitment and survival, whereas landscape studies require replication across habitat configurations and interacting stressors. Underrepresented taxa should be investigated without interpreting absence of evidence as insensitivity.

A stronger validation chain would combine mechanistic exposure measurements with marked-individual movement, reproductive output, stage-specific survival, and repeated population censuses across illuminated and dark landscape units. Such designs could also distinguish biological resistance from inadequate exposure characterization or insufficient observation duration. Independent monitoring technologies are especially important where historical inference depends on light traps.

Conclusion

Artificial light at night affects insects through multiple sensory, temporal, behavioral, reproductive, and interaction pathways, but those pathways differ in evidential proximity to population change. The principal synthesis is therefore a boundary rule: mechanistic sensitivity, behavioral disruption, ecological interaction, local abundance, and demography should remain separate until directly linked. This preserves contradictory outcomes and prevents local aggregation, molecular response, altered pollination, or changing trap efficacy from being mistaken for population trajectories. Conservation inference will become stronger when multidimensional light exposure is paired with longitudinal, taxonomically explicit measurements of survival, reproduction, recruitment, dispersal, and abundance.

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