



Sensory drive and environmental constraints on signal evolution: a mini-review

¹Bianca Moldovan, ^{1,2}Ioan G. Oroian, ³Zsolt A. Grabán

¹ Department of Environmental Engineering and Protection, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Cluj-Napoca, Romania; ² Balkan Environmental Association (BENA), Thessaloniki, Greece; ³ National Association of Pigeon and Small Animal Breeders of Hungary, Budapest, Hungary.

Corresponding author: I. G. Oroian, neluoroian@yahoo.fr

Abstract. The sensory drive hypothesis provides an integrative framework for understanding how environmental conditions shape the evolution of sensory systems, communication signals, signaling behavior, and habitat use. This mini-review synthesizes current evidence on the role of environmental constraints in signal evolution across aquatic and terrestrial organisms, with particular emphasis on visual, acoustic, multimodal, and chemosensory communication. The available evidence indicates that sensory drive is particularly well supported in aquatic visual systems, where variation in light environment can influence both sensory tuning and the evolution of visual signals. Acoustic communication provides complementary evidence, demonstrating that habitat structure and environmental noise can shape signal transmission and promote changes in signal characteristics and signaling behavior. Multimodal systems further reveal that environmental conditions may generate trade-offs or complementary patterns of investment among signaling modalities. However, environmental effects on signals do not necessarily coincide with parallel changes in sensory systems. Conserved sensory traits, morphological constraints, predation risk, foraging requirements, and other ecological pressures may restrict or redirect evolutionary responses. Chemosensation represents an important but comparatively underexplored component of sensory drive. Overall, the evidence supports sensory drive as a context-dependent evolutionary framework in which environmental conditions establish selective pressures, while the resulting evolutionary trajectories depend on the functional constraints and evolvability of both signalers and receivers.

Keywords: sensory ecology, sensory systems, visual communication, acoustic communication, multimodal signaling, chemosensation, sexual selection, coevolution, habitat adaptation, signal transmission, evolutionary ecology.

Introduction. The sensory drive hypothesis, formalized by Endler in 1992, proposes that environmental characteristics influence the evolutionary trajectory of both sensory systems and signaling traits in predictable directions, coupling signals, receivers, and habitat into a coevolutionary framework (Endler, 1992; Cummings & Endler, 2018; Yohe & Brand, 2018; Popescu & Păpuc, 2025; Popescu et al., 2025; Păpuc et al., 2025). A comprehensive 25-year review of 154 studies found broad support for sensory drive across taxa and environments, though the evidence is unevenly distributed: support for environmental influence on sensory tuning is stronger for visual than auditory modalities and more prevalent in aquatic than terrestrial habitats (Cummings & Endler, 2018). Of the 29 studies demonstrating complete coevolutionary evidence - where both the sensory system and the signal varied with environmental conditions - the majority involved fish visual communication in aquatic settings (Cummings & Endler, 2018; Fuller & Endler, 2018). The 19 studies finding no supporting evidence for environmental influence on signaling traits were all terrestrial and almost exclusively involved auditory signals (Cummings & Endler, 2018; Fuller & Endler, 2018).

Purpose of the Study. The purpose of this mini-review is to examine how environmental conditions influence the evolution of animal communication through the sensory drive framework. Specifically, the review aims to synthesize evidence linking

environmental variation with changes in sensory tuning, signal properties, signaling behavior, and habitat choice across different taxa and sensory modalities. Particular attention is given to visual and acoustic communication, multimodal signaling and cross-modal trade-offs, as well as the comparatively underexplored role of chemosensation.

The review also seeks to identify the principal ecological, neurobiological, and morphological constraints that may limit or redirect sensory-driven evolution. By integrating these lines of evidence, the study aims to clarify the extent to which environmental conditions generate predictable patterns of coevolution between signalers, receivers, and their habitats, while also highlighting situations in which sensory systems and signals become partially decoupled.

Theoretical Foundations and the Sensory Drive Framework. Endler's original formulation established that natural selection favors signals, receptors, and signaling behaviors that maximize received signal relative to background noise while minimizing signal degradation (Endler, 1992). Properties of sensory systems bias the direction of signal evolution, such that females prefer males whose signals they can perceive more easily, driving the spread of more detectable male traits (Endler, 1992). Environmental conditions during signal transmission and detection further affect perception, biasing the evolutionary direction of signaling behavior, microhabitat preferences, and ultimately the sensory systems themselves (Endler, 1992; Petrescu-Mag & Proorocu, 2022; Bora et al., 2025). These suites of traits - sensory systems, signals, signaling behavior, and habitat choice - should coevolve in predictable directions determined by environmental biophysics, neurobiology, and the genetics of the traits (Endler, 1992; Petrescu-Mag, 2025a,b; Petrescu-Mag et al., 2026). Because conditions vary in space and time, this process generates diversity (Endler, 1992; Petrescu-Mag, 2025c).

The framework explicitly integrates sensory ecology with evolutionary genetics, recognizing that receivers must use their sensory systems for multiple ecological tasks beyond communication, including foraging and predator avoidance, all of which exert natural selection on sensory properties (Fuller & Endler, 2018). The act of signaling may also make signalers more conspicuous to predators and eavesdroppers, and the environmental conditions under which signaling occurs can modulate these costs just as they modulate signal detectability for intended receivers (Fuller & Endler, 2018). This dual role of the environment - simultaneously shaping signal efficacy and predation risk - constitutes a core tension in the sensory drive framework (Fuller & Endler, 2018) (Table 1).

Table 1

Evidence distribution for sensory drive components across habitats and modalities

<i>Framework component</i>	<i>Predicted effect</i>	<i>Evidence strength</i>
Environmental influence on sensory tuning	Visual > auditory; aquatic > terrestrial	Strong for visual/aquatic; weak for auditory/terrestrial (Cummings & Endler, 2018)
Environmental influence on signal properties	Signals adapt to habitat transmission properties	104 of 126 tested systems show support (Fuller & Endler, 2018; Cummings & Endler, 2018)
Complete coevolution (sensory + signal)	Both sensory system and signal vary with environment	Only 29 studies, dominated by fish vision (Cummings & Endler, 2018; Fuller & Endler, 2018)
Failed sensory drive predictions	No environmental effect on signals	All 19 are terrestrial, 95% acoustic (Cummings & Endler, 2018; Fuller & Endler, 2018).

Visual Signal Evolution Under Light Environment Constraints. The strongest empirical support for sensory drive comes from aquatic visual systems, where water color - shaped by depth, vegetation, and dissolved materials - creates strongly color-biased viewing backgrounds that favor transmission of limited wavelength ranges (Fleishman et al., 2022). In many cases, fish color vision systems have evolved in response to these habitat color biases, further altering the relative effectiveness of different signal colors and producing a tight coupling between sensory tuning, signal design, and environment (Fleishman et al., 2022). Experimental work on guppies (*Poecilia reticulata*) demonstrated that colour patches change within populations over multiple generations under different ambient light conditions, and visual modeling confirmed that these changes increase communication efficiency as perceived by female guppies under each light environment (Kranz et al., 2018).

In surfperch (Embiotocidae), species-specific divergence in visual pigments correlates with environmental variation and produces different sensory biases: some species favor luminance (brightness) detection while others favor chromatic (color) detection, reflecting an inherent trade-off in dichromatic visual detection (Cummings, 2007). Male signal divergence - spectral reflectance of orange, blue, and silver color elements - matches these biases bidirectionally: species with chromatically biased visual systems evolve signals favoring chromatic detection, while species with luminance biases evolve signals favoring luminance detection (Cummings, 2007). This constitutes the first quantitative demonstration of sensory trade-offs driving signal evolution in a bidirectional pattern governed by the environment (Cummings, 2007).

A novel extension of sensory drive has been proposed through the lens of information theory: in darters (*Etheostoma spp.*), the spatial statistics of male color patterns correlate with the spatial statistics of their respective habitats, supporting a sensory drive mechanism based on efficient information coding rather than simple contrast maximization (Hulse et al., 2020). This framework incorporates post-retinal visual processing and may explain the evolution of complex visual patterns that traditional signal detection theory cannot (Hulse et al., 2020) (Table 2).

Table 2

Comparative evidence for sensory drive in visual signal evolution across fish and lizard taxa

<i>Taxon</i>	<i>System</i>	<i>Environmental constraint</i>	<i>Key finding</i>
Guppies (<i>Poecilia reticulata</i>)	Visual (colour patches)	Ambient light spectrum	Colour patches diverge across light environments over generations (Kranz et al., 2018)
Surfperch (Embiotocidae)	Visual (colour/brightness)	Kelp forest optical habitats	Bidirectional signal evolution matches sensory trade-offs (Cummings, 2007)
Darters (<i>Etheostoma spp.</i>)	Visual (spatial patterns)	Habitat spatial statistics	Male pattern statistics match habitat spatial statistics (Hulse et al., 2020)
Anolis lizards	Visual (dewlap colour)	Light intensity and chromatic contrast	Red dewlaps visible in bright habitats; yellow/white in dark (Fleishman et al., 2022)
Centrarchid fishes	Visual (opsins + reflectance)	Contrasting light environments	Signalling traits vary but sensory traits remain robust (Bertinetti et al., 2025).

Terrestrial visual systems present a more complex picture. In *Anolis* lizards, dewlap color correlates with habitat light intensity: red dewlaps are most visible in bright habitats, whereas yellow and white are more visible in darker habitats, supporting sensory drive through the interactive effects of total light intensity and chromatic contrast perception (Fleishman et al., 2022). Behavioral experiments confirmed that red stimuli are most detectable under high light conditions, while yellow and red are equally detectable in low light, demonstrating that shade level may be as important as spectral quality for animals with small eyes (Fleishman et al., 2020). However, several terrestrial studies have produced negative results: diverse colors and patterns can be found in similar light habitats, and animals in distinctly different light environments sometimes exhibit similar colors (Fleishman et al., 2022). In some cases, species' colors were actually less visible in their own habitat than those of closely related species would be (Fleishman et al., 2022).

Evidence for visual sensory tuning in terrestrial ectotherms remains limited. In the tawny dragon lizard (*Ctenophorus decresii*), opsin protein expression does not differ significantly between divergent lineages that differ in the presence of an ultraviolet sexual signal, suggesting that visual sensitivities are highly conserved in terrestrial systems and that multiple competing requirements may constrain divergence of visual sensitivities in response to sexual signals (Dong et al., 2019). Similarly, in centrarchid fishes, while body reflectance displayed species-specific responses to environmental conditions, visual system traits—including opsin gene expression—remained largely unaffected between distinct light habitats, challenging the generality of the paradigm portraying fish visual systems as highly tunable (Bertinetti et al., 2025). Visual acuity itself varies by orders of magnitude across species and constrains the information organisms can extract from stimuli, meaning that hypotheses regarding spatial pattern function must account for the acuity of relevant viewers (Caves et al., 2018).

Acoustic Signal Evolution and Habitat Transmission. Acoustic signals are shaped by the transmission properties of their environments through a process often termed acoustic adaptation, a form of sensory drive (Tobias et al., 2010). Forest-dwelling bird species generally produce lower average frequency songs than open-habitat species because lower frequencies transmit better in dense vegetation (Gonzalez-Voyer et al., 2013). A landmark study of Amazonian bird communities demonstrated that songs of 17 bamboo-specialist species differ in predictable ways from their nearest relatives in adjacent terra firme forest, and that the direction of song divergence correlates with the sound transmission properties of habitats rather than with genetic divergence, ambient noise, or pleiotropic effects of mass and bill size (Tobias et al., 2010). This finding indicates that acoustic adaptation adds significantly to stochastic processes underlying song divergence even between habitats with relatively similar structure (Tobias et al., 2010).

In Asian barbets, song frequency diverged early in evolutionary history and its rate of evolution appears constrained by body size, while characteristics associated with song length showed more recent divergence (Gonzalez-Voyer et al., 2013). The environment in which signals are produced and transmitted can attenuate signal transmission: physical particularities of the signaling environment influence reflectance, contrast, and acoustic propagation (Gonzalez-Voyer et al., 2013). Morphological constraints also interact with environmental effects: beak morphology affects song patterning, and because beak size is under strong selection for foraging efficiency, the relationship between morphology and song structure represents ecological adaptation shaping song evolution (Gonzalez-Voyer et al., 2013).

Environmental noise imposes a distinct constraint on acoustic communication. In the white-throated dipper (*Cinclus cinclus*), a riverine songbird, individuals adjust song amplitude in response to ambient river noise and simultaneously increase conspicuous blinking with white-feathered eyelids to compensate for acoustic masking in high-noise environments (De Framond et al., 2025). The negative correlation between song amplitude and blinking rate represents a noise-driven multimodal shift, demonstrating that animals can dynamically reallocate investment across sensory modalities in response

to fluctuating environmental pressures (De Framond et al., 2025). This fine-tuning of both signal performance and modality underscores the critical role of noise interference in the evolution of complex communication systems (De Framond et al., 2025) (Table 3; Figure 1).

Table 3

Acoustic and multimodal signal evolution across bird taxa under environmental constraints

<i>Taxon</i>	<i>Signal type</i>	<i>Environmental constraint</i>	<i>Key finding</i>
Amazonian bamboo vs. terra firme birds	Acoustic (song)	Sound transmission properties	Song divergence predicted by habitat acoustics, not genetics (Tobias et al., 2010)
Asian barbets	Acoustic (song frequency/length)	Forest structure + body size	Song frequency constrained by body size; length diverges recently (Gonzalez-Voyer et al., 2013)
White-throated dipper	Acoustic + visual (song + blinking)	River noise	Noise-induced multimodal shift from acoustic to visual signaling (De Framond et al., 2025)
New World warblers (Parulidae)	Acoustic + visual (song + plumage)	Vegetation structure/darkness	Negative correlation: more song syllables with less colorful plumage in closed habitats (Laverde-R. et al., 2017)
Antwrens (Thamnophilidae)	Acoustic + visual (song + plumage)	Habitat + flocking behavior	Sensory drive and transfer hypothesis both supported (Beco et al., 2021).

Multimodal Signal Transfer and Cross-Modal Trade-Offs. The transfer hypothesis predicts a negative relationship between investment in different signaling modalities, dictated by the relative costs and benefits of each, and the suitability of the environment for different signal types is central to this trade-off (Laverde-R. et al., 2017). Movement into a dark habitat should favor investment in acoustic over visual signals, while open areas should favor visual signal elaboration (Laverde-R. et al., 2017). In New World warblers (Parulidae), plumage contrast to background and chromatic diversity were negatively related to syllable variety when vegetation structure was a covariate: birds with greater song syllable variety and less colorful plumages live in closed or darker habitats (Laverde-R. et al., 2017). Disparity-through-time analyses showed that when one set of traits diversified at a relatively high rate, the other did not, as predicted by the transfer hypothesis (Laverde-R. et al., 2017). These results demonstrate that sensory drive influences the transfer of investment between traits in different sensory modalities (Laverde-R. et al., 2017).

In antwrens (Thamnophilidae), both sensory drive and the transfer hypothesis received support: significant effects of habitat on both acoustic and visual modalities were uncovered alongside evolutionary trade-offs between song and plumage complexity (Beco et al., 2021). Sex- and trait-specific responses in visual signals suggest that both natural and social selection shape signal evolution in this group (Beco et al., 2021). In Asian barbets, however, no trade-offs between visual and acoustic signals were found; more colourful species actually sing significantly longer songs, and visual signals were more divergent between closely related taxa than acoustic signals, suggesting a role in speciation or reinforcement (Gonzalez-Voyer et al., 2013).

SENSORY DRIVE: HOW ENVIRONMENTS SHAPE SIGNALS AND SENSORY SYSTEMS

Environment → Sensory Systems ↔ Signals ↔ Behavior/Habitat → Coevolution & Diversity

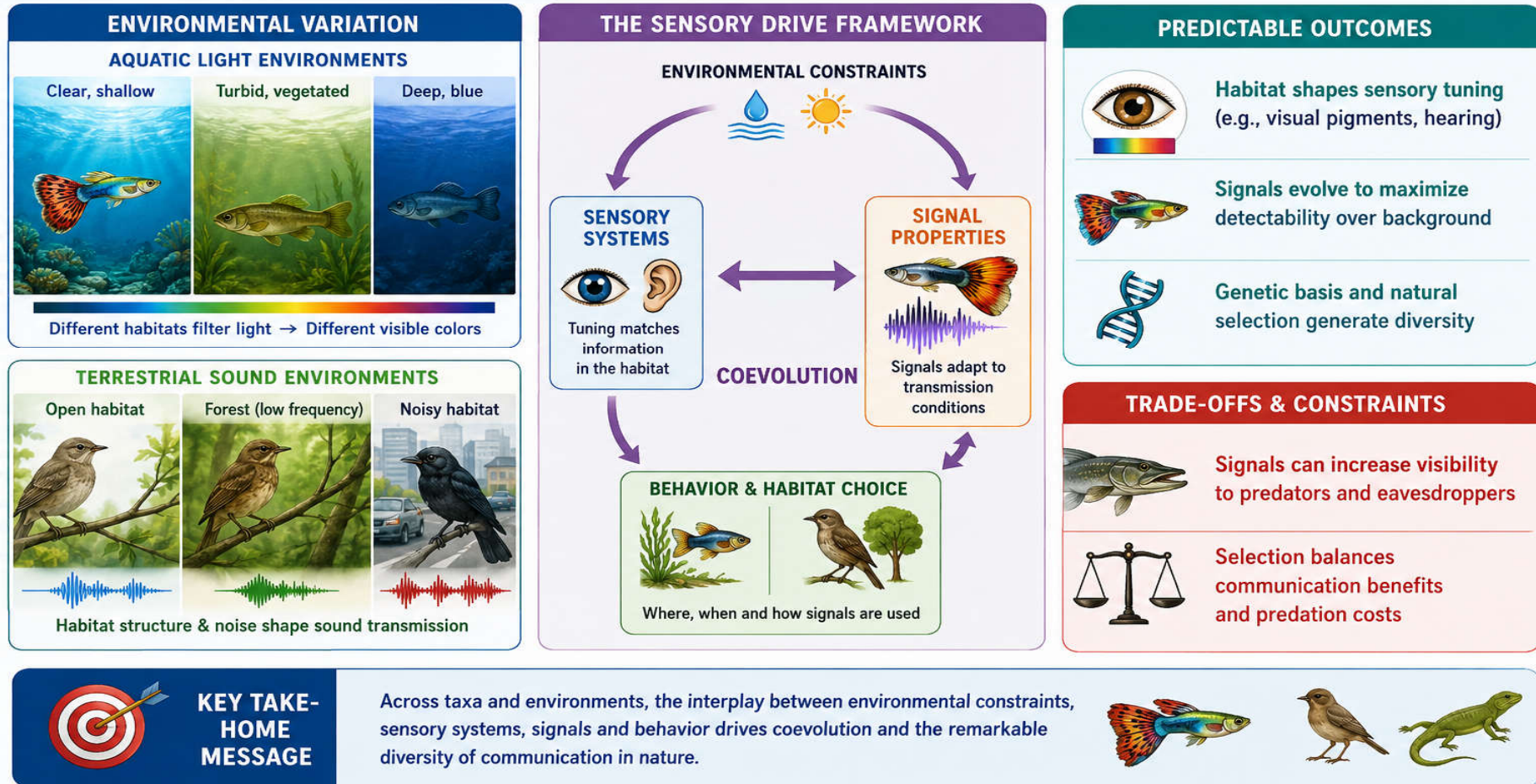


Figure1. Sensory drive: how environments shape signals and sensory systems.

The insular lizard *Gallotia galloti* provides a striking example of complementary divergence across modalities: chemical signal diversity decreased with increasing shrub vegetation cover, while lizards from densely vegetated habitats exhibited greater chromatic conspicuousness and larger chromatic volumes in visual signals (Megía-Palma et al., 2026). Achromatic contrast showed weaker habitat-dependent differentiation, consistent with the hypothesis that luminance divergence is constrained by predator-mediated selection due to the high luminance sensitivity of avian visual systems (Megía-Palma et al., 2026). In open habitats, persistent and chemically diverse secretions may enhance communication efficiency under increased exposure, whereas in vegetated environments chromatic visual signals appear amplified by sexual selection while constrained by predation risk (Megía-Palma et al., 2026).

Sensory Neurobiology, Opsin Tuning, and Constraints on Visual Evolution. The neurobiological basis of sensory drive lies in the tuning of sensory systems to environmental conditions, yet the degree to which visual sensitivities can diverge varies markedly across lineages (Dong et al., 2019). In New World warblers, expression of opsins varies with the light environment occupied by different species: short-wavelength sensitive type 2 opsins (SWS2) are shifted to longer wavelengths in species living in closed forest environments where most short wavelengths are filtered by vegetation (Laverde-R. et al., 2017). Female expression of these same opsins varies with plumage dichromatism, suggesting a direct role for sensory drive in coupling visual tuning and signal evolution (Laverde-R. et al., 2017).

In threespine stickleback, habitat transitions have led to shifts in sensory-drive dynamics: opsin sequence was tuned to enhance the perceived contrast of black fish on a red-shifted light background, while opsin expression was not (Firneno et al., 2024). However, no evidence for homotypic preferences or assortative mating between colour morphs was found, suggesting that some aspects of the visual system and behavior evolve in response to other factors such as foraging or predation, or lag behind opsin sequence evolution in red-shifted environments (Firneno et al., 2024). This partial decoupling of sensory tuning and mate preference highlights that sensory drive does not always proceed as a fully coordinated coevolutionary process.

In groups where the number and spectral sensitivities of photoreceptors are highly conserved—including birds and reptiles—visual sensitivities may be less labile than in teleost fishes and butterflies, which show substantial variation in photoreceptor number and tuning (Dong et al., 2019). This conservatism may constrain the degree to which sensory drive can operate through visual system modification in these lineages, forcing signal contrast to be achieved through alternative mechanisms such as background selection rather than receiver tuning (Dong et al., 2019). The coadaptation of signals and sensory systems with respect to background noise may establish barriers to gene flow between populations in different environments and eventually lead to speciation (Yohe & Brand, 2018), but this requires that sensory systems retain sufficient evolvability to track environmental variation (Yohe & Brand, 2018).

Beyond Vision and Acoustics: Chemosensation and the Scope of Sensory Drive.

While visual and acoustic systems dominate the sensory drive literature, chemosensation - arguably the most widespread sensory modality in animals - has received comparatively little attention in this context (Yohe & Brand, 2018). This gap likely results from methodological difficulties in assessing environmental chemical diversity and the complexity of chemical signals and perception mechanisms relative to acoustic and visual systems (Yohe & Brand, 2018). The sensory drive hypothesis predicts three components for chemosensory systems: habitat-induced background noise influences efficient signal transmission and detection, divergent environments impose different selection pressures on chemical signal production and perception, and sensory systems may become tuned to the chemical characteristics of the habitats in which organisms communicate (Yohe & Brand, 2018). These predictions suggest that chemical communication should be considered an important, yet comparatively underexplored, component of sensory drive.

The broader evidence reviewed here indicates that sensory drive is best understood not as a uniform evolutionary mechanism, but as a framework whose expression depends on the interaction among environmental conditions, sensory physiology, signal properties, behavioral strategies, and ecological constraints. Visual systems provide the strongest evidence for environmentally associated sensory tuning, particularly in aquatic environments, whereas acoustic systems demonstrate that habitat transmission properties can shape signal structure even when sensory systems themselves show limited divergence. Multimodal systems further demonstrate that environmental conditions may alter the relative investment in different signaling channels, producing either trade-offs or complementary diversification among modalities.

At the same time, the available evidence demonstrates that environmental effects on signals do not necessarily imply parallel changes in sensory systems. Conserved photoreceptor characteristics, morphological constraints, predation risk, foraging requirements, and other ecological pressures can limit or redirect the evolutionary response to habitat variation (Dong et al., 2019; Bertinetti et al., 2025). Consequently, sensory drive should be regarded as a context-dependent process in which the environment establishes selective conditions, but the resulting evolutionary trajectory depends on the evolvability and functional constraints of both signalers and receivers. The potential contribution of chemosensation further broadens this framework and indicates that our current understanding of sensory drive remains incomplete (Yohe & Brand, 2018). Taken together, the evidence supports a general conclusion that environmental conditions can profoundly influence the evolution of communication, but the strength, direction, and mechanistic pathway of this influence vary among sensory modalities and evolutionary lineages.

Conclusions. The evidence reviewed here supports sensory drive as a broad but context-dependent framework for explaining the evolution of animal communication. Environmental conditions can influence the transmission and detectability of signals and, in some cases, promote corresponding changes in sensory systems, signaling traits, behavior, and habitat use. The strongest empirical support is found in visual communication, particularly in aquatic environments, whereas acoustic systems demonstrate that habitat transmission properties and environmental noise can substantially shape signal structure and signaling behavior. Multimodal communication further indicates that environmental conditions may redistribute investment among sensory channels, producing either evolutionary trade-offs or complementary diversification.

Importantly, signal evolution does not invariably involve parallel sensory-system evolution. Conserved photoreceptor characteristics, morphological constraints, predation risk, foraging demands, and other ecological pressures may constrain sensory tuning or redirect evolutionary responses. Thus, sensory drive should not be interpreted as a universal or uniform mechanism, but rather as an evolutionary framework whose strength and direction depend on the interaction between environmental conditions, sensory physiology, signal properties, behavior, and ecological constraints. The limited incorporation of chemosensation into sensory-drive research represents an important gap and suggests that the current understanding of environmentally mediated communication evolution remains incomplete. Overall, sensory drive provides a valuable framework for understanding how environmental heterogeneity can generate predictable, yet lineage- and modality-specific, patterns of communication evolution and biological diversity.

Acknowledgements. OpenAI ChatGPT-5.3 - <https://openai.com> - was used for plate editing. The authors assume full responsibility for the content including any material generated or formatted with AI assistance.

Authors Contributions. BM wrote the manuscript; IGO and ZAG read and revised the manuscript.

Conflicts of Interest. The authors declare that there is no conflict of interest.

Data Availability. Not applicable.

Funding. This research received no external funding.

References

- Beco, R., Silveira, L. F., Derryberry, E., & Bravo, G. A. (2021). Ecology and behavior predict an evolutionary trade-off between song complexity and elaborate plumages in antwrens (Aves, Thamnophilidae). *Evolution*, 75(10), 2388–2410. <https://doi.org/10.1111/evo.14325>
- Bertinetti, C., Mosley, C. L., Jones, S., & Torres-Dowdall, J. (2025). Robust sensory traits across light habitats: Visual signals but not receptors vary in centrarchids inhabiting distinct photic environments. *Molecular Ecology*, 34(8), e17721. <https://doi.org/10.1111/mec.17721>
- Bora, F. D., Păpuc, T., & Coroian, C. O. (2025). Guppies, *Poecilia reticulata* Peters 1859, as a model for sexual trait evolution: integrating behavioral, genetic, and ecological perspectives. *Poeciliid Research*, 15(1), 13–18.
- Caves, E. M., Brandley, N. C., & Johnsen, S. (2018). Visual acuity and the evolution of signals. *Trends In Ecology & Evolution*, 33(5), 358–372. <https://doi.org/10.1016/j.tree.2018.03.001>
- Cummings, M., & Endler, J. (2018). 25 Years of sensory drive: the evidence and its watery bias. *Current Zoology*, 64(4), 471–484. <https://doi.org/10.1093/cz/zoy043>
- Cummings, M. (2007). Sensory trade-offs predict signal divergence in surfperch. *Evolution*, 61(3), 530–545. <https://doi.org/10.1111/j.1558-5646.2007.00047.x>
- De Framond, L., Sharp, S. P., Duclos, K., Beleyur, T., & Brumm, H. (2025). Stream noise induces song plasticity and a shift to visual signals in a riverine songbird. *Current Biology*, 35(18), 4570–4576. <https://doi.org/10.1016/j.cub.2025.07.049>
- Dong, C. M., McLean, C., Moussalli, A., & Stuart-Fox, D. (2019). Conserved visual sensitivities across divergent lizard lineages that differ in an ultraviolet sexual signal. *Ecology and Evolution*, 9(20), 11824–11832. <https://doi.org/10.1002/ece3.5686>
- Endler, J. (1992). Signals, signal conditions, and the direction of evolution. *The American Naturalist*, 139, S125–S153. <https://doi.org/10.1086/285308>
- Firreno, T., Welsh, G. T., Gumm, J. M., Larson, E., & Tinghitella, R. (2024). The evolution of sensory systems after signal change in threespine stickleback. *Biological Journal of the Linnean Society*, 143(1), blae076. <https://doi.org/10.1093/biolinnean/blae076>
- Fleishman, L., Perez-Martinez, C. A., & Leal, M. (2022). Can sensory drive explain the evolution of visual signal diversity in terrestrial species? A Test with Anolis Lizards. *The American Naturalist*, 200(2), 236 – 249. <https://doi.org/10.1086/720267>
- Fleishman, L., Wadman, C. S., & Maximov, K. (2020). The interacting effects of total light intensity and chromatic contrast on visual signal visibility in an Anolis lizard. *Animal Behaviour*, 167, 263–273. <https://doi.org/10.1016/j.anbehav.2020.07.008>
- Fuller, R., & Endler, J. (2018). A perspective on sensory drive. *Current Zoology*, 64(4), 465 – 470. <https://doi.org/10.1093/cz/zoy052>
- Gonzalez-Voyer, A., Tex, R. J. D., Castello, A., Leonard, J. A., & Leonard, J. A. (2013). Evolution of acoustic and visual signals in Asian barbets. *Journal of Evolutionary Biology*, 26(3), 647–659. <https://doi.org/10.1111/jeb.12084>
- Hulse, S. V., Renoult, J. P., & Mendelson, T. (2020). Sexual signaling pattern correlates with habitat pattern in visually ornamented fishes. *Nature Communications*, 11, 2561. <https://doi.org/10.1038/s41467-020-16389-0>
- Kranz, A. M., Cole, G. L., Singh, P., & Endler, J. (2018). Colour pattern component phenotypic divergence can be predicted by the light environment. *Journal of Evolutionary Biology*, 31(10), 1459–1476. <https://doi.org/10.1111/jeb.13342>

- Laverde-R., O., Ryan, M. J., & Cadena, C. D. (2017). Evolution of bird communication signals: Transference between signals mediated by sensory drive. *bioRxiv*. <https://doi.org/10.1101/142463>
- Megía-Palma, R., Aguilar, P., Žagar, A., Pie, M., Dajčman, U., Merino, S., Carretero, M. A., & Martín, J. (2026). Environmental determinants of interpopulation variation in chemical and visual signals in an insular lizard. *Oikos*, 8, e12150. <https://doi.org/10.1002/oik.12150>
- Păpuc, T., Popescu, M., & Coroian, C. O. (2025). Parallel evolution of behavioral, life-history, and sexual traits in guppies, *Poecilia reticulata* Peters 1859, under variable predation regimes. *Poeciliid Research*, 15(1), 4-7.
- Petrescu-Mag, I. V. (2025a). Aggression, sexual selection, and neuroendocrine regulation in *Betta splendens*: an integrative mini-review. *Studia Universitatis Vasile Goldiş Seria Ştiinţele Vieţii*, 35(3), 117-120.
- Petrescu-Mag, I. V. (2025b). Behavioral plasticity, honest signaling, and parental investment in *Betta splendens*: an integrative review across environmental and evolutionary contexts. *Studia Universitatis Vasile Goldiş Seria Ştiinţele Vieţii*, 35(3), 121-130.
- Petrescu-Mag, I. V. (2025c). Sexual selection in animals: pigment-based signaling and eco-evolutionary trade-offs. *Studia Universitatis Vasile Goldis Arad Seria Ştiinţele Vieţii*, 35(3), 106-116.
- Petrescu-Mag, I. V., Hărşan, R., & Pojar, T. N. (2026). Animal personality in *Betta splendens*: boldness, aggressiveness, syndromes and domestication. *Aquaculture, Aquarium, Conservation & Legislation*, 19(3), 964-978.
- Petrescu-Mag, I. V., & Proorocu, M. (2022). Temporary red and permanent red: from masculine vigor to sensory trap. *Poeciliid Research*, 12(1), 12-13.
- Popescu, M., Oroian, C., & Bora, F. D. (2025). Evolutionary models of female mate choice: integrating genetic benefits, sensory bias, learning, and sexual conflict. *Poeciliid Research*, 15(1), 23-28.
- Popescu, M., & Păpuc, T. (2025). Behavioural plasticity in female colour preference induced by diet cues in *Poecilia reticulata*. *Poeciliid Research*, 15(1), 1-3.
- Tobias, J., Aben, J., Brumfield, R. T., Derryberry, E., Halfwerk, W., Slabbekoorn, H., & Seddon, N. (2010). Song divergence by sensory drive in amazonian birds. *Evolution*, 64(10), 2820-2839. <https://doi.org/10.1111/j.1558-5646.2010.01067.x>
- Yohe, L. R., & Brand, P. (2018). Evolutionary ecology of chemosensation and its role in sensory drive. *Current Zoology*, 64(4), 525-533. <https://doi.org/10.1093/cz/zoy048>

Received: 30 July 2026. Accepted: 31 August 2026. Published online: 26 September 2026.

Authors:

Bianca Moldovan (BM), Department of Environmental Engineering and Protection, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Mănăştur Street, 400372 Cluj-Napoca, Romania, e-mail: bianca.bordeanu@usamvcluj.ro

Ioan Gheorghe Oroian (IGO), Department of Environmental Engineering and Protection, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Mănăştur Street, 400372 Cluj-Napoca, Romania, e-mail: neluoroian@yahoo.fr

Zsolt Attila Grabán (ZAG), National Association of Pigeon and Small Animal Breeders of Hungary, Budapest, Hungary, 1433 Budapest, Pf. 575, Hungary, e-mail: grabanzsolt@gmail.com

This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

How to cite this article:

Moldovan, B., Oroian, I. G., Grabán Z. A., (2027). Sensory drive and environmental constraints on signal evolution: a mini-review. *Animal Biology & Animal Husbandry*, 19(1), 1-10.