An ecocentric case against satellite constellations

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The deployment of satellite megaconstellations like Starlink, the author argues, threatens to deprive people of the natural night sky that is our human heritage. Beyond this important but anthropocentric worry, satellite megaconstellations pose uncertain and potentially significant concerns for wildlife and ecosystems. They could disrupt the migration patterns of animals who navigate by the stars, and their impact on the brightness of the night sky could result in adverse ecological effects across the globe. Perhaps most insidious of all, human tolerance of this novel threat to the night sky seems to betray a worrisome lack of reverence and respect for the more-than-human universe.

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Ecocentrists have plenty of reason to care about light pollution. In addition to disrupting our sleep and disconnecting us from the stars, artificial light at night is a significant and detrimental threat to wildlife and ecosystems, which have adapted to millions of years of reliable daily and seasonal cycles of light and dark.

A recent comprehensive report commissioned by the International Dark-Sky Association summarizes this threat: "Scientists have studied at least 160 species for effects due to light exposure. They have observed harms at levels from individual plants and animals all the way up to entire populations." Artificial light at night affects living organisms in numerous ways, including "finding food, the time at which certain animals first emerge from their hiding places, plant and animal reproduction, and animal migration and communication," and it can impact entire food webs by "chang[ing] the interaction between predatory species and their prey" (Barentine, 2022: 4). A recent meta-analysis of over 100 studies concluded that, due to its adverse ecological consequences, artificial light at night should be used only when necessary and regulated like any other pollutant (Sanders *et al.*, 2021).

Until recently, we dark-sky advocates liked to point out, on a note of optimism, that light pollution is the easiest type of pollution to clean up – requiring nothing more than the literal flip of a switch (or a natural disaster, such as the 1994 earthquake that caused a city-wide blackout in Los Angeles and prompted some alarmed residents to call the Griffith Observatory to inquire about a strange giant cloud in the sky; they were able to see the Milky Way for the first time). In the past few years, however, we've found our optimism unsettled by a novel threat to the night skies: satellite megaconstellations such as Elon Musk's Starlink.

A new global threat to the night sky

For the sake of providing global high-speed internet access, the satellite megaconstellations planned by companies like SpaceX will add tens of thousands of satellites to our already crowded heavens. At the time of this writing, there are about 5,500 operational satellites in orbit (Union of Concerned Scientists, 2022). SpaceX's Starlink alone is preparing to deploy 30,000 satellites in its second generation of satellites, and other companies like Amazon and OneWeb are planning their own megaconstellations.

I first learned about Starlink and megaconstellations in 2019, when reading the news that the launch of 60 satellites had 'photobombed' the Alpha Monocerotids, a rare meteor shower that was being recorded from the island of La Palma (Dvida, 2019). Ironically, in 2007 La Palma was also the birthplace of the Declaration in Defence of the Night Sky and Right to Starlight, which states that "An unpolluted night sky that allows the enjoyment and contemplation of the firmament should be considered an inalienable right of humankind equivalent to all other environmental, social, and cultural rights" (Starlight Initiative, 2007: 3). Now Starlink and other satellite constellations threaten to deprive everyone on Earth of their right to an unpolluted night sky – as the 'photobombing' betokened. Unlike streetlights or the sky domes of cities, the visual impact of satellite constellations can't be escaped by driving deep into the desert, sailing on the high seas, or travelling to a 'dark sky island' like La Palma.

Astronomers and dark-sky advocates are organized against this novel threat to the night. Last year, the International Astronomical Union created the Center for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference, dedicated to protecting the night sky from megaconstellations (International Astronomical Union, 2022). In December 2022, the US-based International Dark-Sky Association filed an appeal with the US Court of Appeals against a Federal Communications Commission order authorizing the launch of 7,500 SpaceX satellites (International Dark-Sky Association, 2023).

Most opposition to satellite constellations has focused on its impact on astronomy, as well as the loss of our collective human heritage of the night sky and its natural constellations. Little has been said about their possible impact, if any, on non-human species and ecosystems. I happen to believe that the human-centred objections are independently compelling and, indeed, provide sufficient reason to oppose satellite megaconstellations. Even from an anthropocentric perspective, it seems to betray a fundamental misvaluing of

what is important to relinquish the very possibility of viewing a natural night sky for the sake of a fast 5G connection at any point on land or sea.

In the remainder of this paper, however, I will consider non-anthropocentric reasons to oppose continued launches: the satellites could interfere with animals who navigate by the stars, such as some songbirds, and they will contribute to overall diffuse night sky brightness and its attendant ill effects on wildlife and ecosystems. I conclude by suggesting that the attitudes that enable us to permit the launch of satellite megaconstellations are themselves incompatible with ecocentrism.

Non-human celestial navigators

Satellite megaconstellations threaten the heritage of human cultures that continue to prize a tradition of navigating by the stars, but humans are not the only species that makes use of celestial navigation. Worse, we have no way to 'debrief' non-human species when our artificial lights intrude upon and overwhelm their evolutionarily-entrenched celestial cues.

It is well known that the localized sources of artificial light can impact animal migration. Light pollution from cities confuses migratory birds, often drawing them to urban centres where they are vulnerable to building collisions and other threats (*e.g.* McLaren *et al.*, 2018). Artificial light sources can also cause confusion and misdirection for species that rely on the moon for migration. This effect is perhaps best known due to its deleterious effect on sea turtle hatchlings (*e.g.* Thums *et al.*, 2016), and it has also been observed in other animals such as the sand hopper (Williams, 2020).

What about non-human species that refer to the stars to guide their movements? Celestial navigation has been observed in species ranging from Harbour Seals (Mauck *et al.*, 2008) to the Large Yellow Underwing moth (Sotthibandhu and Baker, 1979). Even the African dung beetle is known for its ability to navigate by the stars and the Milky Way. This species has also been demonstrated to be adversely impacted by artificial light at night: when light pollution obscures the beetles' typical celestial cues, they adopt artificial point sources of light as beacons. This increases the chances that multiple beetles will converge and come into conflict, or that beetles will arrive on asphalt or another artificial surface that's not conducive to burying one's ball of dung. Furthermore, when African dung beetles find themselves under light-polluted skies with *no* point sources of light, they simply become disoriented (Foster *et al.*, 2021).

We don't yet know how satellite megaconstellations will affect dung beetles, harbour seals and other animals who look to the stars to guide their movements. We do know, however, that other non-human celestial navigators can be confused and disoriented by false displays of the stars in the night sky. In the 1960s, Cornell scientist Stephen Emlen hand-reared Indigo Buntings and entrapped them in a planetarium with false displays of the night sky. Specifically, Emlen created a deceptive scene in which the night sky appeared to circle around Betelgeuse instead of Polaris. While I am admittedly uncomfortable at the thought of deliberately deceiving birds and disrupting

their natural migration patterns, the results are intriguing: the migratory propensities of the gorgeous Indigo Bunting is not entirely innate; instead, young birds learn which way to fly by studying the stars in the night sky. In Emlen's study, when time came for the birds' autumn migration, the deceived buntings innocently oriented themselves in the wrong direction. In other experiments, Emlen placed mature birds in planetariums in which certain stars or constellations were missing. He discovered that the Indigo Buntings could properly orient themselves if Polaris was missing provided that they could see familiar northern constellations; however, when these constellations were also removed, the birds lost their way (Emlen, 1970).

If Indigo Buntings and other birds can become disoriented by the alteration of the night sky in planetariums, could they also be disoriented by the alteration of the night sky by thousands of satellites in low-earth orbit? In an interview with *Vox*, Emlen himself said, "I do think that will completely screw up birds that are up there at night" (in Resnik, 2021). If we have empathy for our feathered friends, this expert testimony alone should be enough to pause the launches. Perhaps Indigo Buntings and other nocturnal migrants will be able to rely successfully on other cues, like the Earth's magnetic field, or perhaps they will still be able to find their lodestars despite the mess of megaconstellations. But we can't be sure of that, and an obvious application of the precautionary principle means that we ought to halt future launches until the impact on non-human celestial wayfarers can be proven negligible – and stop them entirely if it can't.

Diffuse skyglow

The most obvious way in which satellite constellations affect the night sky are the eye-catching streaks of strings of individual satellites. However, this is but the tip of the iceberg; behind these glitzy spectacles, space junk increases diffuse night sky brightness by reflecting and scattering sunlight, night in and night out. In fact, the collective impact of orbiting satellites has already brightened the night sky to the point that nowhere is truly dark, not even remote dark-sky areas where ground-based light sources are heavily regulated.

In a recent article, Miroslav Kocifaj and coauthors modelled the impact of satellites on diffuse night sky brightness – that is, how bright the sky itself appears, as opposed to the natural and manmade point sources therein. The authors concluded that light scattered by satellites and space debris had already caused diffuse night sky brightness to exceed the "limiting acceptable value of light pollution at astronomical observatory sites" (Kocifaj *et al.*, 2021: L43). According to the researchers' estimates, the cumulative effect is to increase diffuse light by about ten per cent over natural diffuse night sky brightness, which happens also to be the upper limit established by the International Astronomical Union in its standards for observation sites.

While the authors are most concerned about the impact on ground-based astronomical observation, the finding should also worry ecocentrists. It is crucial to note that this level of diffuse night sky brightness caused by space

junk is already discernible by the naked eye. In fact, it is perceptible even when individual satellites are not. As the authors write, "most Earth-orbiting objects cannot be visually detected and tracked individually, since their individual irradiances fall below the visual detection threshold. However, if several such objects are present [...] their combined irradiance may well reach the threshold, and may be perceived as a diffuse skyglow component" (Kocifaj *et al.*, 2021: L43). In other words, satellites are brightening our experience of the night sky – and that of other Earthlings – even when we don't perceive them as distinct objects and thus don't even realize they're there.

This problem, of course, will only increase as more and more satellites are launched into orbit. When existent, SpaceX's feeble responses have focused on dimming the brightness of the Starlink satellites. Channelling Mick Jagger, the favoured response has been to paint them black. However, as Kocifaj and coauthors note, "Any piece of matter in Earth orbit illuminated by the Sun reflects or scatters light" (Kocifaj *et al.*, 2021: L42). Merely painting the satellites will not prevent them from compounding the already enormous problem of diffuse night sky brightness caused by space junk.

Light pollution, as we've noted, has numerous and varied adverse consequences for wildlife and ecosystems. Some are the result of point sources of light, as when sea turtle hatchlings are lured ashore by bright coastal lights or when migratory birds are drawn off-course into danger-filled cities. But other disruptions to biological and ecological processes result from the general brightening of the night sky, such as impacts on the time of day at which animals are active (with implications for predator–prey relationships and food webs), timings of seasonal activities such as mating and migration, and metabolic disturbances.

Underlying attitudes

The threats of diffuse sky brightening and disruption of migratory animals discussed above provide ecocentrists with reason to worry about Starlink and other satellite constellations. Arguably, however, what is most egregious about the launch of Starlink and other such satellites is not what it *causes* but what it *reveals*. Hubris. Disenchantment. Shallowness. Lack of wonder at – and thus reverence for – nature in and for itself. Quite possibly, the attitudes that a person must hold to countenance the launch of satellite megaconstellations are attitudes that a person could not plausibly hold if one is an ecocentrist. An ecocentric mindset may be all-but inevitable if a person approaches the natural world with wonder, humility, empathy and selfless engagement, yet these virtues seem lacking in those who believe it's okay to destroy the night sky for everyone if it means that everyone can have an internet connection.

Simultaneously, those who endorse satellite megaconstellations are willing to deprive others of an important source of enchantment in nature, as well as the awe and humility that can inspire an ecocentric outlook. Virtues like modesty and humility can be instilled by experiences like gazing into the staggering depths of the heavens on a clear and dark night – into that unfathomable vast space beyond us, without us. We inhabit a planet

7.9×10^3 miles in diameter in a universe about 5.47×10^{23} miles in diameter. We are a species 0.3 million years old on a planet 4,540 million years old in a universe 13,800 million years old. With our naked eyes, we can see Andromeda as it was 2.6 million years in the past. We are small. Yet under a night sky filled with satellites, we will gaze into the 'universe' only to see our trivialities and trifles, launched into the heavens merely to broadcast signals back to our phones. It demands a certain anthropocentric hubris to create such a state of affairs.

There is little reason, meanwhile, for an ecocentrist to demand a 5G connection anywhere on Earth. Is this really necessary for the 71 per cent of Earth's surface that consists of water? Or in the half of Earth's terrestrial surface that many of us propose to protect for wild nature? Surely not. We must instead turn our attention to shrinking our societies – and, with it, our internet and cellular data infrastructure – before we colonize all of Heaven as well as Earth.

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