Artificial Lighting Technology And Ecological Light Pollution

The invention of artificial lighting technology is a product of the diurnal nature of man. Human's continuous pursuit of illuminating the night has led to light pollution which occurs when artificial light is improperly or excessively used. Astronomical light pollution causes difficulties in observing astronomical objects because of the increased nighttime illumination while ecological light pollution disrupts the ecosystem's natural lighting regimes. (Longcore & Rich, 2004). Light pollution is primarily caused by road and streetlights, lit buildings, advertising signs, billboards, private lighting (e.g., home), and transportation such as train stations, airports, and harbors (Falchi, 2018). It includes light trespass, glare, clutter, skyglow, and over-illumination. (Posudin, 2014).

Light pollution is becoming more pervasive as the human population rapidly grows and lighting technologies become more advanced. It is thus a global concern that brings negative consequences not only to astronomical research but also to the ecosystem. The gradual changes in the natural light cycle have substantial ecological impacts. (Rosenberg et al., 2019). These changes affect organisms that have behavioral activities and physiological processes that are dependent on either light or dark conditions (Gaston et al., 2013). With this, measures must be taken to control the impacts of light pollution. In seeking ways of resolving this environmental problem, it is essential to acknowledge that the effect of light pollution on the behavioral and physiological rhythms of organisms affects population and community interactions which in turn threaten the balance of the ecosystem.

Many behavioral and physiological rhythms of organisms correspond to the light cycle. The Earth's natural light cycle reflects its rotation which forms the basis of the temporal organization of organisms to which life has evolutionarily adapted (Falchi, 2018). Such biological rhythms require synchronization with the environmental time using external stimuli in the light-dark rhythm (Health Council of the Netherlands, 2000). Natural sources of illuminating the night such as the moon and stars always have low luminosity levels. The introduction and excessive use of artificial light have drastically increased nighttime lighting levels. Thus, the nighttime environment does not follow nature's photoperiod. Exposure to increased lighting intensity will likely modify the biological rhythms of living organisms, therefore, affecting their behavior and physiology.

Ecological light pollution is recorded to have an impact on the biology of various living organisms. Its influence on the behavior of organisms in natural settings is widely documented in field studies while its physiological impacts are known predominantly through laboratory studies (Gaston et al., 2017). Most of the papers were about its effects on individual organisms (Gaston et al., 2015). Artificial light at night either attracts or repels animals. This affects their orientation, and they could either be oriented, disoriented or misoriented by the light (Longcore & Rich, 2004). The way the organisms react to the altered environment affects behaviors such as foraging, migration, communication, reproduction, and hormone regulation.

It was found that exposure to light pollution prolonged the foraging time of some diurnal organisms such as the Platycryptus undatus – jumping spider (Frank, 2009), some species of

insectivorous birds (Lebbin et al., 2007), and waders (Santos et al., 2010), whereas other studies found that artificial light at night shortened the foraging time of some nocturnal animals such as mice (Bird et al., 2004; Farnworth et al., 2016) and some species of bats (Lacoeuilhe et al., 2014). Additionally, some species of bats have increased their foraging activity after being exposed to artificial light (Polak et al., 2011; Blake, 1994).

Migratory behaviors of some animals are also disrupted by light pollution. For instance, the upstream-directed compensatory flight of adult female mayflies is interrupted by artificial light (Szaz et al., 2015). The hatchling orientation of wild turtles is also disrupted by their attraction to artificial light near shore after entering the ocean (Thums et al., 2016). In migrating birds, the principal mode of orientation for navigation is through magnetoreception – a wavelength-dependent mechanism. (Gaston et al., 2013). A study reports that red light disrupts migration direction in silvereyes Zosterops lateralis (Wiltschko et al., 1993) while Erithacus rubecula requires light from the blue-green part of the spectrum (Wiltschko et al., 2007). This shows that, in addition to the brightness, the spectral composition of artificial lighting also has significant biological impacts.

Light pollution has also been reported to affect communication between organisms that utilize light to interact with other organisms. In some species, communication has implications for breeding success hence, artificial lighting at night sometimes affects reproductive behavior when communication between organisms is disturbed. For example, the ability of male glow-worms (Lampyris noctiluca) to locate light lures (Bird & Parker, 2014) is disrupted by light pollution. Artificial lighting also leads to the decrease of the beetle population under the Lampyridae family due to the disturbance of mate location. (Rich & Longcore, 2013). Due to the influence of streetlights, breeding activities forest-breeding songbirds started earlier than usual. Females began laying eggs earlier than those in a neighboring territory while the males started dawn singing earlier than males elsewhere in the forest (Kempenaers et al., 2010).

Some studies document the impacts of light pollution on the physiology of different organisms. Irregularities in melatonin production of humans (Reiter et al., 2011), alteration of the immune function in Siberian hamsters (Bedrosian et al., 2011), and interruptions in the sleeping pattern of the great tit - Parus major (Raap et al., 2016) are all derived from the impacts of ecological light pollution to the circadian rhythm of these organisms. The light pollution in lakes affects the photophysiology of the cyanobacteria Microcystis aeruginosa (Poulin et al., 2014). Reports have long existed that being exposed to artificial light has caused some deciduous tree species to retain their leaves for longer in autumn (Matzke, 1936). A study also reported that exposure to low levels of light or exposure to light over a short period influences a plant’s response to photoperiod (Bennie et al., 2016).

Most of the published research studies are concerned with the behavioral and physiological effects of light pollution on individual organisms but how these effects alter population and community ecology remain poorly understood (Gaston et al., 2015; Gaston et al., 2017). Nonetheless, there are findings wherein artificial nighttime lighting affects population interaction. For instance, Altermatt & Ebert (2016) reported a significant decrease in urban moth populations because of being exposed to artificial light for a long time. Light pollution has also been proven to negatively affect the population dynamics of aphid-parasitoid in which reduction of host numbers was observed (Sanders et al., 2015). Impacts of artificial light on population interactions may be well-documented but there are still existing gaps in understanding how it will affect demographic parameters such as immigration, births, and emigration which shape many

ecological processes (Gaston & Bennie, 2014).

The light pollution impacts on individual species cannot be used to interpret it into effect into ecological communities but the behaviors they exhibit as a reaction to the altered light environment have an impact on community interactions. (Rich & Longcore, 2013; Gaston et al., 2015). A research carried out by Davies et al. (2012) shows that artificially lit areas attract ground-dwelling invertebrates such as ground beetles and spiders. This results in community structure changes because they do not re-disperse in the daylight. Light pollution affects predator-prey relationships, too. In a research study carried out by Becker et al. (2012), large-bodied predatory fish and small shoaling fish flock into artificially illuminated areas. This finding highlights the role of light pollution in potentially increasing the predation levels through higher prey abundances and enhanced foraging capabilities for the visual predators. In the long run, disturbances brought by light pollution to the population and community interactions will cause alterations to the whole ecosystem.

Ecosystems are said to be in a state of equilibrium. Its self-correcting mechanisms allow it to fluctuate around a stable point (Hutchinson, 1948). Competition is usually regarded as the most important mechanism (Rohde, 2013). The examples show that artificial night lighting could cause community changes leading to an imbalance in interspecific and intraspecific interactions such as competition and predation. These changes could influence ecosystem characteristics and functions (Rich & Longcore, 2013). Therefore, light pollution can modify inter- and intraspecific interactions and community structure resulting in a new ecological niche that could eventually affect the balance and function of ecosystems.

In summary, the brightness and spectral composition of artificial light have been proven to influence the behavioral activities and physiological functions of many organisms. The impacts of light pollution on individual organisms are well-documented but studies on population and community interaction that influence the ecosystem are still extremely lacking. Hence, further work on light pollution is needed to broaden current knowledge of its ecological effects which, in the long run, is disruptive to the balance of the ecosystem if current trends persist. Findings on the ecological impacts of light pollution can be used for future work and in identifying ways to reduce its adverse environmental effects.

Current studies have helped to create initiatives intended to minimize the ecological impacts of artificial nighttime lighting. According to Longcore & Rich (2016), in mitigating the effects of light pollution, the need, duration, direction, spectrum, and intensity of light used should be taken into consideration. To effectively minimize adverse impacts of artificial lighting means to optimize the balance between what humans need and alteration of natural light cycles. This can be done by turning on light sources when and where it is required. Install lighting sources only in places that require light and turn off lights at which time they are of little benefit. Improving the design and usage of light sources directs light only to where it is needed. The spectra that provide enough human benefit and have minimum biological impacts should be chosen. The brightness intensity must also be controlled to ensure that the lights are only as bright as necessary for the purpose (Gaston et al., 2017). The alleviation of light pollution can be approached in a variety of ways and does not cost as much as other forms of pollution (Falchi et al., 2011). Artificial light is made for and by humans. Its excessive or improper use has numerous effects on animals, plants, and even humans. With this, let us not wait for these effects to tip off the balance of our ecosystem. It is time that we stop polluting the night and properly use light.