Glare can be categorized into different types [2-3] which are

- **Blinding Glare** describes effects such as that caused by staring into the Sun. It is completely blinding and leaves temporary or permanent vision deficiencies.
- **Disability Glare** describes effects such as being blinded by an oncoming cars lights, or light scattering in fog or in the eye reduces contrast, as well as reflections from print and other dark areas that render them bright, with significant reduction in sight capabilities.
- **Discomfort Glare** does not typically cause a dangerous situation in itself, and is annoying and irritating at best. It can potentially cause fatigue if experienced over extended periods.

2.4 Clutter

Clutter refers to excessive groupings of lights. Groupings of lights may generate confusion, distract from obstacles (including those that they may be intended to illuminate), and potentially cause accidents. Clutter is particularly noticeable on roads where the street lights are badly designed, or where brightly lit advertising surrounds the roadways. Depending on the motives of the person or organization who installed the lights, their placement and design may even be intended to distract drivers, and can contribute to accidents. Clutter may also present a hazard in the aviation environment if aviation safety lighting must compete for pilot attention with non-relevant lighting. For instance, runway lighting may be confused with an array of suburban commercial lighting and aircraft collision avoidance lights may be confused with ground lights [2-3].

2.5 Sky glow

Sky glow refers to the "glow" effect that can be seen over populated areas. It is the combination of all light reflected from what it has illuminated escaping up into the sky and from *all* of the badly directed light in that area that also escapes into the sky, being scattered (redirected) by the atmosphere back toward the ground. This scattering is very strongly related to the wavelength of the light when the air is very clear. Rayleigh scattering dominates in such clear air, making the sky appear blue in the daytime. When there is significant aerosol, the scattered light has less dependence on wavelength, making a whiter daytime sky. Because of this Rayleigh effect, and because of the eye's increased sensitivity to white or blue-rich light sources when adapted to very low light level, white or blue-rich light contributes significantly more to sky-glow than an equal amount of yellow light. Sky glow is of particular irritation to astronomers, because it reduces contrast in the night sky to the extent where it may even become impossible to see any but the brightest stars.

Light is particularly problematic for amateur astronomers, whose ability to observe the night sky from their property is likely to be inhibited by any stray light from nearby. Most major optical astronomical observatories are surrounded by zones of strictly-enforced restrictions on light emissions.

"Direct" sky glow can be reduced by selecting lighting fixtures which limit the amount of light emitted more than 90 degrees above the nadir. "Indirect" skyglow produced by reflections from vertical and horizontal surfaces is harder to manage; the only effective method for preventing it is by minimizing over-illumination [2-3].

2.6.1 Impacts of light pollution

Because the study of light pollution is still in its early days the impacts of this problem are not fully understood. While the increased brightness of the night sky is the most familiar of the many effects of light pollution (it is the most obvious and astronomers recognized it many years ago) many other alarming aspects are still unexplored: for example, the fact that light pollution leads to a great wastage of energy. Lighting is responsible for one-fourth of all energy consumption worldwide, and case studies have shown that several forms of over-illumination constitute energy wastage, including non-beneficial upward direction of night-time lighting. On a global scale, approximately 19% of all electricity used produces light at night [2-3]. The by-product of electric illumination generated by the burning of fossil fuels is the discharge of greenhouse gases. These gases are responsible for global warming and the exhaustion of non-renewable resources.

Light pollution produces many other impacts on the environment. Harmful effects involve the animal kingdom, the vegetable kingdom and mankind. While light pollution is eminently detrimental to nocturnal and migratory animals and to animals in flight, it also produces harmful effects on plants.

2.6.2 Impacts on Plants

Plants use darkness in many different ways. The management of their metabolism, their development and their life programmes are affected. Plants measure and react to night length which means the duration of darkness. For this reason short-day plants require long nights. If such a plant is illuminated temporarily during a long night, it reacts and interprets as if it had experienced two short nights, instead of one long night with a disruption. As a consequence its flowering and developmental patterns possibly will be entirely disrupted: short-day plants normally bloom in the autumn when the day length shortens. They utilise the long nights to start the onset of flowering; and subsequently, as the nights lengthen, the onset of dormancy, which enables them to resist the harshness of winter [4].

Studies suggest that light pollution around lakes prevents zooplankton, such as Daphnia, from eating surface algae, helping cause algal blooms that can kill off the lakes' plants and lower water quality. Light pollution may also affect ecosystems in other ways. For example, Lepidopterists and entomologists have documented that night-time light may interfere with the ability of moths and other nocturnal insects to navigate. Night blooming flowers that depend on moths for pollination may be affected by night lighting, as there is no replacement pollinator that would not be affected by the artificial light. This can lead to species decline of plants that are unable to reproduce, and change an area's long-term ecology.

Trees provide entire ecosystems to numerous animal species. They are harmfully affected by light pollution. Trees have to adjust to seasonal alterations, and artificial light hinders

them from doing so: various trees are kept from losing their leaves by light pollution. This has a consequence on the animals that depend on trees as their habitat. For instance, birds are prevented from nesting in trees as a result of the surrounding light pollution.

2.6.3 Impacts on Animals

Life has emerged with natural patterns of light and dark, so disturbance of those patterns influences numerous aspects of animal behaviour. Light pollution can confound animal navigation, change competitive interactions, alter predator-prey relations, and affect animal physiology [1].

a) Threats to birds

The effect of light in the form of fire or lamps attracting migratory and non-migratory birds at night, especially when foggy or cloudy, has been known since the 19th century and was and still is used as a form of hunting[1]. The reasons for disorientation of birds through artificial night lighting are not well known. Experts suggest that the navigation of birds using the horizon as orientation for the direction is disrupted by lighting and sky glow [5].

Lighthouses

The attraction of lighthouses and ships for birds was first recorded since the first operation in the mid 19th century and was the basis of the first detailed records of bird migration. The fatalities at light- houses depend on the type of signal used. Fixed white lights attract more individuals than flashing or coloured lights [6].

Light beams / Ceilometers

The attraction of light beams has been observed since the 1940s when meteorologists installed ceilometers - light beams to measure the cloud height especially at airports. In 1999 Bruderer et al. studied the behaviour of birds exposed to a light beam and X-Band radar. The light beam caused a change in the flight direction up to 15° and a decrease of velocity up to 3m /sec. Approximately 50,000 migratory birds (largest kill ever recorded at a ceilometer) died on October 6-8, 1954 at Warner Robins Air Force Base in Georgia, when a cold front moved over the Southeast [1]. Filtering the longer wavelength of the lamps used and changing the units from a fixed beam into a rotating one, significantly reduced the number of casualties [5].

Offshore oil / Gas platforms / Light induced fisheries

Due to the fact that oceans have less artificial light sources compared to terrestrial environments, the effect and range of single artificial lighting is much higher. As a consequence of these circumstances marine birds are highly attracted by these sources. The birds are attracted by the flares of the platforms and can be directly injured or killed by heat, collision and oil; but also indirectly by the trapping effect of the light that leads birds to circle around the light source reducing their energy reserves and making them unable to reach the next shore or decreasing their ability to survive the winter or repro- duce. Light induced fisheries use their light to attract fishes and squids but also have an effect on birds. Hooks then can injure these birds [5].

City lights / Horizon glow

The permanent growth of cities and the associated increase in artificial lighting by streetlamps and illuminated buildings has fatal consequences for migratory birds. These mostly nocturnal migratory species are disorientated and attracted by the sky glow which cities produce during the night. This effect arises especially under foggy and rainy weather conditions, with the result that hundreds and even thousands can be injured or killed in one night at one building [7].

Towers

The growing number and height of telecommunication and broadcasting towers cause a growing number of fatal collisions with migratory birds. These structures sever migration routes, mostly of songbirds.

Two reasons are given for collisions with towers. The first is when birds flying in poor visibility do not see the structure early enough to evade it (blind collision). The second mechanism for mortality arises when there is a low cloud ceiling or nebulous conditions, and lights on a tower refract off water particles in the air creating a lit up array around the tower. Birds lose their stellar cues for nocturnal navigation under these weather conditions. Furthermore, they lose all wide orienting perspective they might have on the landscape because they are flying beneath quite a low cloud ceiling. When passing the illuminated area, it could be that the increased visibility around the tower becomes the strongest cue the birds have for navigation, and as a result they tend to stay in the illuminated space near the tower. Mortality occurs when they fly into the structure and its guy wires, or even collide with other birds as more and more passing birds overcrowd the quite small, illuminated space [8].

Newer studies show that using rotating or blinking red lights and white strobe lights can reduce the effect of trapping birds at illuminated towers, but there is still work to do to improve the understanding of the whole effect on the migration process [5].

b) Threats to sea turtles

Effect on adult females

Artificial light has several effects on female turtles searching locations for nests and on hatchlings finding the sea. The female turtles avoid illuminated beaches for their nests with the effect that the nests are concentrated on the less illuminated and shaded parts. This can cause a selection of a suboptimal nesting habitat or special concentration of nests, with effects on the number and sex ratio of hatchlings produced and higher hatchling mortality [9-10]. The nesting behaviour itself can be affected by many factors. The overall nesting success of sea turtles in Florida is between 50% and 80%. The process can be abandoned when turtles encounter digging impediments, large structures, unsatisfactory thermal cues or human disturbance. After ending the nesting process, the turtles return to the sea. This process can be affected by artificial light. In a few cases, lights from car parks, road lighting and housing developments attract the turtles.

Effect on hatchling sea turtle orientation

The hatchlings themselves are affected by the sky glow and direct illumination too.The way that hatchling marine turtles find the sea is based on the fact that the nocturnal horizon over the sea is brighter than that over the land [9,11]. The artificial light of street lamps, houses or sky glow of cities, especially on nights with little or no moon, can dis- or misorientate the hatchlings on their way to the sea. Because of these orientation problems, the hatchlings crawl in the wrong direction where they are threatened by dehydration, predators, and high temperatures after sunrise.

Solutions

To minimise the negative effects of artificial lighting, new strategies of light management are necessary. Light must be used more precisely. It should be less intensive and in longer wave-lengths so it is less disruptive to the wildlife. The regulations must be implemented through laws as is already done in most counties in Florida for example [9, 12].

c) Threats to fish

Reaction (attraction and avoidance) of fish to artificial light depends on the species but affects their natural behaviour in both ways. There are several studies on the use of artificial light at fish farms and deep-sea fish. Most of the studies show that fish avoid white light sources. Nevertheless, there are species that are attracted by light and this is used to catch them by sport anglers or industrial fisheries.

Light attraction method to catch Mukene

Light attraction is widely used by anglers to catch fish in the dark. The FAO reports that fishing with floating lamps is used at Lake Victoria to catch the Mukene using scoop-nets and nets pulled from the shores (beach seines) and from canoes (lampara nets). This method can endanger nursery grounds for immature Mukene, Nile perch and Tilapia because it is used in shallow waters near the coastlines [13].

Salmon farms

Submerged light increases swimming depth and reduces fish density of Atlantic salmon in production cages. These artificial photoperiods are used to postpone sexual maturation and increase growth. Studies in these farms suggest that salmon position themselves in relation to the artificial light gradient to maintain schooling behavior [14-16].

Halibut farms

Light used in Halibut farms influences their swimming behaviour. Artificial light influences the swimming depth and the swimming activity: Halibut swim less and grow more. It may be that the fish are particularly sensitive to ultraviolet damage. Evidence of damage (skin lesions, etc.) has been observed in Halibut. This is particularly the case for fish that are acclimatised to indoor conditions, and which are moved out in the spring, when the sun is
most intense. Farmers can protect their stock with the use of shade nets[17].

Deep-sea fish

A study of lighting techniques in deep-sea fish observation pointed out that white light disrupts the natural behaviour of deep-sea fish. Observations showed that the “average number of fish appearances on camera was significantly greater under red light than white light” [18]. Reasons are the adaptation of the eyes of deep-sea fishes to the dark environment and the possible damage to eyes by bright lights.

Effects on Human Health and Psychology

Medical research on the effects of excessive light on the human body suggests that a variety of adverse health effects may be caused by light pollution or excessive light exposure, and some lighting design textbooks [19] use human health as an explicit criterion for proper interior lighting. Health effects of over-illumination or improper spectral composition of light may include: increased headache incidence, worker fatigue, medically defined stress, decrease in sexual function and increase in anxiety [20-21].

Common levels of fluorescent lighting in offices are sufficient to elevate blood pressure by about eight points. There is some evidence that lengthy daily exposure to moderately high lighting leads to diminished sexual performance. Several published studies also suggest a link between exposure to light at night and risk of breast cancer, due to suppression of the normal nocturnal production of melatonin.

In 1978 Cohen et al proposed that reduced production of the hormone melatonin might increase the risk of breast cancer and citing "environmental lighting" as a possible causal factor. Researchers at the National Cancer Institute (NCI) and National Institute of Environmental Health Sciences have concluded a study that suggests that artificial light during the night can be a factor for breast cancer. In 2007, "shiftwork that involves circadian disruption" was listed as a probable carcinogen by the World Health Organization's International Agency for Research on Cancer. (IARC Press release No. 180). Multiple studies have documented a link between night shift work and the increased incidence of breast cancer [22-25].

A good review of current knowledge of the health consequences of exposure to artificial light at night and an explanation of the causal mechanisms has been published in the Journal of Pineal Research in 2007.

Effect on Astronomy

Sky glow reduces the contrast between stars and galaxies in the sky and the sky itself, making it more difficult to detect fainter objects. This is one factor that has caused newer telescopes to be built in increasingly remote areas. Some astronomers use narrow-band "nebula filters" which only allow specific wavelengths of light commonly seen in nebulae, or broad-band "light pollution filters" which are designed to reduce (but not eliminate) the effects of light pollution by filtering out spectral lines commonly emitted by sodium and mercury-vapor lamps, thus enhancing contrast and improving the view of dim objects such as galaxies and nebulae. Unfortunately this affects color perception, so these filters cannot be used to visually estimate variable star brightness, and no filter can match the effectiveness of a dark sky for visual or photographic purposes. Due to low

surface brightness, the visibility of diffuse sky objects such as nebulae and galaxies is affected by light pollution more than are stars. A simple method for estimating the darkness of a location is to look for the Milky Way.

Light trespass can impact observations when stray light enters the tube of the telescope from off-axis, and is reflected from surfaces other than the telescope's mirrors (if any) so that it eventually reaches the eyepiece, causing a glow across the field of view since it has not been focused. The usual measures to reduce this glare, if reducing the light directly (e.g. by changing one's location or having the light turned off) is not an option, include flocking the telescope tube and accessories to reduce reflection, and putting a light shield (also usable as a dew shield) on the telescope to reduce light entering from angles other than those near the target. In one Italian regional lighting code this effect of stray light is defined as "optical pollution", due to the fact that there is a direct path from the light source to the "optic" - the observer's eye or telescope [26-28].

3. Reduction of Light Pollution

Reducing light pollution implies many things, such as reducing sky glow, reducing glare, reducing light trespass, and reducing clutter. The method for best reducing light pollution, therefore, depends on exactly what the problem is in any given instance. Possible solutions include:

i. Utilizing light sources of minimum intensity necessary to accomplish the light's purpose.
ii. Turning lights off using a timer or occupancy sensor or manually when not needed.
iii. Improving lighting fixtures, so that they direct their light more accurately towards where it is needed, and with less side effects.
iv. Adjusting the *type* of lights used, so that the light waves emitted are those that are less likely to cause severe light pollution problems.
v. Evaluating existing lighting plans, and re-designing some or all of the plans depending on whether existing light is actually needed.

4. Recommendations

i. Light only where needed
ii. Don’t overlight
iii. Don’t waste light
iv. Shine light downwards, using shields and reflectors
v. Light only when needed – use sensors where possible
vi. Light with energy efficient sources such as LED’s and compact fluorescents.
vii. Much more research is needed on the effects of light pollution
viii. Public and government awareness shall be intensified in view of the value of protection, avoidance and decrease of light pollution. Public opinion would need to be shifted regarding light trespass and “second hand” light, the wastefulness of excessive night lighting and the importance of using the right lighting for the right situation.
ix. Legislation needs to be developed to support and require dark sky friendly lighting through by-laws, modified engineering standards and building codes[29].

The variety of environmental conditions is important because it contributes to the partition of resources and greater biodiversity. Various natural processes can only happen during the night in darkness. Examples are resting, repairing, celestial navigation, predating or charging of systems. For this reason, darkness has the equal and amendatory functional importance as daylight. It is indispensable for the healthy functioning of organisms and whole ecosystems.

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Author Profile

Dr. Rasna Rajkhowa was born in Jamugurihat, Sonitpur, Assam. She did her Ph. D. in high energy physics from Tezpur University, Tezpur, India. Currently she is working as Assistant Professor at T. H. B. College, Jamugurihat, Assam. She had published many papers in national and international journals.