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Light pollution: a case for federal regulation

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LIGHT POLLUTION: A CASE FOR FEDERAL REGULATION?

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ABSTRACT

The purpose of this thesis is to examine the body of evidence concerning light pollution and exposure to artificial light and determine if the scientific research warrants regulatory oversight in the United States. The first question that guided this effort was: *Does improper artificial lighting and exposure to light-at-night constitute a risk to human health and safety?* The follow up question being: *Is light pollution a concern to ecological systems, and if so to what extent?* A comprehensive literature review was conducted to ascertain the status of the research—if any—in these two areas and what the findings were.

The overarching purpose of this thesis was to answer the primary question: *Does the scientific research on light pollution and exposure to light-at-night exposure make a case for regulatory oversight, within the mandate of the EPA?* The questions were illuminated by conducting a thorough literature review, doing an informal email survey, and by in-depth interviews with people researching artificial light and with individuals in the EPA.

The study concluded that there is no ready consensus to be reached in this area. Such a disparate topic as light pollution does not readily lend itself to an easy answer. However, the findings show that light pollution and light-at-night exposure do have some negative impact. This is especially true in regards to the night sky and the biota. Whether the EPA should be involved in regulating it is not entirely clear. Their mission statement leads one to presume that certain effects of light pollution do fall under their mandate. More research to quantify the effects of artificial light on humans is critically needed to show causation between artificial light exposure and health problems.

Key words: EPA, light-at-night, light pollution, melatonin, regulation.

1.0 INTRODUCTION

This section provides a recapitulation of the work carried out as part of this thesis effort. It presents the thesis topic, the significance of and interest in the topic, and the research objectives. This section also defines terms and acronyms used in this treatise.

1.1 Topic

Artificial light is prevalent in modern industrialized society. In fact it is so ubiquitous that most people give little or no thought to it. Most people consider artificial light to be a boon to society in almost every aspect. Few consider the impact (both positive and negative) that artificial light has on people and the environment. Artificial light that is considered a nuisance typically has been categorized as "light pollution". Light pollution falls into several different categories that have varying impacts on human health and safety, the surrounding biosphere, and humanity's enjoyment of pristine skies. For many years light pollution was mainly a concern only to astronomers and was thought to be of little or no importance to anyone else; relatively new avenues of research are challenging this long held assumption and calling into question beliefs that people have about artificial light and its impact on the environment. David Crawford, PhD, Executive Director of the International Dark Sky Association (IDA) notes in his article, "Light Pollution—Theft of the Night" that problems associated with light pollution include sky glow, glare, light trespass, a confusing night-time environment and energy waste (27-28). For the purposes of this paper light pollution will be defined as "Any adverse effect of artificial light including sky glow, glare, light trespass, light clutter,

decreased visibility at night, and energy waste" (International Dark-Sky Association, par. 1). Besides its deleterious effect on esthetics and safety, light pollution is increasingly being linked to human health problems and to adverse effects on the Earth's ecological systems including the production of greenhouse gases associated with inefficient and—in some cases—unnecessary artificial lights.

1.2 Significance of Topic

Artificial lighting, properly installed and used, benefits people and society. Sometimes light fixtures (or luminaries) are either unnecessary or pose a hazard to people and to the environment. Problems associated with artificial lighting are glare (what a person sees when bright lights of an oncoming car shine directly into their eyes, for example), light trespass (light put into an area where it is not intended, for example, a neighbors floodlight, lighting the bedroom of another), sky glow (excess light escaping into the nighttime sky where it is not needed) and energy waste (a consequence of overabundant, superfluous lighting or improper light fixtures).

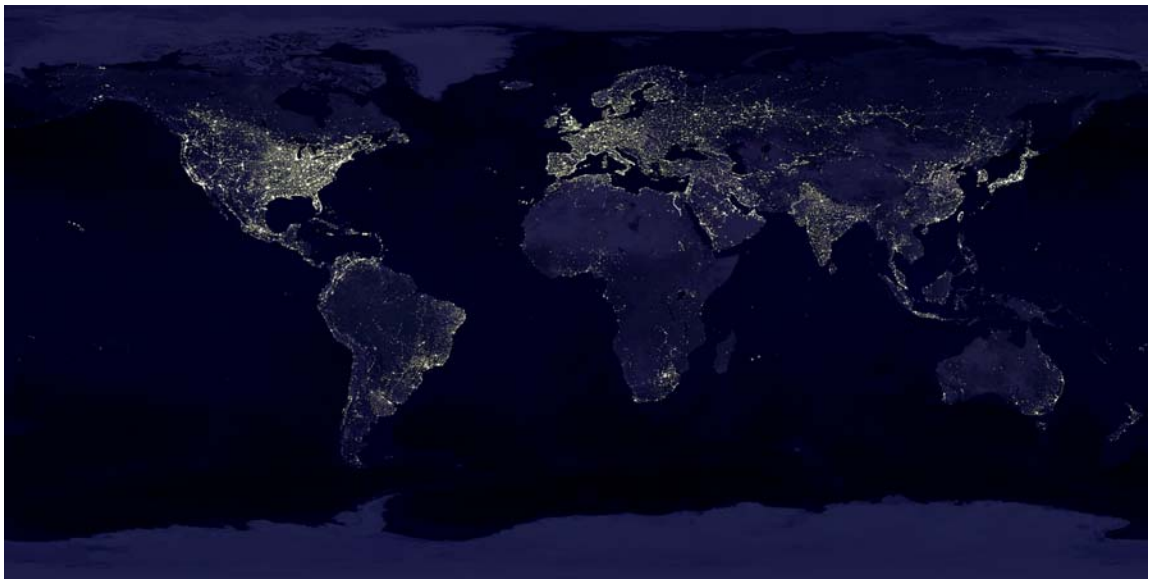
Research on light at night (LAN) shows that artificial light can have a negative impact upon the biota. In the preface to their text, Ecological Consequences of Artificial Night Lighting, editors Travis Longcore and Catherine Rich state, "As the night is ever more brightly lit, at least we [people] can close the shutters. But what of the plants and animals?" (xv). Research shows the harmful impact that artificial light has upon different animal species, including sea turtles, birds, lizards, insects, and even plants. In some cases the research is ambiguous—that is, a ready-made answer (lighting is bad) is not

easily deduced. Yet, artificial light clearly has an impact on the biosphere outside of the human arena, an impact that may deserve attention in the regulatory scheme of this nation. Although some regulation has been instituted—mostly at the local level—one wonders if artificial lighting has garnered enough interest at the national level or if such scrutiny is warranted.

Perhaps the most interesting research that is being conducted on light pollution, and light-at-night exposure, involves light and human health. This research appears to link exposure to light-at-night to melatonin suppression and a general disruption of our innate circadian rhythms which are based on the natural cycles of light and dark. The mechanism for this is not entirely understood, but it appears that exposure to light-at-night affects the way the human body synthesizes melatonin which is an important anti-oxidant, which when suppressed by light-at-night *may* lead to an increase in certain cancers.

The magnitude of the light pollution "problem" may be likened to that of Indoor Air Quality (IAQ). Indoor Air Quality is not just one concern, but rather a plethora of related issues (such as radon, formaldehyde, mold, carbon monoxide and environmental tobacco smoke) that falls under the catchall term of IAQ. Both problems (light pollution and IAQ) include many issues. The primary difference between the two is IAQ is an acknowledged environmental concern and regulated in the United States, by the EPA, whereas light pollution is not federally regulated. Further, IAQ is a chemical problem whereas light pollution is a physical one. As light pollution becomes an ever-larger concern, and as research mounts on its effects, it seems plausible that in the future some national oversight may be warranted under the mandate of the EPA. The following

picture, a mosaic of satellite images, shows the Earth at night. This one picture clearly shows the magnitude of light pollution as an issue. Earth is illuminated to such an extent that it is easy to pick out cities and other distinguishing geographic areas.



Picture 1.1 – Earth at Night: (http://veimages.gsfc.nasa.gov/1438/earth_lights_lrg.jpg)

1.3 Reason for Interest

Interest in light pollution has been gaining momentum in recent years. Artificial light is ubiquitous in our society and only recently has research into light-at-night and light pollution gone beyond the obvious astronomical concerns. People in western civilization are increasingly exposed to an unnatural cycle of light and dark which is contrary to our evolutionary precedent as a diurnal creature. This exposure could potentially short-circuit our circadian rhythms with repercussions that only now are gaining researcher's attention. Besides this relatively new avenue of inquiry, research shows that artificial light's impact on the biota has definitive consequences. Sea turtles

and migrating birds are two types of animals that have been studied extensively in this context, and researchers are also looking at many other animals. Beyond the impact on the biota some people are concerned with the effect light pollution has on our view of the night sky as a natural resource. Some believe the night sky has an intrinsic value all its own that should be protected as a natural resource. The author's interest in this topic stems from his activity as an amateur astronomer who values the night sky as a resource and it also stems from his regular exposure to artificial light-at-night working a swing shift.

1.4 Research Objectives

The research thrust was to ascertain the current status of light pollution and light-at-night research, identify its chief researchers, and to answer the following questions:

1. Does improper lighting (defined as light pollution) and exposure to artificial light-at-night constitute a risk to human health and safety?
2. Is light pollution a concern to ecological systems, and if so to what extent?
3. Does the scientific research on light pollution and exposure to light-at-night make a case for regulatory oversight, within the mandate of the EPA?

The literature review examined scientific journals, textbooks, scholarly magazines, conference proceedings and websites. Sources were limited to those written in (or translated into) English. The literature review was conducted to identify areas with a great deal of knowledge, areas with lesser degrees of knowledge (that is, where less research has been conducted), and areas where little or no research was found in the

literature. The purpose of the research was to answer the research questions listed previously, and bring together disparate areas of the discipline and forge it into a cohesive whole.

1.5 Research Focus

Light pollution is an extensive, multi-faceted problem. This study looked at the major effects of this phenomenon. The primary research questions, however only encompassed light pollution effects on the biota, and possible effects on human health. Hence, the literature review takes in a broader swath of the research whereas the primary concern of the thesis is to obtain the answer to the question: is the research on light pollution and exposure to light-at-night sufficient to warrant federal regulation, under the stated mandate of the EPA?

Although extensive research confirms degradation of the skies for astronomical purposes less is known about artificial lights' impact on people and the biota. Furthermore, the researcher believes that this thesis is the first time anyone has asked whether the problem of light pollution warrants regulation at the federal level of the United States government.

1.6 Definitions

Circadian – Having to do with a rhythmic cycle, entrained by light and dark exposure.

Diurnal – "Daily." Generally refers to animals active at day and less active at night.

EPA – Environmental Protection Agency.

IAQ – Indoor Air Quality.

IDA – International Dark Sky Association.

LAN – Light at Night.

Luminaire – Light fixture.

Lux – Measurement of light.

Melatonin (MLT) – Hormone synthesized by the pineal gland.

NIEHS – National Institute of Environmental Health Sciences

NIMH – National Institute of Mental Health

Pineal Gland – Endocrine gland located in the brain. Responsible for melatonin production.

2.0 BACKGROUND

> *In the beginning God created the heavens and the earth. The earth was without form and void, and darkness was upon the face of the deep; and the Spirit of God was moving over the face of the waters. And God said, "Let there be light" and there was light. And God saw that the light was good; and God separated the light from the darkness.*
>
> (Genesis 1:1-4)

The cycle of light and dark is as old as the beginning of the solar system, some 4.5 billion years. Human beings—indeed all life forms on Earth—have evolved with a natural rhythm of light and dark that varies by season and latitude. The biblical author of Genesis noted this and found it to be good, as noted above. Just in the last 100 years with the modern illuminated era have large parts of the world been swathed in artificial light. What has this done to our environment? Is it a positive development? Is it good to interfere with the natural cycles of light and dark? And if not, what are the drawbacks and do they constitute a risk to people's health and safety or to the biosphere at large? If the effect of artificial light is not entirely benign, to what extent does it appear to be detrimental? And, if shown to be harmful does it argue for federal regulation like other pollutants? Should light even be considered a pollutant?

Research on artificial lighting and its impact fall into four primary categories, which are:

1. impact on esthetics (astronomical uses and enjoyment of the night sky)
2. impact on wildlife (ecology)
3. impact on people (health and safety) and
4. impact on the environment by way of energy consumption.

These areas have some crossover in their impacts and referencing. Associated with these

primary avenues of research are those that are secondary in nature to this thesis (that is, research done on light-at-night and on an associated reduction of crime). This research is all relatively new (within the last 40 years or so) and the research being done on the impact on human health is the latest. Therefore, the field is burgeoning with opportunities for examination. The following literature review gives an expansive overview of the state of this research, its implications and importance.

3.0 LITERATURE REVIEW

3.1 Light Pollution and Esthetics

Light pollution is a major concern to astronomers, both professional and amateur. Astronomers need dark skies in order to study very faint objects. The professional astronomical community has been in the forefront of light pollution research as it is in their best interest to see this problem curtailed or eliminated. As noted by authors Alvarez del Castillo, Crawford and Davis in their paper, "Preserving our Nighttime Environment: A Global Approach" light pollution has been recognized as a problem since the 1920s. The article also points out that in the early 1970s light pollution was increasingly seen as a threat to their profession (56). Although professional astronomers are only a tiny fraction of the population at large it is thought that artificial light was first considered a problem due to their attention to this matter. Of greatest concern to astronomers is the phenomenon known as "sky glow". Bob Mizon, author of Light Pollution: Responses and Remedies defines it thusly: "Sky glow is light which is being carelessly, or sometimes deliberately, projected from the ground or a structure, coloring the night sky and reducing the visibility of astronomical objects" (28-29). More artificial lighting leads to more sky glow, reducing opportunity for astronomical observations, and leads to a marred nighttime sky. Sky glow is a consequence of improperly shielded lighting, improperly aimed lighting, and unnecessary light fixtures, which puts light into unintended areas. Another major consequence of the overabundance of artificial lighting is a great deal of energy waste.

Light pollution research by the astronomical community includes:

1. modeling night sky brightness through satellite measurement (Cinzano and Elvidge; Cinzano, Falchi and Elvidge)
2. satellite monitoring of light pollution as a policy device (Petraikas and others)
3. monitoring the growth of light pollution over North America in the last 50 years (Cinzano)
4. precisely measuring light loss from street lighting (Gillet and Rombauts)
5. light pollution monitoring of the suburbs via geographic information systems (Chalkais and others)
6. hyper spectral remote sensing of light pollution (Barducci and others), energy loss (Isobe, Hamamura and Elvidge) and,
7. research on the effects of artificial lighting on the environment and humans (Kirschbaum).

This research has been shared with the scientific community at large to gauge the impact of artificial lighting on the environment.

David Crawford, formerly an astronomer at Kitt Peak and co-founder and Executive Director of the International Dark Sky Association in Arizona, notes,

> Light pollution is truly an environmental issue. The night is part of the environment too, and producing so much wasted energy lost by poor lighting has other major adverse impacts as well. In some sense, astronomers are like the 'canaries down the mines'; we are so sensitive to poor lighting that we are suffering much more than the general public—and we are crying out for help." ("Light Pollution: The Problems, the Solutions" 27).

When light is viewed as an environmental contaminant we find it is a problem of esthetics—not just for astronomers but also for everyone concerned with our environment and our impact upon it.

3.1.1 Light Trespass, Glare and Skyglow

The effects of light pollution are categorized for this research endeavor into four basic categories. And as noted above the phenomenon of greatest importance to the astronomical community is sky glow. Two other effects that are considered in this literature review are light trespass and glare, which may be of greater importance to the average person. Mizon notes that light trespass is "not just an astronomer's problem. The quality of many people's lives, whether or not they observe the stars, is seriously affected by neighbor's insensitive lighting, or the glare from road lamps, needlessly entering their property. And humans are not the only species troubled by stray light" (43). The Lighting Research Center, at Rensselaer Polytechnic Institute, notes on its webpage on light trespass, that it is not easily measured, and it can be highly subjective (par. 1). While true, this does not necessarily mean that light trespass does not impact people or that it has gone unnoticed. Ploetz states that litigation concerning light pollution has been tried under the common law precepts of nuisance and trespass (1001). Light trespass may not be an insurmountable problem, if people are made aware that it is easy to overcome. The article, "Let There Be Light (Not)" states "Simply replacing a 60- or 75-watt bulb with a 40-watt bulb in an opaque-top porch light will eliminate light trespass onto a neighbor's property while still illuminating the front of a house.

Likewise, a shielded light fixture will direct the light downward, where it's needed, and prevent both light trespass and skyglow" (22). Light trespass, while perhaps not a "big deal" in the pantheon of environmental problems facing us today, could become a larger issue, if exposure to artificial light-at-night can be conclusively linked to human health problems.

Along with light trespass and skyglow, glare from artificial lighting is a concern. Lockwood says that glare is "caused by overly bright lights, and building floodlights—[it] is literally blinding drivers. They can't see people in the cross-walk ahead of them, or cars stopped on the side of the road" (22). On its webpage "What is Glare?" page, the Lighting Research Center of the Rensselaer Polytechnic Institute, on its webpage states:

> Glare is the sensation produced by a light source that is sufficiently greater than the light level to which a person's eyes are adapted. Glare causes annoyance, discomfort, or loss in visual performance and visibility. The headlamps of an approaching car, for example, may cause glare. Another common source of glare is light shining through a window onto a television screen. Effective lighting designs avoid glare.
> (par. 1)

Glare—undoubtedly a nuisance—can thus be considered a hazard. Anybody who has been blinded by oncoming headlights or had a spotlight shined into their eyes will know that. Indeed glare can be disorienting at best, and may constitute an even greater hazard when driving. Crawford believes that glare is all too common, but should improve as the lighting technology gets better ("Light Pollution-Theft of the Night", 27). Schreuder also mentions billboards as contributing to light pollution and says "car headlamps presumably will contribute to the light pollution". He warns, however, "studies in this area are urgently needed, particularly as many call for increased intensity

of car headlamps. It should be noted that one might doubt whether this move will result in positive effects for road safety." (191). Thinking more light is better is a factor contributing to the onslaught of artificial light on western civilization. Nigel Pollard a light consultant says, "Better lighting does not necessarily mean more lighting. Quality does not equal quantity" (137). And that great quantity of artificial light is impacting the night sky.

While the overall esthetics of a dark night sky may not seem to cry out for regulatory supervision, some feel otherwise—that the night sky deserves legal safeguarding. In effect, some people want to treat the night sky as a universal heritage worthy of protection by law, without invoking artificial light's effects on safety, the biosphere or human health. Ploetz claims that many people consider the night sky a natural resource, worthy of protection (996). A few jurisdictions in the United States have some laws to protect the night sky. States with light pollution laws include Texas, Connecticut, Maine, New Mexico, Michigan, and Arizona (1018-1024). Worldwide there are national laws in the Czech Republic, and Chile (Alvarez del Castillo, Crawford and Davis). Most of these laws are designated to protect specific areas that are either ecologically sensitive or have astronomical facilities, and which are—in some cases—economically important. "To date there is no federal, and relatively little state, legislation in place to reduce light pollution and its impacts, and the majority of legislation for reducing this relatively new type of pollution largely exists at the county and municipal levels" (Ploetz 1017). Noted in the paper, "Preserving our Nighttime Environment: A Global Approach", authors Alvarez del Castillo, Crawford and Davis state that Michigan is unique in that, "The Michigan Dark Sky Park (Lake Hudson Recreation Area) was the

first in the U.S.A. to be established, and these preserves continue to be established in State Parks and on local levels" (55). While this is a good start, the increasing use—and misuse—of artificial lighting may necessitate further action. As the Earth's population grows and many nations experience a surge of industrialized growth (China and India being two prime examples) the pervasiveness of artificial lighting may become a larger problem, and require more attention devoted to solutions. Cinzano, a noted researcher in the field of light pollution modeling, says that by 2025 quite possibly fewer than 100 stars will be visible from the urban areas of Italy. His calculations for Europe and the United States are equally alarming (Feder 24).

It is interesting to note that the National Park Service (NPS) has implemented a plan for the effective monitoring of light pollution at five parks. "According to Chad Moore, physical scientist at Pinnacles [a national monument] and coordinator of the project, the ultimate goals are to establish a measurable standard for light pollution, provide resource managers at park units with measurement tools, and raise awareness of light pollution in the general populace" (Updike 14). This shows light pollution research and education are gaining attention in some circles. Updike also notes the financial impact of all that wasted light: "In addition, excessive exterior lighting wastes energy—costing the United States more than $1.5 billion annually", which echoes other authorities' findings on energy waste (Percy 2001; Crawford 1992 and 1998; Isobe, Hamamura and Elvidge). Ultimately the bottom line may be one of the most effective tools to educate people about the pernicious effects of light pollution. After all, who doesn't want to save a dollar?

3.2 Light Pollution and Ecology

> "The last word in ignorance is the man who says of an animal or plant: 'What good is it?'... If the biota, in the course of aeons, has built something we like but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intelligent tinkering."-Aldo Leopold
>
> ("Artificial Lighting and Sea Turtle Behavior", par. 20)

Since Thomas Edison's electric bulb lit a societal revolution over 100 years ago mankind, particularly western civilization, has profoundly changed his habitat. This change, of course, was the illumination of the night with artificial light and its attendant "wholesale transformation of the nighttime environment over significant portions of the Earth" (Rich and Longcore, Synthesis 413). And as noted in the introductory quote the entire ecosphere has potential importance in the grand scheme of things. This portion of the literature review considers the research on the impact of artificial light on animals and plants. Thereafter, the final portion of the literature survey concludes with research on artificial lighting's effect upon human health.

3.2.1 Light Pollution and Sea Turtles

Some of the best-documented research on artificial light's impact are those on sea turtles and migratory birds. The research on light's deleterious effects on sea turtles and their hatchlings may be as close to definitive as any research done on light pollution to date. Michael Salmon, professor in the department of Biological Sciences at Florida Atlantic University has extensively studied the impact of artificial light on sea turtles in

Florida. Salmon notes in the article “Artificial Night Lighting and Sea Turtles” that, “we’ve recognized the severity of this impact for only about 30 years” (163). Salmon’s paper, “Protecting Sea Turtles from Artificial Lighting at Florida’s Oceanic Beaches” delves into the nesting behavior of loggerheads, green turtles, and leatherbacks. His main contention is that artificial light affects nest density (that is, fewer nests where there is more light) (146). “Female choice of nesting site is strongly biased by coastal development and its associated lighting” (147). He also contends that artificial lights disorient new turtle hatchlings, and could cause them to be unable to find the sea, and be more prone to exhaustion, dehydration, and predation by other animals (148). This “seafinding” is the main crux of the problem of artificial light’s impact upon the behavior of nestling sea turtles. Hatchling sea turtles in a natural environment use visual cues to reach the water from their nests. The presence of artificial light makes it more difficult—and in some cases impossible—for sea turtles to get their bearings and find the ocean. “Each year, artificial lighting results in the death of many thousands of Florida hatchlings” (Bertolotti and Salmon 702). Witherington reports in his article, “The Problem of Photopollution for Sea Turtles and Other Nocturnal Animals”, "that each year millions of Florida sea turtles are misdirected with many thousands killed because of it" (305). He also notes that, “there is ample laboratory evidence for the change of rhythmic behavior under artificial lighting conditions” (306).

A variety of schemes attempt to mitigate the problem of artificial lighting on sea turtle behavior. Most involve engineering modifications or controls on existing infrastructure. These include the use of embedded roadway lighting (Bertolotti and Salmon), or the use of filtered streetlights in areas where sea turtles nest (Sella, Salmon

and Witherington). In a cautionary aside, Salmon notes that, "it is difficult to determine a causal relationship between more lighting and less nesting" ("Protecting Sea Turtles from Artificial Lighting at Florida's Oceanic Beaches" 150). Attempts to mitigate the problem through engineering controls (153-161) does not get to the cause of the problem: artificial light being put into places where it does harm.

3.2.2 Light Pollution and Birds

Artificial lights' impact on the avian community is another well-researched aspect of its influence on an animal community. "Ecologists estimate that up to 5 million birds nationwide die annually crashing into communication towers. In the Meadowlands, the lights on such towers lure birds like a homing beacon. The New Jersey Audubon Society is worried about proposals to erect more towers in the area, which serves as a superhighway for migrating birds" (Diskin, par. 16).

Gauthreaux and Belser, two avian researchers, write in their paper, Effects of Artificial Night Lighting on Migrating Birds, "the tendency of birds to move toward lights at night when migrating and there reluctance to leave the sphere of light influence once encountered has been well documented" (71). Their research also shows that migrating birds are liable to have greatly increased mortality around lighted chimneys, bridges, buildings, and other structures (74). There also seems to be some evidence that seabirds who are attracted to artificial lights have a greater than average mortality rate (through collisions, and loss of bearings), but the problem has not been studied enough to reach any hard and fast conclusions (Montevecchi 108). Other research has been done on

the effect of artificial lighting on a nesting population of godwits (de Molenaar, Sanders and Jonkers), wherein a small impact was noted on their nesting behavior. Further research shows that bird attraction to light is a much larger problem. "Nobody is certain of the total number (of birds) killed across North America. But Michael Mesure of the Fatal Light Awareness Program (FLAP), a Toronto organization working to publicize the problem, estimates that at least 100 million birds are killed annually by manmade structures. 'More birds die each year through collisions than died in the *Exxon Valdez* spill'" (Bower 95). Migrating birds are particularly prone to ill effects from artificial lights. "Scientists speculate that when they fly near urban areas, the bright lights short-circuit their steering sense. Numerous reports have documented birds flying off course toward lights on buildings, towers, lighthouses, and even boats. 'Both birds and insects demonstrate positive phototaxis' says Sidney Gauthreaux" (Bower 94). Phototaxis is the phenomenon of an animal moving towards or away from light. Another study correlates the phases of the moon and seabird attraction to artificial light, with fewer incidences of birds being attracted to artificial lights during the full moon phase (Telfer 406-413). It is believed that the full moon's light attenuates the effect of artificial light.

3.2.3 Light Pollution and other Animals and Plants

Other researchers have studied a broad spectrum of the animal kingdom and the effect of artificial lighting upon them. Bats and their prey (Rydell), reptiles (Perry and Fisher), salamanders (Wise and Buchanan), fish (Nightingale, Longcore and Simenstad), insect attraction to streetlamps (Eisenbeis), moths (Frank), and fireflies (Lloyd) have all

been scrutinized. These researchers found mild to severe impact on a broad section of the biosphere. The intersection of artificial light-at-night and animal populations covers a huge spectrum and it can be safely said that artificial light-at-night, by and large, has an increasingly negative impact on many different species. Scientists are concerned about consequences for the viability of some populations.

Moth attraction to streetlights (an example of phototaxis) and the increased likelihood of predation by bats, may not rank highly in concern for the environment, but what of "disruption of that natural lighting regime [which] may have significant consequences for species richness and community composition" in regards to fish (Nightingale, Longcore and Simenstad 270)? "Trout have been shown to have their behavior disrupted by floodlights. Halibut spawning times change as a result of artificial lights. Even deep sea organisms don't escape" (Smith 59).

The studies done to date are indicate an overall negative impact on the biota, but the researchers are quick to caution, that in many cases much more research is needed. Nightingale, Longcore and Simenstad note, "Further research is needed to understand the extent and significance of observed fish responses to artificial light cast into the underwater environment" (270). Salmon notes, in regard to sea turtles that, "it is difficult to determine a causal relationship between more lighting and less nesting" ("Protecting Sea Turtles From Artificial Night Lighting at Florida's Oceanic Beaches", 150). The presence of buildings and people are other factors that may influence turtle nesting.

Even less is known about artificial lights' bearing upon plants. Briggs says that, "without doubt artificial lighting affects plants. Not so clear, however, is whether artificial lighting poses any short-term consequences to an individual plant or long-term

consequences to any particular species in nature". He concludes, "research is badly needed in this neglected area of plant biology" (406). Other, anecdotal evidence seems to indicate artificial light has an overall negative impact on deciduous plants as well (Harder 248). The research reviewed for this portion of the thesis appears to show that artificial light has a negative effect upon the biota. The extent of that impact is less than clear however, and potential synergistic effects with other manmade products and processes (chemicals, etc.) are clearly begging for further inquest.

3.3 Light Pollution, light-at-night and Human Health

Artificial light and its effect on human health is a relatively new area of research. Pursuing this line of inquiry is ultimately central to the thesis question: does light pollution, and light-at-night pose a risk to human health that could necessitate regulatory oversight?

Artificial light has crept up slowly on western society until the unnatural seems natural. That is to say, humanity evolved with varying hours of almost complete darkness (natural) and now in almost every setting in the urban and suburban environments in the United States—and across the western world—the night is fractured and pierced by artificial light which is inherently unnatural to diurnal creatures such as mankind. Both our outside and inside environments have become evermore lit up with the non-stop glow of artificial light. Jeremy Smith notes this in his article, "Starry Starry Nights", "We have become obsessed by brightening up whatever dark corner remains, a strange combination of evangelism and paranoia" (61). A nonstop, all-night, all-shift,

mentality is prevalent, throwing our natural circadian rhythms into an uproar with unknown—perhaps dangerous—costs. Accompanying this unnatural disturbance is the fact that many people are not exposed (or exposed very) little to natural sunlight. This too may preclude adequate entrainment of our natural bodily rhythms.

"Many human physical functions follow a daily rhythm or a 24-hour cycle. These cycles are called circadian rhythms. The word circadian comes from the Latin "circa dies" which means "about a day." Sleeping, waking, digestion, secretion of adrenalin, body temperature, blood pressure, pulse and many other important aspects of body functions and human behaviour are regulated by this 24-hour cycle. These rhythmical processes are coordinated to allow for high activity during the day and low activity at night." ("What is the Definition of Rotational Shiftwork", par. 10). These rhythms are necessary for regulating your bodily functioning, and can be thrown awry by exposure to light at night. Stephen Pauley, says, "since we are born into a world of artificial lighting, we do not give much thought to how light disrupts the normal 24 hour circadian rhythms present in all organisms. Biological clock rhythms are found in all living things, even in organisms as simple as algae" (589). These rhythms appear to be set (or entrained) by "environmental factors, especially optical radiation (Stevens and Rea 281). With more people working indoors, exposure to natural light (sunlight) is much less than what our ancestors received, which may upset these rhythms. Seasonal afflictions (like seasonal affective disorder—SAD) are linked to lack of exposure to natural light during the winter months, when there is less naturally occurring light. "Although the mechanisms associated with SAD are still unclear, it is believed that the lack of daylight availability during winter months triggers the symptoms of the disease (MG Figuerio and others 24).

These studies have been popularized by the media, and are more or less familiar to anyone who is exposed to seasonal variations in natural lighting (those in mid Northern and mid Southern latitudes for example). But what of shift workers (people who work non-traditional hours) and others who are exposed to artificial light-at-night, and force their bodies into unnatural patterns of light and dark? Only recently have the consequences of this behavior been studied to any extent, and the research *appears* to indict light-at-night exposure as upsetting to our basic metabolism and potentially a risk factor for certain cancers.

What is the mechanism or mechanisms through which exposure to artificial light-at-night can lead to health problems? The most likely candidate is the body's synthesis of melatonin. Melatonin (MLT) "is a protective, oncostatic hormone and strong antioxidant having evolved in all plants and animals over the millennia" (Pauley 588). It is "synthesized by the pineal gland, a pea sized gland located in the center of the brain. MLT is normally produced in darkness with highest levels occurring between 2:00 and 4:00 AM" (591). This hormone is a powerful regulator of our sleep cycles, and interference with its production may prove to have deleterious consequences. Melatonin and its' effects are key to understanding artificial light, and its impact on human health. "In the words of Blask (a noted researcher in this area), 'physiological nighttime levels of melatonin put tumors to sleep at night' while during the day when melatonin concentrations are normally low there are no limitations on their growth. Blask also is quoted as drawing the analogy that during light exposure at night tumors become 'insomniacs'" (Reiter and others 357). Other research also seems to indicate that melatonin is a powerful antioxidant and appears to "generate a favorable response in the

treatment of human cancers" (Megdal and others 2005).

The synthesis of melatonin appears to be greatly affected by exposure to light. Researchers Richard G. Stevens of the University of Connecticut and Mark Rea of The Lighting Research Center at Rensselaer Polytechnic Institute, note that, "electric lighting in the built environment is generally more than sufficient for visual performance, but may be inappropriate for the maintenance of normal neuroendocrine rhythms in humans; e.g., insufficient during the day and too much light at night" (2001, 279). "In year 2002, Brown University neuroscientist David M. Berson discovered a previously unknown function for retinal ganglion cells (RGC)." He showed that these cells are intimately tied with the "retinal-circadian light transmission system" and are extremely sensitive to blue light. RGC "control(s) the human circadian clock", and "tells our bodies how to regulate multiple body functions such as body temperature, the release of hormones from our pituitary gland, sleep patterns, and our production of MLT from the pineal gland" (Pauley 590). It is interesting to note that some research indicates that blind people have a lower incidence rate of breast cancer, than sighted people (Pauley 590). Pauley also states that cancer rates are lower in the developing world. Perhaps indicative of the influence of exposure to artificial light? That is, in the developing world, there is much less artificial light that people are exposed to, and perhaps a lessening of the cancer risk.

Some researchers (MG Figuerio and others) postulate that human circadian rhythms and melatonin production are most affected by blue light. "Since the 1960s lighting technology has progressed from the incandescent bulb (yellow light) to today's HID [high intensity discharge] lamps. Street lights like the amber colored HPS [high pressure sodium] lights, white colored MH lights, blue-green colored MV lights, and

white colored, high output fluorescent lights, expose humans to more and more blue light wavelengths than in earlier times". Further research has indicted blue light is more harmful to the body's synthesis of melatonin, than other wavelengths (Pauley 592).

Other researchers have examined many of the published theories on the presumed light and cancer link. To quote at length, from one study:

> In summary, this meta-analysis suggests that shift work, including work as a flight attendant, increases the risk of breast cancer by 48%. The fact that risks for both flight attendants and other night work occupations were essentially identical provides an argument against previous theories suggesting that the increased incidence of breast cancer in flight attendants is due to effects of increased radiation or electromagnetic exposure. Rather, the observed increased risk of breast cancer may be associated with engagement in night work and a related decrease in melatonin production (Megdal and others 2031)

This research appears to indicate that night-shift workers (that is, those exposed to artificial light-at-night) have a higher risk of breast cancer than the average population. Others have examined this hypothesis (Graham, and others; Stevens and Rea; Figueiro, Rea, and Bullough "Circadian effectiveness of two polychromatic lights in suppressing Human Nocturnal Melatonin"; Figueiro, Rea and Bullough, "Does architectural lighting contribute to breast cancer?") and the research *suggests* exposure to artificial light-at-night has a negative effect on human health and well-being. Pauley implies that the research done to date is good enough to effect changes in how lighting is installed and used.

Researchers Cos, Mediavilla, Martinez-Campa, and others, from the department of Physiology and Pharmacology, School of Medicine at the University of Cantabria conducted a study which suggests that exposure to light-at-night induces tumor growth in rats. "Our results give experimental support to the epidemiological data describing a

possible influence of nocturnal light in mammary carcinogenesis and encourage the study of melatonin-based treatments to reduce the risk of carcinogenesis in people exposed to light-at-night" (270). Their test results seemingly indicate that growth of mammary tumors is enhanced via exposure to light-at-night. Pauley summed up the relevance of this study, "about 40,000 women die each year from breast cancer, and the cause of 50% of the breast cancers in the U.S. is unknown. The electric light is the hallmark of modern life in the industrialized world and could possibly be linked to higher rates of breast cancer" (590). It would be unwise to extrapolate between studies of rats and assume causality for human tumor genesis and propagation. It is suggestive, however. At a minimum, the link between exposure to artificial light-at-night and the development of cancer is one that should be scrutinized to the highest degree in order to properly quantify the problem, if indeed, there is one.

3.4 Light Pollution and Energy

Light pollution is strongly associated with energy waste. This waste is not only monetary in nature; a vast majority of American energy comes from non-renewable resources so this represents a significant waste of assets. This waste of fuel in the form of coal and natural gas leads to an increase in greenhouse gas emissions and contributes to acid rain. Thus, the generation of artificial light has definite environmental impacts upstream of its actual use. This effect is coming under increasing scrutiny because of the threat of greenhouse warming and the desire to be as energy efficient as possible, which is of great concern to American business. "Globally, buildings are responsible for

approximately 40% of the total world annual energy consumption. Most of this energy is for the provision of *lighting*, heating, cooling and air conditioning" (Omer 1). At least two billion dollars is wasted annually in this country due to needlessly lighting the dark (Gent 55). One only needs to look at all the billboards, neon signs and other light going straight into the nighttime sky—where it is completely squandered—in the cities of this country to grasp the magnitude of this problem.

In order to quantify this pernicious aspect of artificial lighting, it is important to examine the amount of money being wasted by inefficient lighting. Quoting from the International Dark Sky Association's Information Sheet #26, "Economic Issues in Wasted and Inefficient Outdoor Lighting":

> Let's look at the 175 watt dusk-to-dawn mercury vapor light in some detail. It retails for $29.95 or even less. The system uses about 210 watts of overall energy when we consider the ballast and other factors. Most security lights and street lights are switched on and off by a photocell, sometimes as part of each fixture, sometimes controlling a group of fixtures. These dusk-to-dawn lights burn approximately 4100 hours a year (4100 / 365 = 11.23 hr per night), and this value is nearly independent of the latitude of the location, as the seasonal effects average out over the year.
>
> Multiply: 210 watts x 4100 hours = 861 kilowatt-hours (KWH) energy used each year. At 8¢ per KWH (the national average electrical energy cost: some places are lower, but just as many are higher, some even twice as high), the average cost of operating such a lamp is about $69 per year. That is over twice the purchase price of the fixture. Where energy costs are high, the annual energy usage costs over three times as much as the fixture or more. And this is for a fixture designed to last 20 to 30 years. Here we have a prime example of how those who look only at the initial cost are unaware of the real costs. We must take a long-term view. Tucson (about 600,000 population) probably had over 20,000 such lights until a mass change-over to better lighting sources was accomplished. (The local utility replaced several thousand of these mercury lights that they owned; think how many more are owned by private citizens.) So the annual operating cost of those mercury fixtures in Tucson alone was nearly 1.4 million dollars. The population of the United States is about 500 times that of Tucson. So the annual operating cost of that single type of fixture is over 700 million dollars. If all of these fixtures were replaced with quality 35 watt low pressure sodium fixtures (getting better

> lighting as well), the country would save over 500 million dollars per year (pars. 3-4).

This article also notes that at least 30% of the energy coming out of that fixture is wasted leading to the loss of up to 500 million dollars. Further noted in this article is the impact on the upstream consumption of non-renewable fossil fuels to generate the electricity:

> It takes, on the average, 0.47 tons of coal (940 pounds) to produce 1000 KWH of electricity, so one ton of coal can produce 2100 KWH of electricity. It takes about 1.8 barrels (76 gallons) of crude oil to produce 1000 KWH of electricity, so one barrel of crude oil can produce 556 KWH. The wasted light therefore equates to an *annual* waste of at least six million tons of coal (think of the added acid rain and air pollution.) or 23 million barrels of oil (think of the added oil imports). These are non-negligible amounts, to be sure (par. 8)

The importance of this misuse should not be understated. American dependency on fossil fuels to derive the vast majority of its energy has only increased over time. People need to be aware of the negative consequences of wastefully lighting the night.

Light pollution is unique in the pantheon of environmental problems facing mankind. Light is a physical (rather than chemical) phenomenon. To stop light pollution seems easy: turn off the lights. The same cannot be said for a chemical contaminant in the groundwater or carbon dioxide in the air; these things must be taken out physically or allowed to breakdown naturally, which may take many years. While the solution to light pollution problems may on the surface appear easily solved, in reality they are not. Which lights to shut off? Which lights to replace? When to shut them off? Who will pay for this? Some may even question whether light should be considered pollution at all by its "classic" definition. Author Verheijen, an expert on lights' effect on the biota says: "the term pollution refers not only to the intrusion of undesirable or dangerous material into the natural environment, but also to an undesirable or dangerous change in some

environmental factor" (2). This definition seems to incorporate light as a pollutant in the environment by its effect the biota. Regardless of light being accepted as a "classic" pollutant, its upstream impact as a source of wasted energy consumption cannot be overlooked. Defined as a polluting source, what are some ways to mitigate light's impact on energy use and waste? Replacement of incandescent fixtures with compact fluorescent (CFL) bulbs, the use of dimmer switches and motion-detectors all have a part to play in neutralizing energy waste from lights. Paul Vrabel notes, "ultra-efficient fluorescent lighting, light-emitting diodes (LEDs), daylighting techniques, controllable luminaries and other cutting-edge technologies provide a new set of tools for office, warehouse, retail, hospitality, residential, and other lighting design applications" (48). Although many people may not be ready to accept that artificial light may have a pernicious effect on human health and the environment, almost everyone has the desire to save money and this is especially true of business. Efficient use of artificial lighting helps the bottom line and the use of natural light also appears to be beneficial. Vrabel states that, "a store using daylight from skylights can have as much as 40 percent higher sales than those without, according to a study conducted by the Heschong Mahone Group. This may be because natural light provides better viewing of products, especially colors" (54).

4.0 METHODOLOGY

The primary methodology that was used to illuminate the thesis questions, and corollaries, was the in-depth interview. It was felt that the inherent nature of the topic is so broad and expansive, that in-depth interviewing was the best way to weave the tapestry of separate elements into a unified whole joining this far-flung topic, and attempt to answer the primary thesis question: Does light pollution constitute enough of a threat to the biota or human health to justify national oversight and regulation? Interviewees were selected in an attempt to bridge the gaps of knowledge in the discipline. Professionals from the medical arena, the regulatory field, and the ecological areas were targeted for interviews. The underlying crux of the interviews was to garner information that was used to fill the gaps identified in the literature review, what opportunities for solution there are, review what each discipline knows about the problem, and draw out from each individual what their perspective on light pollution is, and where we as a society (and world) should go from here in relation to the "problem" of light pollution. The researcher conducted in-depth interviews to properly bridge the gaps in knowledge, while maintaining a time frame allowing the research to be finished in a timely fashion. Furthermore, the mission statement of the EPA was examined and was used as a starting point, to try and establish if light-at-night exposure and light pollution's attendant problems identified in the literature review fall under the purview of the EPA.

The medical/physiologic personnel interviewed were, Richard Stevens, PhD, University of Connecticut Health Center, David E. Blask, PhD, M.D. of the Bassett Research Institute in Cooperstown, N.Y, Dr. George "Bud" Brainard of Thomas Jefferson University, and Dr. Mark Rea of the Lighting Research Center. These

gentlemen have been involved in extensive research on the effect that artificial light-at-night exposure has on human health. The researcher attempted to elicit their overall perception of light-at-night, its effects on people, and whether or not—in their opinion—light-at-night should be regulated at the federal level in this country. In conducting the interviews, the researcher tried to:

- Identify the latest research involving exposure to light-at-night and humans
- Quantify the risk of exposure to light-at-night (if any) to humans
- Identify specialty areas of research
- Elicit opinions on regulatory action
- Elicit opinions on current legislation regarding light pollution
- Ask for information on other researchers who may provide more information for follow-up
- Ask for help in identifying overlooked research

The ecologists that were targeted for interviews were Dr. Michael Salmon of Florida Atlantic University and Dr. Blair Witherington of the Florida Wildlife Conservation Commission. Both researchers have done extensive work on assessing artificial light's impact on sea turtles. Conducting these interviews, the researcher attempted to:

- Identify the latest research involving exposure to light-at-night and sea turtles
- Quantify the risk of exposure to light-at-night (if any) to the turtles
- Identify any specialty areas of research that they are currently involved in
- Elicit opinions on regulatory action and current legislation regarding light pollution and light-at-night
- Obtain any other pertinent data regarding the status of light-at-night research on the biota
- Ask for information on other researchers who may provide more information for follow-up

- Ask for help in identifying overlooked research

Clark Reed from the office of the EPA in its EnergyStar Program was identified and interviewed. He was asked to comment on how EPA treats light pollution, and in what manner. The administrator of the EPA, Dr. Stephen Johnson was also contacted for an interview, as other attempts to contact a lower-ranking functionary were unsuccessful. The interviewer attempted to ascertain the regulatory agency's stance on light pollution, and its associated costs to people and the environment at large. The researcher attempted to:

- Identify the agency's stance on light pollution
- Show a connection (or lack thereof) between the research on light pollution and the EPA's overall mandate
- Ascertain the agency's direction in regard to the future status of light pollution
- Ask for information on other regulators who may provide more information for follow-up

In order to conduct the interviews, a detailed interview guide was developed for each group of interviewees. The interview guide was utilized in order to have a framework that allowed for consistency and provided guidance to keep the interviews on track in order to answer the thesis question and associated corollaries. The interview guides provided a basis for the interviewer to inform the interviewee(s) of the rationale for the research project, the content and direction of the research, the background of the interviewer, and other salient points. The interview guide was also used to provide direction and information regarding the recording of the interview, and gave assurances of anonymity, if requested. The interview guide also specified the fact that the interviews must be conducted via telephone, due to travel constraints. The interview guide also

stipulated that the recorder could be turned off at any time, if the interviewee so desired.

An adjunct to the in-depth interview was a questionnaire, delivered via email, to persons on the researcher's personal electronic mailing list. This was done to fill in blanks on what people in general think of light pollution. The rationale behind such a quasi-scientific "poll" was to ascertain the knowledge that is out among the "masses" and to elucidate what they think should be done (if anything) to address the "problem", if, indeed it can be considered a problem. This was conducted before the interviews were scheduled. The hope was to identify any areas that the researcher had overlooked by personal bias and to gain a fresh perspective about the issues of light, light pollution, and light-at-night. The expectation was to garner opinions on the importance (or lack thereof) of light pollution, light-at-night, and its consequences. There was no pretense that this "survey" was anything but an unscientific poll to sound out people on their perceptions. The outcome yielded anecdotal evidence that helped focus interview questions. Prior to sending the questionnaire the researcher gained approval from the committee. The questionnaire was delivered to 41 people in the interviewer's mailbox and was returned by 15. It was time limited (that is, the contacted persons were asked to return it within a short time frame) in order to keep the research moving forward and to examine any worthwhile responses and incorporate them into the interviewing protocols, which was done.

5.0 RESULTS

The following chapter presents the results of the research conducted for the body of this thesis. Each salient problem identified in the methodology is looked at in the context of answering the overarching thesis question: *Does the scientific research on light pollution and light-at-night exposure make a case for regulatory oversight, within the mandate of the EPA?* Some sections of the research were easily finished while other portions proved more problematic especially gleaning information from the EPA in the form of an interview.

5.1 E-Mail Questionnaire Results

These results are presented in there entirety in Appendix B. It is interesting to note that the people who were contacted had definite opinions and thoughts about this topic. The findings are not presented in the body of this thesis as the information that was gained is anecdotal at best. Hence it has little scientific grounding. Some of the more interesting comments were included to illustrate what people think of artificial light in the context of being a pollutant.

5.2 Artificial Light and Human Health

More than any other aspect of artificial light's impact on the environment, its effect on human health, both positive and negative, proved to be the most interesting and controversial aspect of this project. This research on artificial lights' impact on humans

is relatively new. Dr. Stevens first proposed exposure to light as a potential cause of breast cancer in 1987 (Bullough, Figuerio, Rea "Does Architectural Lighting Contribute to Breast Cancer?). Stevens is a cancer epidemiologist at the University of Connecticut Health Center, and was the first interviewee. Dr. Stevens described his interest in this topic, thusly:

> The thing I am most interested in is breast cancer. Why [do] women get breast cancer? Because the big dietary studies [that] were hitting in the early 1980's were showing no relationship of anything to breast cancer—anything in the diet at least at the time; now I think that diet is still important. But the big studies, at least show that total fat in the diet has no relation to breast cancer risk. I wonder[ed] what the heck else changes with industrialization and I realized that the introduction and increasing use of electric power is the hallmark of industrialization. And then from there I wondered how on Earth that could effect breast cancer risk? I started learning about melatonin, the hormone and the fact that light can suppress it, and that maybe electromagnetic—the so-called power frequency fields—fields could lower it. And over the intervening years the light relationship to melatonin is very strong and very….well, it's pretty clear. There is no doubt that light can suppress melatonin. The question now for us, is how much light? What time of the day is most important? What's the spectrum?

Additionally, the researcher interviewed Dr. David E. Blask of the Bassett Research Institute; Dr. Blask holds both PhD and MD degrees and is a senior research scientist and head of the chrono-neuroendrocinology lab. He described his interest in this topic:

> I became interested in melatonin in the pineal gland and its potential effects on cancer. And that interest developed over 30 years ago. And I've been working in the area of how melatonin produced by the pineal gland at night inhibits cancer growth. And since we knew from animal studies that light was a very potent inhibitor of the ability of the pineal gland to produce melatonin; Worker suspected that light during darkness or exposing animals to constant light throughout their 24 hour cycle might stimulate cancer growth, especially breast cancer growth. And in fact a few experiments done in the early days of this research back in the late 70s early 80s bore this out. And the effects of constant light exposure on animals had a stimulatory effect on breast cancer development and growth was thought to be mediated through the suppression of melatonin.

He then described Dr. Stevens' contribution to the research which put their work into context:

> And Dr. [Richard] Stevens came along in 1987 and looked at the prevalent data in the literature, including ours, and came up with his light-at-night hypothesis. He had wondered why there was this increase in breast cancer risk associated with industrialization and proposed that you know something about industrialization and westernization was responsible for this increased risk of breast cancer. [He] apparently had developed and couldn't account for it by other risk factors. He came up with the idea that maybe it was electrification; that was a big, big factor in the industrial revolution. And then saw that indeed there was something about electrification that is light and when it is present at inappropriate times...that is when it is present during the night can shut down the production of melatonin, which we and others had shown has anti-cancer effects. We became interested in the effects of light on human health…specifically human cancer.

Dr. George "Bud" Brainard of Thomas Jefferson University is a professor of neurology and pharmacology; Dr. Brainard described his interest in light's effects on physiology. He stated his interest in light's effects started as a teenager and described his career:

> My entire adult career has been focused on this as well. My formal training has ultimately put me in the position to study this professionally. So having said all that, Tim, back when my interest was first developing the classical scientific understanding was that the human pineal gland was a vestigial organ that did nothing other than serve as a good radiological landmark in X-rays of the skull. There was a developing science showing that in animals it responded to light but it was not until 1980 that a group of scientists at the National Institute of Mental Health (NIMH) showed that bright light exposure at night suppressed melatonin in healthy young men. The lead author was Al Lilly and it was published in Science. That finding opens the door for doing what animal researchers have been doing with animals for years. And that came out while I was doing my work in graduate school. I contacted the lead author, Al Lilly and we ultimately agreed I could do a postdoctoral fellowship with him to train to how to learn how to do those kinds of studies and that was my first postdoctoral fellowship.

Dr. Mark Rea, director of the Lighting Research Center at Rensselaer Polytechnic Institute of Troy, New York was also interviewed. His background is in biophysics and the human factors associated with light. All of these

researchers are heavily involved with lighting research and had varying ideas about the primary question of this thesis. When conducting these interviews a standard set of questions contained within an interview guide was used, which was described in the methodology section. When the conversation moved outside of these guidelines, the researcher followed the lead of the interviewee and attempted to draw out as much good data as possible. Overall the interviews went well if slowly; those who gave their consent have their interviews reproduced in Appendix A. In order to break down the results the questions asked of each interviewee was listed followed by their responses. The questions that were asked may have varied *slightly* with each interview, but in essence the questions below are representative of what was asked of each researcher. Each interviewee had the opportunity to review his transcript in order to assure that what was captured and transcribed not only was grammatically accurate but reflected their true intent. The responses are not necessarily complete as they stated. Only the data that had bearing upon the research focus and question was included and answers were edited for grammar and clarity while retaining the meaning of the interviewee.

5.2.1 Researcher Interviews

Conducting the interviews with the researchers named above yielded some of the best information gathered during the course of the research. Each person spoke thoughtfully about this topic and each held different opinions about the severity of the problem, the ways to address it, and what its potential impact could be on human health. Dr. Stevens was alone among the researchers in his stance that light-at-night exposure

should be regulated (to some extent) by the EPA. The other researchers felt that this would be "premature" (Blask and Brainard). Dr. Rea was even more adamant stating that a lot more qualitative research must be done and a proper definition of "light pollution" accepted by the scientific community. The following interview excerpts are juxtaposed to show commonalities and differences in their response to the questions that were posed to them.

Question: Do you feel that light pollution should be regulated under the auspices of the Environmental Protection Agency per their mission statement on their webpage which reads, "The mission of the EPA is to protect human health and the environment. Since 1970, EPA has been working for a cleaner, healthier environment for the American people"?

Dr. Stevens noted immediately that artificial light should be defined as light made by humans as opposed to sunlight and other celestial phenomenon. He elaborates:

> So all of it's light. They're all photons. And they all have a biological effect. But the artificial light differs in a couple of extremely important ways to our evolutionary biology, our circadian physiology. One is the timing; the sun is predictable, 12 hours of light, and 12 hours of dark, seasons and weather permitting. It is also generally speaking, a much different intensity and spectrum. So, yes it is a broad complicated issue.

He went on to elaborate:

> However, I would think for regulatory purposes if some agency was in charge of the mandate of investigating and then perhaps regulating how light was done. There would be one office for artificial lighting. And then under that there would be the sub-areas, some of which you just mentioned. The effects on human physiology, the effects on ecology, the effects on street lighting and safety for motor vehicles, glare, light trespass and like that.

When asked directly if artificial light should be regulated per the EPA mandate he unequivocally stated,

> I think EPA is appropriate. And I am confident they will [get involved]…in fact I don't know what they are doing *right now*. I know the National Institute of Environmental Health Sciences which is right across the pond from EPA down at Research Triangle Park, NIEHS is taking this area very seriously, to do research

> on the human health aspect. And I think also the environment in general. Although they are not charged with ecology, per se, so I'm sure, I feel very confident EPA….I hope they are investigating it now…[are] thinking about it. And then I am confident they will get into this.

The researcher confided in him that it was nearly impossible to reach anybody at the EPA who would comment. "Well EPA for unavoidable reasons is a very political entity. There is tremendous political pressure on EPA, so they're going to be [careful]….they're a public institution, and they need to respond to this, you know. But, they're going to be careful". Dr. Stevens's expertise as a cancer epidemiologist was described to the researcher as "the study of the distribution and causes of disease in populations. How does a disease distribute? Is it more common in men than women? Is age a factor? Does smoking increase your risk that sort of thing…as opposed to the biology or the treatment of it." Epidemiology shows correlation between working night shifts and increased cancer rates. Yet it must be remembered that correlation does not prove causation. Dr. Rea stressed that very point in his interview stating that "you have to measure the input which is the light and the output is the health then you have to have a functional relationship between the two [and] we're a long way from that."

Dr. Rea stressed constantly that more qualitative data was needed before anything could be regulated, barring lights' effect on sea turtles, which he felt demonstrated a clear-cut cause and effect relationship. He also felt that the term "artificial light" was not useful scientifically. A portion of the interview reveals his thoughts on the matter (A=Dr. Mark Rea; Q=Tim Berthaume):

> A: Well I think that no biophysical process could differentiate a photon generated by the sun or a photon generated by some electric light source, right? So why is it important to refer to it as "artificial"?
>
> Q: Now you've got me confused.

A: Well how about moonlight for example? You would not consider that to be artificial?

Q: Right, right.

A: You would not consider its light to be artificial?

Q: Certainly not.

A: OK, and what if they have health consequences? We're not going to talk about it?

Q: I guess I would not be looking at that.

A: I think if you want to get a scientist's view you have to distance yourself from the adjectives like "artificial" light. So the question really is what impact does light—defined in terms of spectrum, intensity, distribution, timing, and duration—what does that have to do with some measure of outcome? It should not be prejudicial in regard to artificial or natural. Those carry with them baggage that is unnecessary for scientific inquiry as to what the impact would be. And the reason why I bring that up, when you link artificial light and you ask me about deleterious effects the other question that comes up is: why just look at deleterious effects? Why not consider the impact of light on things that improve health? Do you think that's possible?

Although Dr. Rea expressed concern over the use of the term "artificial" in describing light by this researcher it was felt that it was necessary to keep that convention in this thesis to provide a meaningful question. That is to say, the researcher knew beforehand that sunlight, starlight or moonlight could not be subject to regulation (that is, you can't turn off the sun but you can turn off or change a street lamp). In essence, Dr. Rea felt that a great deal more research on quantifying light and exposure to light (both artificial and natural) is paramount. He also stressed circadian balance as possibly more important than exposure to artificial light-at-night to overall human health. He also felt the epidemiological work carried out by Dr. Stevens and others, indicating working at night leading to an increase in breast cancer, could be a result of several factors, including diet.

He noted in his interview:

> Putting ourselves in concert with the light-dark cycle seems to me to have—all the evidence seems to suggest that's a very positive thing; night-shift nurses who seem to be asynchronous with the light-dark cycle seems to be a clear indicator of unhealthy kinds of activities. At least that's what the epidemiological evidence would suggest. So I think that it's less about light and it's more about coordinating the light-dark cycle…whether you're taking a treatment for a disease or whether you're trying to maintain positive health. That really seems to be the key concept. So yes, I believe there is a link between light and health. But, expanding that light-dark cycle with good health is what we're really talking about here. I think that's where the discussion will end up.

Doctor Blask who has been involved in research for over 30 years, echoed Dr. Rea's concern when asked the same question about light pollution falling under the regulatory umbrella of the EPA:

> I don't think we have the results of enough studies yet to go that far…you know for federal legislation. I think that would be premature at this point. Although I think the data that is emerging are certainly pointing in that direction. But if you were to say do we have enough scientific evidence at this moment to justify concrete legislation to ban light pollution as a health risk? At this point [it] would be arguable. I think there is evidence indicating it is a hazard under certain circumstances and it depends on so many factors. When you say light pollution what are you talking about? Are you talking about wavelengths of light? Brightness of light? What is your duration of exposure? Timing of light? We have to do more research to find out more about the characteristics of light and under what circumstances those characteristics may be detrimental to us in terms of health risk. Now in terms of cancer certainly our research supports the idea that light [at night] is a risk factor for breast cancer. Again we need more research to corroborate that. And to make an argument that indeed you would need to pass, if not federal legislation certainly local ordinances at some point. And I think this is going to be an issue that is going to continue to emerge. But I don't think we're their yet. Absent something like that—you know people ask me all the time, "Well what do you recommend?"—I say prudent avoidance of light at night in your own life. And that is sleeping in a darkened environment. And minimizing, if not totally eliminating any exposure to light at night for obvious reasons of health. You should be able to get a good night's sleep and minimizing your exposure to enough light that would suppress your melatonin and do away with the protection that melatonin appears to offer in terms of protection against the development and growth of cancers. So, that's my answer. I can't give you a yes or no answer to your question because it's not really at the stage where you

can say that.

Dr. Blask felt that EPA's role at this juncture could be one in which they helped educate the public and raise awareness about lighting issues. "I think an educational page by the EPA or blurb about what we do know about the potential ill-health effects of light-at-night, I think that would be very useful. And [it] gave a synopsis of where we are in terms of what we know and provided information to the public; I think that would be very useful." Dr. Brainard also felt that trying to regulate light pollution at this point would be futile. He said:

> It's premature for the EPA or any regulatory agency to attempt such regulation. What the other agencies should do is support the necessary research so that one day regulation can be possible. It would be a nightmare if they tried to regulate on the basis of what we know. Having said that let me qualify it. There are lots of reasons to be concerned about exposure to light-at-night as a potential risk factor for the onset of cancer. However, if you rush in and try to do that [regulate] before you know all the particulars you're just going to create more problems then help. So, that's the deal.

For the next portion of the interviews the researchers were asked to speculate about the future of their light-at-night research. Questions were asked about the validity of their research and if they felt further experiments would tend to null their results or strengthen the case for artificial light having a negative impact on human health. When asked if the link between exposure to light-at-night and melatonin suppression and the associated cancer risk could be proven wrong, Dr. Stevens weighed in:

> Sure, it could. You caught me there. The word "proof" I have to define the word "proof" for you. And that is a consensus of experts. There will be no proof in any absolute sense that it's right or wrong, *ever*. But, yes given that definition of proof—a consensus of experts—including myself, the evidence may accumulate that says on balance I will say on the basis of the evidence, I don't think that light has much or anything to do with breast cancer risk. That could happen. And of course the other side could also happen.

Dr. Blask concurred stating, “Oh yeah. And you always have to be ready for that in science. You always have to expect that that may happen” (that a given hypothesis is overturned). He went on, “something could come along; you are going to have to realize that there’s a body of literature—a preponderance of literature now—that argues for this [exposure to artificial light and attendant human health consequences], and it would take a preponderance of literature in the other direction to cause me to jettison the hypothesis that we believe in.” Dr. Brainard also stood strongly behind the research on light-at-night and melatonin suppression. He said, “I think this will go to conclusion in my opinion. I think that the evidence will continue to accumulate and it will hit sufficient weight that their will be a broader scientific consensus; we are not there yet, but hazarding my best professional guess it will get there eventually.”

5.3 Artificial Light and Ecology

Artificial light’s effect on animals is one area of the research that has shown straightforward results. Light affects both nesting sea turtles and migrating birds in a negative fashion. There is clear unambiguous research that shows artificial lighting is confusing to hatchling sea turtles and leads to misorientation, disorientation and ultimately to a higher mortality rate. In order to obtain firsthand information on these studies, two researchers that have been involved in doing research on sea turtles and their interactions with artificial light were contacted. Dr. Michael Salmon of Florida Atlantic University and Dr. Blair Witherington of the Florida Wildlife Conservation Commission consented to be interviewed; an attempt to contact Sidney Gauthreaux, a noted researcher

on birds and artificial light, was to no avail.

Dr. Salmon described his position:

> I am a professor in the department of Biological Sciences at Florida Atlantic University. My specialty is animal behavior and I work primarily with marine animals, especially sea turtles. And I'm interested in their sensory, biology and behavior. One of the first projects I did [working on my PhD] was an experimental study that tried to identify the stimuli that is used by [turtle] hatchlings to reach the sea. And in the process of doing those experiments and reading the literature I saw a few publications on how artificial lighting interfered with the ability of hatchlings to locate the sea. And that sort of got me going on an experimental approach to try to analyze the problem.

Dr. Salmon is also the author of many articles and papers describing light's effects on sea turtles and is a professor of Biology at Florida Atlantic University. Dr. Witherington explained his qualifications:

> I work for the Florida Wildlife Conservation Commission as a research scientist. I have graduate degrees from the University of Central Florida and the University of Florida and I principally work on sea turtles. Much of my work involves sea turtles on nesting beaches and that includes how hatchlings find the sea with the various anthropogenic challenges that we put to them like lighting and other things as well; there are a lot of troubles that sea turtles have on beaches and the research has a lot of applied aspects. So research and management are intermingled and I end up doing both those things in my job.

Both researchers have been involved with studying the effects of light on turtles for over 20 years.

5.3.1 Researcher Interviews

Witherington and Salmon were very clear in their interviews regarding the impact that artificial light has upon the sea turtle community in Florida. Both agreed the impact was a negative one, and both felt that the EPA should be involved with this problem, whether it was as a regulating body or one involved with researching artificial light and

it's impact on the environment The same question that was asked of the medical scientists, was asked of the two biologists:

Question: Do you feel that light pollution should be regulated under the auspices of the Environmental Protection Agency per their mission statement on their webpage which reads, "The mission of the EPA is to protect human health and the environment. Since 1970, EPA has been working for a cleaner, healthier environment for the American people"?

Dr. Salmon answered:

> Actually in response to your question I looked up the EPA webpage. There's a lot of information there on studies that they do in the environment that involve animals and plants. So while their mission is primarily to protect human health and the human environment they're also interested in the ecology of that environment; and if you look at their website there are studies that deal with toxicology, dealing with all aspects of how human activities affect the well-being of wild organisms. So on that basis I feel they should also tackle problems with artificial lighting; in fact they don't but I think that's largely because we haven't made a very good effort in this country—that is the scientific community has not made a very good effort—to inform them about the widespread effects of artificial lighting on wildlife. To a certain extent that is because the effects have only been appreciated within the last 5 to 10 years and very few people are actually working in the field. But, nevertheless to get back to your question, should the EPA be involved? My feeling is yes they should be. And it would be perfectly consistent with a lot of work they are presently doing.

Bringing further insight to this topic he stated in response to a later question regarding artificial lights' impact:

> There is no question whatsoever that birds and insects and many other kinds of animals are harmed by artificial lighting. And knowing that and knowing the economics involved in wasting energy [producing artificial light] a national policy on the topic of lighting can't help but be beneficial. The problem as always is conveying information to people in positions of power the importance of doing something about it and having the resources set aside to actually implement the changes because it's not going to be cheap

It is interesting to note that Salmon said the EPA should be involved, but he did not mention in a regulatory capacity. Dr. Salmon is in concurrence with others that the EPA would serve as a useful tool to educate people to this phenomenon. Dr. Witherington had

stronger feelings when asked the same question:

> It [artificial light] should be regulated as a pollutant by an agency that is used to regulating pollutants [EPA] and I have some strong feelings about that and a few reasons why. The most important reason is that light behaves like a pollutant and therefore a lot of the things we've learned about regulating and mitigating other pollutants can be applied to solving problems that are caused by light—artificial light in the environment. Light has both a point source and non-point source origins; that is to say that you can go to a source and address the light coming from the source…you can shield the light, you can change its direction and you can even change the quality of the light and that will affect its pollution effect. And there are also non-point source problems that need to be solved on a much broader scale—there's lots and lots of light contributing to an overall effect. So, pollution agencies have learned a lot about how to use regulatory authority to solve problems with chemicals and even thermal pollution—and although light is a bit different from other pollutants I think the philosophy that would govern or mitigating its effects is similar to other types of pollution.

Witherington notes that light, while acting like a pollutant in some regards it is not like other pollutants. Light is a physical phenomenon unlike "classic" pollutants like lead or leachate which are chemicals or human byproducts. What most non-scientists consider "light" is only a small portion of the electromagnetic spectrum which spans infra-red radiation to cosmic rays. This difference may be one of the reasons that artificial light has not been subject to as much scrutiny as other environmental concerns. After all what is more common than sitting in a lighted room whether at the office or home? Witherington went on to tell the researcher how light that is made by people affects the sea turtles:

> Artificial lights that can be seen from a nesting beach cause sea turtles to move in the wrong direction. And in terms of hatchlings, this is really important because they need to enter the sea very quickly and when they move in the wrong direction it generally means that they never reach their goal of getting to the ocean. And that means that they die. So it's a mortality problem. Not just harassment but mortality; and in adult turtles they can be disoriented as well and move in the wrong direction—often the result isn't as lethal as for hatchlings—but they are disoriented or misoriented you know they can either have no bearing or choose a bearing that is in the wrong direction when they are trying to find the

> ocean. But light also influences nest site choice in adult turtles so it can be considered habitat degradation. You can light up a beach and turn a perfectly good nesting beach into a beach where very few turtles nest. So I guess in essence that's the problem.

In the case of sea turtles the research is both clear and unambiguous: artificial lighting has a deleterious effect. Yet, is this problem of sufficient magnitude to warrant EPA oversight under their mandate? Is it part of their mission? Or perhaps it should be regulated only at the local or state level? Dr. Salmon notes in his article "Artificial Night Lighting and Sea Turtles", "marine turtles are exceptional creatures whose continued existence has intrinsic value, despite the costs" (167). Further he notes that continued development of Florida will continue impacting the sea turtles unless something is done. He states: "But perhaps, by then, we will have adopted a national lighting policy so that not only coastal marine life, but all wildlife, can benefit" (168). With this thought of overarching national policy the EPA was contacted to obtain their thoughts on artificial light and its place on their docket.

5.4 Artificial Light and the EPA

In order to answer the primary thesis question, *does the scientific research on light pollution and light-at-night exposure make a case for regulatory oversight, within the mandate of the EPA,* the researcher contacted two people within the EPA. A number of attempts to gain an interview were attempted, including placing phone calls, and sending numerous emails to EPA administrators, ranging from those involved at the regional level, all the way to contacting the EPA director, Steve Johnson. These efforts yielded little; the researcher was able to conduct a short interview with Clark Reed who is

involved with the EnergyStar program. The researcher did get a short reply from the office of the administrator, which is reprinted wholly below. The rationale for utilizing the EPA as the standard federal regulatory agency that the researcher was concerned with, was its mission statement which reads: "The mission of the Environmental Protection Agency is to protect human health and the environment. Since 1970, EPA has been working for a cleaner, healthier environment for the American people" ("About EPA", par. 1). An argument could be made that artificial light has impacts both on human health and the environment. As noted earlier the impact that artificial light has upon sea turtles (a part of our environment and wildlife heritage) is a clear case of cause and effect. The effect of light on human health is not as clear. Nevertheless the researcher wanted to gain the EPA's thoughts on artificial light and where it fits in with their stated objective.

5.4.1 EPA Interview

The only "true" interview conducted with the EPA was with Clark Reed. The researcher identified himself, explained the research thrust and asked permission to record the interview, which was agreed to. He then identified himself, and described his background and work status:

> I work in the Climate Protection Partnerships Division at the Environmental Protection Agency. And that division is part of the Office of Air and Radiation…and I work specifically in the Energystar Program which is a voluntary program that promotes energy efficiency in consumer products as well as commercial and residential. I have a master's degree in environmental policy from Tufts and an economic degree from the University of Washington.

When asked if and how the EnergyStar program addressed light pollution, he

commented:

> EPA's EnergyStar program is about voluntarily reducing greenhouse gas emissions through energy efficiency. Our focus has been on buildings, not their parking lots, really because the vast majority of carbon savings and monetary savings comes from the building itself. How do we address light pollution or excess light in EnergyStar? We recommend good lighting practices with literature, like following [unintelligible] agency standards. We recommend reducing light in overlit areas, controlling light by installing photometers to turn lights off in the daytime, switching to more efficient lamps and this type of thing.

He also felt that the term "light pollution" was misleading, and did not feel that the EPA mandate encompassed light at this point. He said,

> Let me comment first on the term "light pollution". To me that's a creative term to describe glare. And just speaking loosely, pollution to the EPA defines something that is chronically or acutely toxic to plant and animal life. And yes, you know glare is annoying. Glare can be inefficient, wasteful. Glare can even be dangerous on the highway, but excess light in and of itself does not contaminate the air, the soil or the water. Glare simply does not fit into the classic definition of pollution as we see it here at EPA. As you are well aware EPA gets its regulatory authority from Congress which passes laws like the clean air act…and the clean air act states EPA shall regulate air pollutants that in the agencies judgment cause or contribute to air pollution which maybe anticipated to endanger public health or welfare. The agency has judged that there are basically 6 classic criterion pollutants to address: sulfur dioxide, nitrous oxides, carbon monoxide, ozone, particulate matter and lead. Actually just today the Supreme Court ruled in case you hadn't already heard we have to reconsider regulating carbon dioxide. So, excess light is not on that list.

Mr. Reed went on to say that EnergyStar was a program that looked at the "bottom line" for business. Increased efficiency, less waste, yields a higher return for companies. He felt that this was the ultimate driver for firms to incorporate voluntary initiatives like EnergyStar. "At the end of the day their pollution prevention or their monetary savings from energy efficiency is pollution prevention and vice versa." While the EnergyStar program is a valid pollution prevention program, in that it saves the upstream cost of making electricity that is squandered by inefficient products, it truly does not attempt to

directly impact light pollution. Further research at EPA was in order. After fruitless attempts trying to contact several regional administrators, the researcher went directly to the EPA director, Dr. Stephen Johnson.

> The following e-mail was sent to Dr. Johnson on Monday, April 23 of this year:
>
> "Dr. Johnson,
>
> I am a student who is currently writing his master's thesis. I am researching light pollution and the effects of light on humans. In order to complete the research portion I am conducting interviews via telephone with prominent researchers in the field to answer my primary thesis question which is: *Does the scientific research on light pollution and light-at-night exposure make a case for regulatory oversight, within the mandate of the EPA?*
>
> I have attempted to contact various personnel at the EPA with limited success. Basically I would like to speak with someone familiar with how regulations come to be within the agency, if light exposure is anywhere near to being on the docket, and so forth.
>
> I realize that you as director of the EPA will probably not be able to conduct such an interview. However, it is my hope that you can forward this to somebody who would be willing to help. Interviews are conducting via telephone, with a recorder attached to facilitate transcription. Typically they last between 20 minutes and one hour. Afterwards I transcribe the interview and send the typed script to the interviewee for review and correction. If this is not feasible I can forward a questionnaire as an ersatz interview.

Your attention to this matter is greatly appreciated.

My regards,

Tim Berthaume"

The reply came one week later. Tom Eagles of the EPA sent the following response:

"Dear Tim Berthaume:

Steve Johnson has asked me to respond to your email of 23 April. I Work in EPA's air policy office, and have had long experience with regulatory development, so I can probably shed some light (no pun intended) on the issues you raise.

Your most basic question is "how regulations come to be" in EPA, and

whether light exposure regulation is anywhere on the horizon.

The short answer to both questions is that EPA only creates regulations under specific Congressional authority, and that none of our authorizing statutes (for example, the Clean Air Act and Clean Water Act) has any provisions regarding light pollution or light exposure. Unless and until Congress passes a law authorizing us to do so, EPA cannot address these issues.

Of course, that begs the question of what does it take to get Congress to pass such a law? The answer is, generally, public pressure from individuals and interest groups, generally backed up (in scientific cases like this) by emerging science. The most illuminating (!) current example is the ferment in Congress about global climate change, and what to do about it.

In the case of light-at-night exposure, I personally feel that it's a growing nuisance, with some scientific repercussions (e.g., interference with ground-based telescopes) but I doubt that it's anywhere near the point where Congress is likely to be willing to seek a regulatory solution. But the situation may well be more serious than I realize, and in such cases, persuasive writing by well-grounded academics is one principal way to raise consciousness and agitate for change.

Even given what I have said, you still might find it interesting to peruse the EPA website to get a sense of how the Agency handles the issues that are currently on its plate. The URL is www.epa.gov.

Good luck with your studies.

Sincerely,

Tom Eagles"

While this response does not qualify as an interview it was the only answer that was forthcoming from the EPA, barring the interview conducted with Mr. Reed. Although no direct answers were able to be asked, it can be inferred that the EPA right now does not have light pollution directly on their agenda. Naturally they are concerned with the production of energy that is used to power inefficient products which includes lights. At this point that appears to be the only way that the EPA is involved with this topic.

The results that were garnered in the course of the research were somewhat unexpected. When conducting the literature review some of the papers could lend themselves to the conclusion that artificial light exposure was indeed unhealthy for people and was close to being a "scientific slam-dunk". Upon closer examination this conclusion proved spurious for the most part. The research is indicative that artificial light exposure has an effect; the extent of that effect is still unquantified for the most part. Much more research needs to be done on human light exposure to contain this problem and quantify its myriad impacts. This point was made very clear by the interview with Dr. Rea. On the other hand, research on artificial light and sea turtles is a well developed science. The results are apparent: artificial light negatively impacts sea turtles, especially the hatchlings as they migrate towards the sea. Likewise the research done on its effects on birds is fairly conclusive…again artificial light having a negative effect. Research conducted on artificial lights effects on the night sky shows a negative impact for the astronomical community and those who enjoy unsullied nature.

There is also little doubt that artificial light used wastefully contributes to upstream environmental harm. This is a result of burning fossil fuels to make energy that is wasted on inefficient lights. This is a significant misuse of resources. While the EPA does not address light pollution directly it is involved in helping people to use energy efficient products including light fixtures. The research conducted in order to answer the thesis questions was not conclusive in all areas that were examined.

6.0 Analysis and Discussion

A great deal of effort was expended to answer the questions that were posed for this thesis. The following section presents the analysis of the research.

6.1 Artificial Light and Human Health Analysis

This portion of the research focused on the primary question. To paraphrase: is artificial light-at-night exposure harmful to human health? Enough to warrant oversight by the EPA? Causality appears to be the largest stumbling block to a definitive answer. In other words, there is no overwhelming evidence linking exposure to light-at-night and ill health effects. In their paper, "Light during Darkness and Cancer: Relationships in Circadian Photoreception and Tumor Biology", the authors note the problems in tying artificial light to cancer growth:

> While accumulating evidence points toward potential for the various work schedule and lifestyle factors to influence tumorigenesis and progression, causality remains elusive and likely reflects significant variability with physiologic context. For example, it seems that the pathway by which melatonin influences tumor development and progression is dependent upon fatty acid availability and metabolism (521).

Dr. Rea gave a detailed explanation of light's potential impact on health, during his interview. He specifically warned that getting the subject quantified was of paramount concern along with having a proper outcome measurement:

> But you have to get the spectrum, the intensity, the distribution; [you must get] all those things correct and then you have to tell me what health is. Like the rate of cancer growth or it could even be sleep quality or it could be cortisol [levels]. And so in that context light can modulate some of these behaviors, some of the hormones that have been linked to health. So our goal is to try to maximize the benefits and minimize the deleterious effects

Artificial light as noted by Dr. Rea has some curative properties that were not examined in this paper. For example treating people with high intensity fluorescent light to remedy SAD (Seasonal Affective Disorder) is one such use, which shows that artificial light can be used to help people in a medical context. Dr. Brainard likewise was reluctant to urge regulatory oversight of artificial light onto the EPA, and he also noted the healing properties of properly used artificial light. During his interview, when asked if the EPA should consider voluntary compliance and education about light issues, he said:

> Sure. It just depends on how severe it is [the problem of artificial light] and how likely it is people could hurt themselves without the intervention of the government. So the standard bodies that really set limits on light safety, there are two of them: one is the American National Standards Institute and the other is ACGIH (American College of Governmental and Industrial Hygienists). And they set these guidelines and by and large that's how it's done. But whether or not it would need further regulation….I'll give you another example, light therapy is currently being used for people with winter depression. It's pretty well studied and understood for about 25 years. So the standard of practice is to prescribe a bank of fluorescent lights that are quite bright—10,000 lux—for a patient to use on a daily basis. And if a person is going to be responding to that light there's a high likelihood that they will improve. This is exactly the kind of device that the FDA—the federal government—could choose to regulate; currently they have chosen not to. They have allowed the marketplace and the manufacturers to use good sense marketing and standards for that medical device. But it really is a medical intervention; so it's hard to predict whether the fed needs to come in or will come in once and if criterion evidence is reached.

Dr. Stevens felt that EPA would eventually regulate artificial light under their mandate, but perhaps not under the so-called "melatonin hypothesis." In his interview he said [emphasis mine],

> Yeah, I think it [EPA] will [regulate]. It should. *But not necessarily for the potential cancer connection.* But, the Environmental Protection Agency should investigate what to do about perhaps national regulation on outdoor lighting in particular, and perhaps they will be involved in indoor lighting as well.

Dr. Blask, when asked if this aspect of artificial light would be subject to regulation in the future, stated:

> I do think it's going to be an issue that is subject to regulation down the road. Again if the research continues to indicate more than it indicates at this point [with] ill effects on health and in particular cancer, yeah I think this will continue to be a serious issue. That will [be] down the road, if we stay on the trajectory we're at right now, will be the subject of regulatory issues. I get the sense from my colleagues in the lighting industry—and from being invited to lighting industry-type meetings—that the lighting industry is trying to get ahead of this. So they're very interested in what we're doing and what our research shows.

The researchers agreed (other than Dr. Stevens) that this issue *for now* is not one that necessitates EPA regulation. That is not to say that exposure to artificial light-at-night is healthy for a person. By making some inferences and examining the body of literature, one can see that the research on this phenomenon is in its infancy and, as the evidence comes in, perhaps the need for regulation will become more obvious. Blask, Stevens and Brainard all felt that the research indicates that artificial light has a potential negative impact on human health, but they opined that quantitative data does not yet support a national "artificial lighting" regulation. Regardless of the issue of regulation, to put the artificial light phenomenon in context, the researchers were asked where concern about artificial light fits in with other global environmental issues. Dr. Blask expounded on this point:

> That's hard for me to say, because you could make the case—and the lighting industry has made the case—and are trying to develop more efficient lighting. Light pollution contributes to global warming because of the carbon emissions. You have coal-powered plants that are generating electricity and inefficient light bulbs...and you're putting carbon into the atmosphere. So in that context you'd have to say that it is part of the global warming issue. But in terms of it's effects on health like our survival…in terms of specific things like the cancer issue I couldn't give you a good [answer]…I'd have to see a chart on where all these things range. I think that global warming is obviously the biggest problem of our time right now. Because if things go the way it seems…it's not going to matter if

> we have electric lighting, so that becomes a moot issue. So everything is dependent upon that. I think light pollution and the potential ill effects on health rank high [or are] nudging up. I think they are potentially very important, especially in the area of cancer. I think that's going to be the biggest factor in health that we have to contend with because we have this real definitive link through suppression of melatonin and other aspects in the circadian system, other aspects of circadian disruption besides melatonin suppression. But melatonin suppression is certainly major and if that research continues to develop—again along the trajectory we've seen thus far—I think that this will be considered a very high priority issue.

Dr. Brainard weighed in on this topic, noting that light is an essential component of life. He also emphasized that this research is relatively new, and it may not rank high compared with other global problems [emphasis mine]:

> Light is absolutely critical to all life on the planet or virtually all life on the planet. Very few species can live without access to light, so the first thing you have to keep in mind is, it's responsible for our food chain and it has many beneficial and essential regulatory purposes for our species and many species. Also light can be used as a therapeutic intervention and I already gave you that example. So right there is the crux of it: anything that is capable of healing a disease, there is always two sides to that. If it can heal, it can also harm if it's used incorrectly or inappropriately. It's a double-edged sword. The studies that are around on the value of light for promoting and helping human health are tremendous. *There's only a fairly small relatively speaking, group of studies showing there is a possible risk factor. That really needs to be fleshed out and until it's fleshed out it's really hard to weigh it against other problems.* I mean global warming? Yes, global warming is absolutely real, it's coming it's not a good thing and it's been known for quite some time despite the political pressure to suppress it. That being said, how immediately the effects of global warming are going to be seen, that's anybody's guess. Because we know nobody can predict the weather, let alone geophysical cycles of heating and cooling. You know it's all done in extremely sophisticated computer models. So how big is the problem [light pollution] compared to other problems? Let's take on global starvation. 500 million people starve a year. A better way to encapsulize it: three individuals starve every 10 seconds, right? It's not for a lack of mankind having the capacity to grow food, to store food and to ship food. We had the green [agricultural] revolution a long time ago. There's adequate capacity to grow, distribute and provide food for every man, woman and child on the planet right now and yet every 10 seconds three people die of starvation or malnourishment. So in my mind global starvation and malnutrition is a far worse problem.

Dr. Stevens did not want to rank this issue compared to other global environmental problems. He did caution as to its *potential severity,* however*:* "In the long run, lighting the night could be as every bit as catastrophic as global warming." In conclusion, the experts are sounding a cautionary note on artificial light exposure, but do not have enough evidence to promote regulation at this stage. Yet, several of the researchers interviewed (particularly Dr. Stevens) felt artificial light exposure should fall under the EPA's purview, and could perhaps be a part of their educational outreach, and research efforts. All agreed there should be a great deal more research to quantify the nature of the problem. Dr. Rea stressed this several times. This would entail a complete analysis of our lighted environment, including both natural and artificial sources. The nature, duration and exposure times to the stimuli are all in need of quantification. Potential studies should also include lifestyle factors (when a person works for example), and other risks associated with health to be sure there is a true cause and effect relationship. Artificial light acting synergistically with other inputs should also be studied. As of now, little has been done in this area, and it seems that in the current political climate little will change in the near future. Dr. Blask told the researcher that they are having a terrible time getting funding for basic research of this type and, unless this changes, it seems unlikely that the necessary science will be not done. It can be stated unequivocally that a great amount of research is necessary on exposure to artificial light to put it into its true context as an environmental health hazard to people, if indeed it is one.

6.2 Artificial Light and Ecology Analysis

The research that was initiated for this portion of the thesis was more conclusive, in regards to artificial light having a negative effect on a portion of the biota. The published literature was quite extensive in examining the ill effects of artificial light on nesting sea turtles. And this literature review conclusion was backed up for the researcher by the interviews conducted with Dr. Salmon and Dr. Witherington. Both felt that the impact of artificial light on the sea turtles warranted some oversight by the EPA or another national agency. Dr. Witherington spoke about the lighting ordinances in Florida that are community or county wide. He felt that oversight could be warranted by the EPA as a majority of problems for the turtles result from non-point sky glow, from communities far away from the ocean. He spoke about the pervasiveness of the lighting problem:

> I think it is an interesting avenue to pursue because just like other forms of pollution we often can't solve the problem completely. We're human beings with only modest night vision and we need a little bit of light to see at night. There are legitimate concerns for nighttime safety and security. There is going to be some light used in our future. We can't just turn off all the switches. So it's worthwhile looking at the sources we use to imagine how they can serve our purpose without causing significant harm to other aspects of our world. To this end it will help to apply the best available technology to our lighting so that we have lights that are useful to us but that have minimal effect on human beings and animals. So, just like it would be imprudent to cease use of every chemical that could do our environment harm if in the wrong place, neither should we simply try to turn off all offending light sources. We can however, regulate how harmful substances and energy are used and how they get released into the environment.

Dr. Salmon went on to explain the contributions being made by his students in helping to actually measure the problem of artificial light and nesting sea turtles, thus

showing that as a "problem" artificial light can be shown to have a negative effect on at least one animal species. He explained some of the work he and his students have done:

> I think one of the most important contributions that my students and I have made towards this whole problem is to show that it's possible to do experiments and to quantify the responses of the animals to artificial lighting and to do experiments to test mitigation solutions or to propose mitigation solutions before they are implemented. To give you an example: one of the things we've been very interested in is whether the whole effort to reduce the effects of artificial lighting on sea turtles can be done by modifying light sources themselves - particularly the wavelengths of those light sources. We've developed protocols in our laboratory that are actually testing the so-called "turtle safe" lights. It might seem to be common sense that before you install "turtle safe" lights anywhere you figure out if they work. But in point of fact that hasn't been what's been done in the past.

One may presume that the safeguarding of nesting sea turtles would fall to some agency other than the EPA. Yet the cause of this harm is man-made artificial light. And if one takes the EPA's stated mission of protecting the environment, at face value, one would assume that this would—to some extent—fall under their domain. This is a conundrum of sorts. The stated mission would seem to incorporate a vast swath of problems, including artificial light and the biota; yet, in reality the EPA is a political entity and as of now, the problems associated with light are not a priority for the agency. It is problematic at best if the EPA will become involved with regulating light exposure on the biota. It seems unlikely that this will happen, considering the neutral response that was put forth by agency representatives in the course of the research. Other federal agencies such as the Department of the Interior or the U.S. Fish and Wildlife Service could perhaps bring a regulatory stance to this issue, if the EPA decides that this does not fall under their mandate. The decision to regulate will be based on political will and having enough people in positions of importance deciding to take a stand. This may not

happen until enough people know about the negative impact that artificial light has on the biosphere.

6.3 Artificial Light and Esthetics Analysis

The topic of artificial light and esthetics is the "classic" light pollution that is the bane of the astronomical community worldwide. The skyglow phenomenon discussed in the literature review has a pernicious effect for astronomers and those who enjoy an untainted night sky. There is no doubt of its cause: wasted artificial light being squandered by misdirection and overuse. But in the context of this thesis, does this problem necessitate regulation by the EPA?

Although a formal interview with an EPA regulator was hard to come by, the response received from the office of the chief administrator, mentioned this topic. Tom Eagles wrote:

> In the case of light-at-night exposure, I personally feel that it's a growing nuisance, with some scientific repercussions (e.g., interference with ground-based telescopes)—but I doubt that it's anywhere near the point where Congress is likely to be willing to seek a regulatory solution. But the situation may well be more serious than I realize, and in such cases, persuasive writing by well-grounded academics is one principal way to raise consciousness and agitate for change.

It is doubtful that the EPA considers this area a priority issue that needs to be looked into by their staff. This was confirmed by Clark Reed, who works in the EPA's EnergyStar program. He stated in his interview, "I think if you want to look at who has regulatory authority for excess light look at the local governments. As you know lighting ordinances are made at the local level just like building codes are. The federal

government really does not play a regulatory role and has not played a regulatory role in this local issue." It is interesting to note that Mr. Reed feels that this topic is best regulated at the local level. And in fact the laws that are on the books right now concerning artificial light and light pollution are almost exclusively at the local level. The fact is light pollution and exposure to light-at-night are not mentioned on their website is confirmation that indeed, this topic is not currently on their radar.

One aspect of this problem, noted in the literature review, is the fact that there have been attempts to quantify this type of light pollution, which is known as skyglow. This typically is the first step in administrating a problem: "what gets measured gets managed." Authors Cabello and Kirschbaum state,

> The current mathematical models of the urban light pollution are restricted to a specific situation, that is, the astronomic observations. Those models do not take into account other factors that are related with the causes of the light pollution in a particular city. The next stages of the investigation are related to the estimation of the necessary set of parameters like those shown in table 7 (149).

Their research was aimed at building a "knowledge base" in order to have quality data to assist governmental and private agencies to be able to make informed decisions regarding the use of artificial light (142). Other researchers have also made inroads into the modeling of light pollution using GIS (Geographic Information Systems), and the use of satellite monitoring of light polluted areas, which was mentioned in the literature review. This is the first step to management. Dr. Rea in his interview mentioned this concept of measuring certain parameters of artificial lighting:

> So when we come to light pollution I think we have a general concept of what that is; but what we've been trying to do is to convert those to reliable, measurable aspects of the general concept of light pollution. And we feel there are three concepts that need to be defined: first of all is obscuring the stars and you can measure that either by flux or by bioluminance on a defined plane and so we now can have a system measuring it. So if somebody says well you

> produce more light pollution in the context of reducing stars, now you can measure how much light there is and more easily quantify it.

Measurement of light flux, and other aspects of research on artificial light ruining the quality of the night sky for the astronomical community is being done currently. As noted earlier in this paper the community of astronomers is only a small portion of the total population. For the general public, the preservation of the night sky may be seen as protection of a worthy natural resource. Why should people be concerned about this? The researcher conducted an email interview with Dr. Crawford of the International Dark-Sky Association, in which he expounded,

> We live not only in our town (or wherever) but in the world and in the universe. We (most people) have lost touch with that fact, to the detriment of our environment (holds for most aspects of the environment, not just the night). We need to be in touch with it, the real *it*, not just as seen on TV. What a crime if our children and their children never can see the Milky Way, the stars, or the real night life around them. Need we destroy nature (in all sorts and all ways) for "progress"? I hope not. So, education and awareness again [are important].
>
> Furthermore, the night has been a vital aspect of many cultures and religions and life. It still is in words, but not in reality. One note only: churches in this country (and there are parallels in other religions and cultures) that "The Heavens Declare the Glory of God." But they use terrible outdoor lighting and destroy that view. Why? Why are they not one of the strongest allies for a viable view of the heavens and of the Night? Awareness again [is important].

This need for education on this topic of light pollution is one in which the astronomical community has been in the vanguard. Crawford notes in the article, “Light Pollution: The Problem, the Solutions”, that “the main problem is that there is still a vast lack of awareness of the issues, the problems, and the common sense solutions. Education is the main thrust of most current activities” [of the International Dark-Sky Association] (“Light Pollution: The Problems, The Solutions”, 16). This lack of knowledge is also echoed by Kaplan (170), who says that a lot of the lighting ordinances on hand, now are a

contributing cause of light pollution. Isobe, Hamamura and Elvidge (researchers at the National Observatory in Mitaka, Japan and the NOAA National Geophysical Data Center) have been using department of defense satellites to measure the amount of light wasted by improper lighting note,

> The fraction of people enjoying astronomical observations and star-watching is not large, that is, only one tenth of one hundredth of the total population. In order to get the support of the majority of people, we have to develop a clear way to educate the public. Since we have the DMSP (Defense Meteorological Satellite Program) data, we are trying to develop a new way to reduce light pollution (363).

John Percy of the University of Toronto also avers that, "education is the first step in preserving the astronomical sky" (353). Although his main concern is for the astronomical community he reveals that, "light pollution is obviously undesirable because it is a symptom of inefficient, ineffective lighting; major cities waste millions of dollars each year in lighting the night sky" (353). Percy also feels that light pollution may be an ideal way to teach science and a great way to involve students in effecting change. Dr. Margarita Metaxa shares this sentiment and believes that "educating the world about astronomy and light pollution is a major challenge which can be met if we [professional astronomers] work together with interested organizations" (152).

Knowledge sharing and bringing people together on lighting issues is one of the most important matters being done today by the astronomical community. And if the impact of artificial lighting has a proven negative effect on the biosphere (including people) its importance for the non-astronomical community is greatly increased. Hence, the research can be distributed to the community at large and be used to implement effective policies and guidance protocols for the use of artificial lights in a responsible manner.

Although education, and voluntary initiatives are important, Dr. Crawford stated in his email interview, “Voluntary action is needed. It is essential. But so is governmental regulation. Just as in water pollution, air, electrical dangers, plumbing, toxic waste, and on and on”. Further, he felt that the EPA should be researching this phenomenon. “Research (support it and do it), education (learn about it themselves and then do whatever they can to educate all others) to many target audiences and by many means, written, oral, multimedia, etc., and regulate as best one can. Work with other agencies to do the same, individually and collectively.” The International Dark Sky Association, as noted earlier, is in the forefront of the effort to have light pollution considered a true environmental threat. The methods employed are education, the conducting of symposia, and community outreach. In the opinion of the researcher it is highly unlikely that the EPA will consider any regulation of light pollution and artificial light based on the esthetics of the night sky. The rationale for that being that the majority of Americans are either urban or suburban dwellers. Hence, they have never known “natural” night skies and place little or no value on them as part of their environmental heritage. And the EPA being a political entity will almost certainly not regulate something that is not on the current radar screen of public perception. The IDA’s activities and growing concern over the wasted energy component may help to make this issue more “mainstream” and force EPA to at least do some basic research on artificial light’s overall environmental impact.

7.0 Conclusions

The following section summarizes the results of the research findings and specifically addresses the research questions.

7.1 Thesis Question, Part 1

Does improper lighting (defined as light pollution) and/or exposure to light at night constitute a risk to human health and safety?

The results of this research effort demonstrate that while light can have a negative impact on safety in terms of glare, the research linking exposure to light-at-night and human health hazards is much more tenuous. More research is needed quantifying human factors and light exposure. The circadian rhythms that are entrained by natural cycles of light and dark assuredly are affected by exposure to light-at-night, but that extent is unclear. The link between exposure to light-at-night exposure and reduced levels of melatonin (the "melatonin hypothesis") appears to have validity. Whether or not this leads to an increase in breast cancer is still under investigation. Authors Brainard, Blask and Jasser state that,

> Light exposure, the status of physiologic circadian rhythms, diet, and exercise habits, though recognized as bearing a potential influence on cancer outcome, are less well-defined in their roles in cancer pathophysiology and are consequently often given subordinate attention in clinical approaches to cancer. Continued rigorous empirical inquiry into the physiology and clinical implications of these habitual, integrated aspects of life is highly warranted at this time (521).

Clearly there is a body of evidence that makes the case that humans have a significant physiologic response to artificial light exposure. As noted in the results section this can be of a negative or positive nature. The inherent nature of that risk must be studied and quantified by scientists to put it into a context whereby scientifically valid conclusions may be drawn. At this point in time the links between light-at-night exposure and human health risks are suggestive at best and need further scrutiny to draw valid conclusions. More basic research is needed in order to prove or disprove artificial light's impact on human health and the extent to which it is a problem.

7.2 Thesis Question, Part 2

Is light pollution a concern to ecological systems, and if so to what extent?

This portion of the research indicates that light pollution is indeed, a concern to ecological systems. It appears that artificial light has a negative impact on many different species. In particular migrating birds and sea turtles have been shown to be harmed by artificial light. Blair Witherington, one of the researchers interviewed for this work says in his article, "The Problem of Photopollution for Sea Turtles and other Nocturnal Animals", "in Florida, each year, approximately one million hatchling sea turtles are misdirected by lighting which results in hundreds of thousands of hatchling deaths" (305). Furthermore he states that, "on a single night, flood lights at a park on Padre Island, Texas, USA killed approximately 10,000 birds representing 39 species" (305). This clearly is a negative influence on the environment.

Witherington and Salmon, both conveyed to the author the fact that artificial lights do harm sea turtles, and cannot be considered benign. Both felt that the EPA was an appropriate agency to help in mitigating this problem. Part of the rationale for involving the federal agency is the fact that improper lighting, miles from nesting beaches, contributes to skyglow, and impacts the turtles in a deleterious fashion. They felt the scope of the problem went beyond local regulations and ordinances. Dr Salmon expounded in his interview [emphasis is mine],

> What I do know is that there have been national policies and programs implemented in Europe in particular. And they've been very successful. You don't really have to have vast amounts of scientific knowledge to know that artificial lighting affects wildlife. The data from what I understand on the effects of artificial light on humans is fairly…..the effects are very slight and there is some question whether or not they actually occur; *but there is no question whatsoever that birds and insects and many other kinds of animals are harmed by artificial lighting*. And knowing that and knowing the economics involved in wasting energy [producing artificial light] a national policy on the topic of lighting can't help but be beneficial. The problem as always is conveying information to people in positions of power the importance of doing something about it and having the resources set aside to actually implement the changes because it's not going to be cheap. The benefits are all long term and in some European countries they've already done that [implemented a national lighting ordinance].

Artificial light has a known negative impact on both sea turtles and birds. Other research shows impacts on other species as well. The extent of that impact is not known as well as that on the turtles and birds. Nevertheless it can be said with no ambiguity that artificial light does have a bearing on the biota. Taking the EPA mission statement at face value, it can be concluded that indeed the impact of artificial light on these animals warrants oversight by the EPA.

7.3 Thesis Question, Part 3

Does the scientific research on light pollution and light-at-night make a case for regulatory oversight, within the mandate of the EPA?

This part of the research yielded mixed results. There seems to be little scientific doubt that artificial light affects organisms of all sorts, all the way from insects to people. However, the degree to which it affects animals and people varies all over the charts. As noted above, clearly artificial light has a harmful impact on sea turtles and birds. Less clear is its impact on people. If the EPA's mission includes protection of wildlife then it can be said that the research shows that the EPA should regulate. This is not entirely clear however. To reiterate, the EPA's mission states, "The mission of the Environmental Protection Agency is to protect human health and the environment. Since 1970, EPA has been working for a cleaner, healthier environment for the American people" ("About EPA", par. 1). One could presume that the environment includes the animals that live within it. However the EPA being a political agency is hesitant to act without a specific mandate from Congress. Tom Eagles, who works in the EPA administrator's office, wrote me saying, "EPA only creates regulation under specific Congressional authority, and none of our authorizing statutes (for example, the Clean Air Act and Clean Water Act) has any provisions regarding light pollution or light exposure. Unless and until Congress passes a law authorizing us to do so, EPA cannot address these issues" (par. 3). Herein, a person could get lost in bureaucratic wrangling, semantics and inter-agency minutiae, while shedding very little light on the problem. The very nature of light itself does not easily lend itself to regulatory solutions, as it is not a "typical"

pollutant. It is physical, not chemical. It is not persistent, but can be shut off instantaneously. And yet it does impact people and the environment, both positively and negatively. Dr. Crawford has likened light to a drug. In his email interview, Dr. Crawford elaborated on the nature of light:

> As with any other drug, light can be a big help, when needed. It must be carefully matched to the specific need and then monitored as to its effectiveness. If "overdosed" (too much light) it is not good. If misused, it is not good (glare, spill light, etc). It is costly and there can be (and often is) a great waste of scarce dollars. It is much hyped by those who stand to make a profit. It can even be a killer. But that is no reason to not use it, when it is well understood and "prescribed." It can be of great value, when needed and when well matched to the need. It can be a terrible problem to individuals and to the nation when badly understood or used.

There is also a substantial body of evidence that concludes that artificial lighting has a negative impact on the night sky. One can make the case that the night sky is a part of the environment. And yet, it is extremely unlikely in the author's opinion that the EPA will attack this problem in this context. This highlights the Janus nature of artificial light. If used properly, it is a boon. If used, improperly, it is a bane. Hence, clarity on this question is not forthcoming. It seems that the research done to date, would likely exclude EPA from regulating light. This does not mean that artificial light does not have a negative impact on the environment. It does. This investigation has shown that, but it has also shown that EPA is very unlikely to become involved with artificial light regulation at this point. That may change in the future if research shows a definite cause and effect relationship with human health problems. And that may be the most important part of this research endeavor, the clear need for more basic research on light's effects on people. There are some tantalizing clues, especially in epidemiology, linking exposure to artificial light-at-night to human health effects, but more quantification is sorely needed.

7.4 Next Steps

During the course of research, many different avenues of inquiry opened themselves for investigation. In order to bring a successful (and timely) conclusion to the project, it was necessary to focus on only a few of the effects of artificial light. Artificial light has a negative impact on the esthetics of the night sky. It has a negative impact on some species of animals, particularly sea turtles and birds. It also has an impact on people, although the extent of that is less clear. Table 7.1 shows a breakdown of the research conducted for this thesis.

Table 7.1-Research Results Breakdown

Light Pollution Component	Impact (Y/N);Positive (+) or Negative(-)	Within EPA Mission Statement
Light Pollution & Skyglow/Esthetics	Y, -	Conditionally, yes
Light Pollution & Ecology	Y, -	Conditionally, yes
Light Pollution & Energy	Y, -	No. Although upstream energy production is.
Artificial Light & Human Health	Y, +/ (tentative)-	No. More research needed

In table 7.1 a positive effect of artificial light on human health is noted. This is in reference to the treatment of SAD (Seasonal Affective Disorder) by banks of fluorescent light. The research was not as conclusive regarding a negative impact on human health, yet most authorities feel it can and does have an effect. The overall picture shows artificial light has an impact on the environment. In some cases it is clearly negative in nature. However, much work needs to be done quantifying our photic

environment before regulations would be prudent in regards to its effects on human health. Furthermore, it is felt that education and research should be the focus of the EPA at this point. It would not be unreasonable for the EPA to have an educational page on its website devoted to lighting issues. Groups such as the IDA have taken an educational approach and bring in lighting engineers, doctors, and regulators to their symposiums to bring together the many disparate groups that have a stake in artificial lighting. For the time being, a cautious approach is needed when considering the impact of artificial light on the environment. In this context of insufficient data regarding artificial light exposure and human health, it would probably be wise to invoke the precautionary principle when considering artificial lights impact on human health and the environment. This statement reads,

> When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically.
>
> In this context the proponent of an activity, rather than the public, should bear the burden of proof.
>
> The process of applying the Precautionary Principle must be open, informed and democratic and must include potentially affected parties. It must also involve an examination of the full range of alternatives, including no action. ("Precautionary Principle", pars. 9-11).

In other words, even if it is not (now) a proven health hazard, act accordingly and protect yourself. EHS professionals would be wise to research some of these effects of light, and perhaps incorporate some cautionary precepts to protect their workers. This would especially hold true for people who work non-traditional shifts. Raising awareness of the potential impacts of artificial light to a population long blinded in its industrial glare, will go a long way to minimizing the negative effects reported in this research.

Appendix A

A.1 Blask Interview

Interview with Dr. David Blask, PhD, MD
March 13, 2007, 3:20 PM-4:20 PM

Conducted via telephone by Tim Berthaume

Q=Tim Berthaume
A=Dave Blask

Q: Hello, this is Tim Berthaume. I would like your permission to record this and to transcribe this interview.

A: Tim, this is Dave Blask and I give you my permission to record this interview.

Q: Thank you. First and foremost I want to say thank you very much. Feel free to go wherever you wish to go. And I appreciate your time, and I think this interview will help my thesis immensely.

A: No problem. Thanks for asking me. I appreciate the opportunity to maybe help you out.

Q: Great, great. First and foremost Dr. Blask I would like you to identify yourself, your credentials, where you work, who sponsors your research, and any other pertinent information.

A: Ok, well I am David Blask. I'm a PhD, MD. I'm a senior research scientist and the head of the laboratory of chrono-neuro-endrocrinology at Bassett Research Institute, which is part of the Miriam Bassett Hospital in Cooperstown, New York. I'm also a research scientist in the department of medicine at Columbia University College. And I think that covers that.

Q: How long have you been with Bassett Research Institute?

A: I just finished my 15th year.

Q: All right. My first pertinent question to my thesis is when did you first become interested in the effect that artificial light has on human health? (Edited for clarity)

A: Well it started when I became interested in melatonin in the pineal gland and its potential effects on cancer. And that interest developed over 30 years ago. And I've been working in the area of how melatonin produced by the pineal gland at night inhibits cancer growth. And since we knew from animal studies that light was a very potent inhibitor of the ability of the pineal gland to produce melatonin; Worker suspected that light during darkness or exposing animals to constant light throughout their 24 hour cycle might stimulate cancer growth, especially breast cancer growth. And in fact a few experiments done in the early days of this research back in the late 70s [and] early 80s bore this out. And the effects of constant light exposure on animals had a stimulatory effect on breast cancer development and growth was thought to be mediated through the suppression of melatonin. But no experiments really…none of those experiments really directly addressed the mechanism. In other words we couldn't really determine from those early experiments whether it was the ability of light to suppress melatonin or some other effect of light that was really responsible for breast cancer stimulation. Prior to those light experiments—experiments done by a number of workers including our own lab—it showed that if you took out the pineal gland without affecting the light cycle at all...those animals developed more breast cancer than those that had intact pineal glands. Experiments earlier then that and other tumor models concluding that…a tumor model of skin cancer called melanoma where this was shown to be the case. Actually the very earliest work indicated that if you remove the pineal gland that there could be a stimulation of tumor growth that would occur. And the light exposure experiments in animals began after that; and we came along in the mid to late-'80s and showed that in human breast cancer cells, that if we exposed the cells to melatonin at a physiological nighttime concentration…that is a level of melatonin that would be found in human blood at the peak of melatonin in the middle of the night…that breast cancer cells would grow much slower. So that was really the first evidence to show that number one, melatonin at physiological concentrations had a direct inhibitory effect on cancer growth, and number two specifically on human breast cancer growth. And Dr. [Richard] Stevens came along in 1987 and looked at the prevalent data in the literature, including ours, and came up with his light-at-night hypothesis. He had wondered why there was this increase in breast

cancer risk associated with industrialization and proposed that you know something about industrialization and westernization was responsible for this increased risk of breast cancer apparently had developed and couldn't account for it by other risk factors. He came up with the idea that maybe it was electrification; that was a big, big factor in the industrial revolution. And then saw that indeed there was something about electrification that is light and when it is present at inappropriate times...that is when it is present during the night can shut down the production of melatonin, which we and others had shown has anti-cancer effects. We became interested in the effects of light on human health…specifically human cancer. Really based on our own work on melatonin's inhibition of cancer growth and the knowledge that we could stimulate cancer growth by taking out the pineal gland or exposing the animal to constant bright light. But we didn't really have a public health context in which to put that data. And it was really Dr. Stevens' hypothesis that put it into a framework that made sense in terms of this perhaps being a real public health issue. And so, could in fact electric lights at night could account for this apparent increase in breast cancer risk associated with industrialization, perhaps through a suppression of melatonin? So everything sort of stemmed from there. I really got interested specifically in the public health aspects of this right after I saw that paper and met Dr. Stevens and started collaborating with him in 1987, so to answer your question—and I didn't answer it very briefly but—it was a two stage development of interest. Primarily based on our initial work on melatonin's anti-cancer effects and this context that "Bugs" Stevens put it in terms of the public health issue.

Q: What is the function of the pineal gland outside the production of melatonin?

A: Well that is its primary function. Its primary job is to make melatonin at night and to provide that "signal of darkness" to all the organs and cells in the body and that's how your liver and your heart and virtually every other organ in the body knows that its dark. Obviously your internal organs don't have eyes so there's no way that they can know whether it's light out or dark out, so when melatonin rises in the blood at night because of increased pineal production the special receptors in these tissues and cells all over the body sense that increase and these receptors get tickled and set off intracellular signals that signal the cells that melatonin is high and so it must be dark. The pineal melatonin signal has been called the hormone of darkness or the vampire hormone. It's been called the chemical expression of darkness. It really provides a biological signal for darkness and the duration or time that melatonin is increased in the blood really defines how these tissues and organs of the body sense that it is dark. So the longer the dark period the

longer melatonin will be high in the blood. The melatonin signal provides information about photoperiodic length. The melatonin signal tells the cells of the body its dark, so in a way it provides the body with clock information. It acts like a clock. In parts of the world where we have great seasonal changes based on dramatic changes in daylight like here in the northeast that expansion or contraction of the nighttime melatonin signal with longer or shorter nights. Or during the winter or during the summer provides the cells and tissues of the body with seasonal information as well. So not only do your cells and tissues and organs know what time of day it is based on the melatonin signal but they can know what time of year it is. And that's important for species that breed on a seasonal basis like some deer and sheep as two prominent examples. Hamsters also breed on a seasonal basis if they are maintained in the wild and their whole reproductive cycle is dependent on the length of the night versus the daytime. And that information about seasonal daylight or nightlight from melatonin is what synchronizes their reproductive cycles with the appropriate season of the year.

Q: That's really interesting. I have one follow-up question to that. Melatonin as a hormone signal, what exactly does it "tell" your cells to do? To go into a quiet period…a period of repair…less cellular activity...? (Edited for clarity)

A: Well it depends on the cell. It depends upon what activity you're talking about because you know some cells are more active in the body at night then during the day.

Q: Can you give me an example?

A: In humans, for example, certain metabolites might go up during the nighttime. I can't tell you—we don't know if all of those things that go up during the night are necessarily the result of melatonin, all right? A lot of this research is still being worked out. But, generally speaking with respect to melatonin and cancer cells for example—use one which I have expertise in—it makes cancer cells less active during the night. It slows down their metabolism; they don't divide as rapidly during the night. Whereas during the day they are more active they're more metabolically active—their rate of cell division goes up and that appears to be controlled by the nighttime melatonin signal. So in that case melatonin does quiet down cell activity. On the other hand this seems to occur in humans your immune activity—or at least a particular part of your immune system, T-cells—tend to become more abundant and more active at night. That increase in activity appears to be queued by melatonin. So, there you have two diametrically opposed

actions of melatonin at night that seem to be opposite. In one case melatonin is an inhibitor or a suppressor of the activity of one type of cell, that is, the cancer cell. And in the other instance it appears to be a stimulator or enhancer of the activity of another type of cell…cells of the immune system, in particular T-cells. So that's probably the most prominent example I can give you. So it depends on the context of what the melatonin is going to do. So the same signal can do opposite things. In seasonally breeding species, for example like sheep versus seasonal breeding in the hamster. When melatonin is high during the long nights of the winter in the hamster for example, when melatonin is high, for a long time during the night. That provides an inhibitory signal to their reproductive system, so there reproductive system literally atrophies and goes away in the winter months so these animals don't reproduce until the spring. Whereas in sheep the opposite occurs. The same melatonin signal basically, high melatonin for a long time during the night—only in that case the melatonin signal stimulates the reproductive system of the sheep—so that they breed during the winter. So you get what I am saying?

Q: Yeah. It's dependent.

A: It's dependent on the context.

Q: Right, OK. All right. Do you feel that light pollution and exposure to light at night should be regulated under the auspices of the EPA, per their mandate: "The mission of the Environmental Protection Agency is to protect human health and the environment? Since 1970, EPA has been working for a cleaner, healthier environment for the American people."? Do you feel that light-at-night and exposure to it has enough consequences that the EPA mandate would hold that under its umbrella, so to speak? (Edited for clarity)

A: Well, we don't have, I don't think we have the results of enough studies yet to go that far you know for federal legislation. I think that would be premature at this point. Although I think the data that is emerging are certainly pointing in that direction, OK? But if you were to say do we have enough scientific evidence at this moment to justify concrete legislation to you know ban light pollution as a health risk? At this point [it] would be arguable. I think there is evidence indicating it is a hazard under certain circumstances and it depends on so many factors. When you say light pollution what are you talking about? Are you talking about wavelengths of light? Brightness of light? What is your duration of exposure? Timing of light. We have to do more research to find out more about the characteristics of light and under what circumstances those

characteristics may be detrimental to us in terms of health risk. Now in terms of cancer certainly our research supports the idea that light [at night] is a risk factor for breast cancer. Again we need more research to corroborate that. And to make an argument that indeed you would need to pass, if not federal legislation certainly local ordinances at some point. And I think this is going to be an issue that is going to continue to emerge. But I don't think we're there yet. Absent something like that—you know people ask me all the time, "Well what do you recommend?"—I say, [have] prudent avoidance of light at night in your own life. And that is sleeping in a darkened environment. And minimizing, if not totally eliminating any exposure to light at night for obvious reasons of health. You should be able to get a good night's sleep; and minimizing your exposure to enough light that would suppress your melatonin [that] does away with the protection that melatonin appears to offer in terms of protection against the development and growth of cancers. So, that's my answer. I can't give you a yes or no answer to your question because it's not really at the stage where you can say that…

Q: In your opinion does light pollution deserve to be treated like IAQ (Indoor Air Quality, that is. radon, ETS, etc.) for the purposes of regulation? (Question edited for clarity)

A: I think an educational page by the EPA or blurb about what we do know (about) the potential ill-health effects of light-at-night; I think that would be very useful. And [it] gave a synopsis of where we are in terms of what we know and provided information to the public; I think that would be very useful. I don't know what these things are in terms of what you're talking about radon and you know I see things in the media every so often that you know radon...you have to protect yourself against the accumulation of radon in your cellar. In order to sell the house you have to have radon levels measured and those kinds of things.

Q: I apologize for the lack of clarity on this question. Basically the EPA regulates or has an informational set for indoor air quality, but like I said its multi-discipline; that's how the research I've done on light pollution is very similar…

A: Yeah, yeah. I think an informational approach on light pollution at this point would be very good. There's a guy I met recently at the annual meeting of the Dark-Sky Association of Tucson, and I met a lawyer from the United Kingdom who deals with

these issues of light pollution. And specifically the health effects with respect to their—I guess their counterpart, the UK counterpart of the EPA. I just heard part of his talk. I don't have it handy with me but I can give you his email…

Q: That'd be great.

A: He's a real nice guy. I think it would be worth talking to him about what they're doing in the UK in this regard...maybe it would help out your thesis. Basically [what] they're talking about is light pollution as I recollect from his part of the talk I heard, like noise pollution. And regarding it as a nuisance.

Q: There's actually—and I hate to interrupt—there is some court cases that have gone to trial in this country and have been treated very similar, as noise pollution…

A: Yeah, yeah. And he had some very interesting ideas about what constitutes…. in terms of litigating some of this stuff what constitutes light trespass...you are familiar with that obviously?

Q: Yes.

A: He made the comment, and I never thought about it this way, but actually trespass means that you would purposely…like going on someone's property; you're really only trespassing if you know, you see a sign and you know it's posted but you purposely go on that person's property anyway. That would be trespassing. If you were to accidentally happen upon someone's property that was posted—let's say you didn't see it—that wouldn't be considered, legally, trespassing. And he was saying with light, that if you have a bright light and it goes into your neighbors windows, that if you put that light up for security reasons and not to bust the chops of your neighbor, there was no malice intended that is not really light trespass. The intent is important. If you put that light up to bug your neighbor—to make it go in his window—than that would be light trespass. So, what they're trying to do is change the terminology. I guess they're developing legislation that calls this "light nuisance," you see?

Q: Yeah.

A: Or I call it annoyance. And to get around the strict restrictions on trespass…anyways

it would be worth talking to this guy.

Q: Yeah, if you can send me his email?

A: I'll send you his email.

Q: At the IDA conference you were at did you give a presentation? (Edited for clarity).

A: I was at two IDA conferences. I was at an international conference in Washington with Dr. Stevens and Dr. Brainard. We, all three spoke. Then I was at the regular annual meeting in Tucson a week later. I just [got] back from that so….I didn't present at the annual meeting in Tucson. I usually do present there. But since I already presented at the annual meeting—where a large portion of the crowd was at the international meeting—there was really no point in me presenting anything. I was there for informational purposes. And I'm a member of the IDA.

Q: Me too. Do you feel that the research done on light-at-night and it's health effects is disbursed widely enough? That is, are people being exposed to this knowledge in a timely fashion outside of the serious medical journals?

A: Yeah, yeah. I do, I think it is. I can tell you our own research is being published in the top research journals and we've published…in fact our last important, what I consider probably one of the most, if not most important paper we published at the end of 2005 was published in Cancer Research. And that's the most widely read and considered to be the world's best cancer research journal. So, yeah, this stuff is getting out into top of the line, peer-reviewed research and medical journals and I think, you know, that the media is doing a pretty good job of covering it. I'm a little disappointed in the national news, you know NBC, CBS, and CNN haven't covered this or given it more exposure. There was just something published in the Washingtonian. [It] was an excellent article done by John Mackenen back in January. And Science News published a number of articles. [unclear] has done an excellent job in covering the latest work, particularly our work, very prominently in that widely read journal. So, it's getting out there. I think the national television coverage could be better.

Q: A follow-up to that question, have you had much contact with the regular media? And if so what was the experience like? (Edited for clarity)

A: Yeah, yeah. I get a lot of contact with journalists and various newspapers and magazines. It's been by and large I think excellent you know. They've done a good job. My experience I've had with them has been very good.

Q: Are there any other leads that I should contact?

A: Have you talked with "Bud" Brainard?

Q: No. You know actually his name was given to me by my committee. Do you know where he works? (Edited for clarity).

A: Well, I'll give you his number. He's at Thomas Jefferson University in Philadelphia in the department of Neurology. His name is Dr. George Brainard, but he goes by "Bud". You should definitely talk to him. And I'll get you the email for this chap in the UK.

Q: I appreciate that. Down to the final few questions. Do you feel that light pollution and exposure to light-at-night will be subject to regulation in the future whether through the EPA or some other government body? (Edited for clarity)

A: I do think it's going to be an issue that is subject to regulation down the road. Again if the research continues to indicate more than it indicates at this point, ill effects on health and in particular cancer, yeah I think this will continue to be a serious issue. That will be down the road, if we stay on the trajectory we're at right now, [it] will be the subject of regulatory issues. I get the sense from my colleagues in the lighting industry—and from being invited to lighting industry-type meetings—that the lighting industry is trying to get ahead of this. So they're very interested in what we're doing and what our research shows. The problem is that we're having difficulty making further advancements in this area because the research funding is just flat. There's no money. It's expensive to do these kinds of experiments especially in humans, so we depend primarily on the National Institutes of Health in particular the National Cancer Institute for our funding. We do get some funding from private foundations but the bulk of our funding has come from the national cancer institute. And the budgets are flat. Your chances of getting a grant right now are like 1 in 10. It's literally a crapshoot. It's really a terrible time in that regard. We have a whole list of experiments—because I collaborate with "Bud"—that we've got sitting in the can waiting to be done and we can't do them

until we get the funding for it. So when we go to these meetings and the people in the lighting industry say, "can you find the effects of wavelengths on this and that?" We go "no" and we haven't because we don't have any money to continue this research. That's a real problem. Insofar as this field—the various aspects of research—depend on federal funding. What we learn down the road in terms of impact on the regulatory issues down the road is going to be sooner or later you know? The longer it takes us to do this research the longer it's going to take to get to the point where we get that critical mass or reach that threshold of research that says, yeah we need to do some serious regulatory oversight here.

Q: Excellent. Do you think the research that you are doing in this area could be proven wrong in the future? (Edited for clarity)

A: Oh yeah. And you always have to be ready for that in science. You always have to expect that that may happen. You hope that it doesn't happen, that's human. You're always taught that you can't be married to your favorite hypothesis, you know? But we all are. That's just being human…scientists are human…most scientists are human. I know a few who don't seem to be. But if you get this sort of attitude that scientists are above it in terms of their objectivity...scientists are a very objective lot by and large and we tend to be very critical thinkers because we have to be. We're always criticizing and trying to shoot holes in one another's research and that's how it should be. But the point is that scientists are not—I don't think scientists are dispassionate about their work. I think anyone who says that is a liar. That's my own personal opinion. I like to think that I am open to other hypotheses—even hypotheses that would throw mine down into the toilet. I like to think I could be open-minded and on some level I am…but it doesn't mean I would like it. If someone came out next week that said all this stuff that Blask is saying you know—he's full of shit. I wouldn't be too happy about that. I would look at the research very critically: it had better be really, really good and really, really convincing. It had better be really, really good, otherwise I will counterattack like you won't believe. And people call that defensive, well yeah. I like to argue with people...scientists like to argue, it's what we do a lot. And we don't like coming after one another even good friends. But if you're going to attack me—attack my work—you better have something better, OK? Because I'm not interested in what you [believe]…if a scientist says, "Well, I just don't believe that." My question is, "Why don't you believe it?" What alternative evidence do you have that causes you not to believe it? And if they say, " Well I really don't." Well, I go nuts over that. That's…that to me is total bullshit.

I'm not interested in what you believe. If you can't defend it…at least offer me an alternative hypothesis—even if you don't have data—well I really don't care. But if you tell me you don't believe it because you have really good data that refutes the hypothesis well then I'll sit down with you. And I want to know. Even if you don't have data if you say, "Well I don't have data but I have an alternative hypothesis that I think is as good, if not better than yours", and if it sounds reasonable to me…I'll have to chew on that. I'd be interested in what you had to say. But just telling me you don't believe it I don't want to have anything to do with you, you know? Go talk to your momma or something like that. I have very little tolerance for that. So, I guess I've given you a long-winded answer to the question that, yes something could come along; you are going to have to realize that if there's a body of literature—a preponderance of literature now—that argues for this, and it would take a preponderance of literature in the other direction to cause me to jettison the hypothesis that we believe in. In other words if one paper came out that refuted this work that wouldn't be enough even if it was really good, all right. If one person, even if it was the best lab in the world, and they came up with really good data that indicated that what we are proposing is wrong; we'd have to acknowledge that and we would have to deal with that. But that wouldn't be sufficient to turn the field around and say all bets are off…all right. There would have to be an accumulation of data like that to make a convincing counterargument. There's the old adage: extraordinary claims in science require extraordinary data. And so we think that we have presented some—you know as extraordinary data as you can get in this field—to support what we claim. So we'd have to see something comparable on the other end to support a counterargument. But you always have to be ready for that and in the end if some other data comes down the pike and it's consistent and it's reproducible that refutes your hypothesis than you gotta give it up. And that's a hard thing to do. What we're really trying to do is pursue the truth here. I wouldn't like it [to be refuted] but as a scientist I would have to accept that and than think about it differently.

Q: Excellent. Last question Doctor. In the pantheon of overall global environmental problems (global warming, deforestation, etc.) where do you think—right now—the exposure to artificial light and light pollution rank? (Edited for clarity)

A: That's hard for me to say, because you could make the case—and the lighting industry has made the case—and are trying to develop more efficient lighting: that light pollution contributes to global warming because of the carbon emissions. You have coal-powered plants that are generating electricity and inefficient light bulbs...and you're

putting carbon into the atmosphere. So in that context you'd have to say that it is part of global warming issue. But in terms of it's effects on health like our survival…but in terms of specific things like the cancer issue I couldn't give you a good [answer]…I'd have to see a chart on where all these things range. I mean I think that global warming is obviously the biggest problem of our time right now. Because if things go the way it seems…it's not going to matter if we have electric lighting, so that becomes a moot issue. So everything is dependent upon that. I think light pollution and the potential ill effects on health rank high [or are] nudging up. I think they are potentially very important, especially in the area of cancer. I think that's going to be the biggest factor in health that we have to contend with because we have this real definitive link through suppression of melatonin and other aspects in the circadian system, other aspects of circadian disruption besides melatonin suppression. But melatonin suppression is certainly major and if that research continues to develop—again along the trajectory we've seen thus far—I think that this will be considered a very high priority issue.

Q: Very good, Doctor.

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A.2 Stevens Interview

Interview with Dr. Stevens, PhD
March 6, 2007, 3:30 PM-4:30 PM

Conducted via telephone by Tim Berthaume

Q=Tim Berthaume
A=Dr. Stevens

Q: This is Tim Berthaume and I just want to get your permission to record this interview?

A: What?! Of course not! All right. Yes. No problem, you may record this.

Q: Thank you, Dr. Stevens. I just want to start off by saying thank you very much; I know you are a busy man and I am going to try and keep this under an hour. I'm suspecting since you are my first interviewee that it will actually go a little bit quicker than that. I got a list of about 9 questions that I thought we would go over them…

A: OK.

Q:...and basically see where they take us. I don't have an axe to grind. I'm just trying to find out who you are, your research….

A: Well, you have a Canadian accent. I am very very suspicious of Canadians…

Q: [laughter] That is pretty funny, because when I went to Washington one of the first things they asked me was, "Are you from Canada"? I said I am from Upper Michigan, which is right next door. That is pretty funny. Question one: I would like you to identify yourself, your credentials, your current research and background.

A: Well I am Richard Stevens; I have a B.S. in Genetics, which I got in 1974 [unclear]; and a PhD in epidemiology from the University of Washington. And I've been interested in cancer etiology for a very long time, and I've done cancer epidemiology in a number of different areas. I became interested in why breast cancer is so common in

industrialized nations, in the late 1970's really. I started thinking about electricity and how they might impact the risk of breast cancer and I started thinking about that in the mid-1980s.

Q: Can you explain what exactly is "epidemiology"?

A: The textbooks say that epidemiology is the study of the distribution and causes of cancer...er disease in populations. How does a disease distribute? Is it more common in men than women? Is age a factor? Does smoking increase your risk that sort of thing…

Q:...Very interesting…

A: As opposed to the biology or the treatment of it.

Q: Now, you said that you are naturally interested in the distribution of breast cancer, and of course for this interview I am kind of angling in on the light exposure. I did read something from The Washingtonian; I believe that said you had been puzzling over the increase in breast cancer and…as an insight, were you first more interested in exposure to electrical fields or you know, was it the light? When you first thought of the…

A: The thing I am most interested in is breast cancer. Why women get breast cancer. Because the big dietary studies, were hitting in the early 1980's and showing no relationship of anything to breast cancer—anything in the diet. At least at the time, now I think that diet is still important. But the big studies, at least show that total fat in the diet has no relation to breast cancer risk. I wonder[ed] what the heck else changes with industrialization and I realized that the introduction and increasing use of electric power is the hallmark of industrialization. And then from there I wondered how on Earth that could effect breast cancer risk? I started learning about melatonin, the hormone and the fact that light can suppress it, and that maybe electromagnetic—the so-called power frequency fields—fields could lower it. And over the intervening years the light relationship to melatonin is very strong and very...well, it's pretty clear. There is no doubt that light can suppress melatonin. The question now for us, is how much light? What time of the day is most important? What's the spectrum? For the EMF stuff its still [a] totally conflicted area. I think the evidence is pretty good that short-term power frequency magnetic field exposure does not affect melatonin. We don't know. Observational studies inferring long-term exposure do report effects on melatonin. So we

just don't know about that.

Q: That is interesting. (Discourse omitted from transcript). I think at the time [1992] it [EMF studies] was kind of popular in the news media to an extent….

A: Yes it was. And it was highly controversial. There was actual acrimony—a lot of acrimony about it. There were very powerful scientific figures like Robert Adiar who was (and I don't know this for a fact) but I was told he was a former advisor to the first President Bush, scientific advisor—A member of the National Academy of Sciences and from Yale. And, he represented a lot of other very good scientists who felt that the EMF study stuff was junk science, and terrible and irresponsible. So it was hard to do work, in a way, in that environment. Battelle, at the time was [doing] at least a million dollars a year of research on EMF was being funded at the time in the early 90's.

Q: I guess that sounds like quite a bit. It did seem to have like a half-life, or an exposure time in the media in the early 90's. Do you feel that, these powerful concerns—these people—would say something like that because they wouldn't want regulations on exposure to something that is so common, you know that they were putting the cart before the horse, so to speak?

A: It's a very large issue, product liability. Progress in society and new technologies, on one hand that do benefit a lot of people. Balanced against the possibility that some aspects of these new technologies are causing some harm. And there are terrible stories about industries which have for decades completely ignored the harm that the product does. The coal industry is an example. Coal is wonderful for the country; there are many benefits to it. But for a very long time coal miners lived in awful conditions, and died young. The coal companies—this is old stuff—but I think it is a model for how it should *not go* ideally. So we've come up to the present day, and it's still…the FDA regulates the pharmaceutical industry, and with good reason. Even still you get things on the market that evidently causes some harm. So, how is society supposed to balance the harm and the benefit? So here we have electric power; and you have to have large transmission lines, somewhere, right. And so this controversy perhaps about childhood leukemia arose in the late 1970's, actually. 1979 really. I think the turning point was Wertheimer and Leeper. They were honest people who did a good job with the resources they had. They published an honest paper in a journal. And then it kind of snowballed. The media played a large role in it. This was just a great story for the media….and I

don't say that admiringly. It went from there. So the question is the cost and the benefit. The benefits to electric power are real obvious. So what, if any are the costs? One of the costs is the taking of land to site these things. Putting herbicides below the power lines...going through neighborhoods…and we have to balance that. Then the question is: do these [electromagnetic] fields have any effect on our health? I think that these people like Adair, and others who were very loud and very critical; I think they're honest. I think they were honest in their outrage. They were also, often funded by the electric power industry, and I don't fault the electric power industry for funding it. But it got pretty nasty. And it got to the point where there was an overreaction. And in fact we—the scientific community—lost all funding for EMF research in America. There is still a fair amount [of research] being done in Europe. And I think that's wrong. I think that this effect of electric and magnetic fields even at extremely low frequencies on biological systems is a fair and interesting scientific question that should be pursued at some level.

Q: I agree. It's like anything: everything should be open to enquiry. (Editorial comments excised). Do you feel that the research done on light exposure and health effects has been dispersed enough? That is, are common people being exposed to this knowledge in a timely fashion? Do you think there is enough information being put out about the research that has been done so far?

A: That's a tough one to answer as well. But I'm not shy about trying to answer tough questions. The easiest thing to say is I don't know what is appropriate or inappropriate. I don't like the public getting all kinds of conflicting messages about anything. And I'm in the health area so it is frustrating sometimes to see so much information that comes out of the health area much of what is wrong or proves to be incorrect later and is conflicted. I don't see any solution in a free society for that however. There are two types of science journalists in America. Excuse me; there are two types of journalist in America who cover science. One are the science journalists like for publications like Science News and the New York Times and the other major newspapers and NPR. And they are uniformly in my experience—and I have a lot of experience with them—excellent. For example there's a person named Susan Brink who used to write for US News and World Report and she now writes for the LA Times. And when you talk to a journalist like that, it's a pleasure. They want to get the science right. And they want to put it in context. The other type of journalist who covers science are the general assignment ones, who follow things like the New England Journal of Medicine and JAMA. And they have to get their story into the evening news and they don't have good nor bad motives. They

just have to get a story. And I think that's where the problem as I see it—the gross misrepresentation—"hot dogs cause leukemia in kids" and things like that. Which, that actually came from a legitimate newspaper and there's actually reason to think they might because of the nitrates and nitrites; but it's a complicated long story and the evidence is weak and inconsistent. But the point of that is it made a huge stir some years ago. So how do we deal with that as a society? Well the best way is to have scientist's who are trained in communication with the public. And that is not being done at schools of public health for example. And Johns Hopkins, I think it was started to realize this long ago—I think it's Johns Hopkins that realized this—and started putting together courses for their graduate students in epidemiology and clinical research on the media. And there are things you can learn about how to talk to—even the general assignment people. They don't want to do a story that's wrong. But they got to have a story.

Q: And they may not have time to do all the background work.

A: So, does that make sense to you? I don't think there's any way to control this from the media perspective. But there is a way to improve it. By the training of scientists. And for light-at-night specifically…for me, OK now it's just a personal opinion. The amount of information going out to the public about light-at-night and cancer, breast cancer in particular is going at the right pace. It is getting more and more attention as more and more good research has been done and published and supports it.

Q: In just the limited research I've done in the last 7 months or so, I would have to agree. A lot more information now seems to be published in mainstream articles. For example the article in the "Washingtonian"…

A: Yeah, he did a nice job. He did a very very good job. And he spent a lot of time. And he went back and forth with me and the others in that article. He really wanted to get the context right and facts correct.

Q: Does the general population (that is, nonscientists) know about this, light-at-night and health connection? (Edited for clarity).

A: Many people I see socially who are non-scientists, many have heard of this idea that shift-workers have more breast cancer.

Q: (Lengthy editorial excised); Could you tell me a little bit about the conference you were in, in Washington a couple if weeks ago?

A: Yeah, that was the international Dark Sky Association's sponsored a multi-discipline, cross-discipline conference on artificial lighting and everything: ecology, esthetics and health. It was a marvelous group. You've been to their website?

Q: Yes.

A: Good. And one of the philosophies of the founder, David Crawford, is on this issue—and this is unusual among advocates or activists—his attitude is we are not going to carry signs and scream that the night sky is being polluted. We're going to educate those who use lighting and the government. And, so it's really an educational approach. And I've seen just in the last few years a real change in the architectural lighting community's response to this issue. I think that Crawford's International Dark Sky Association's approach is working marvelously well. Because at this conference there were people from the federal highway administration, and others who want light. They want to light the night. And they feel strongly that they have good reason to do so: for security and safety and like that. But they're starting to shift. And being defensive about the idea of turning down the light to saying: "How can we get what we need done, and turn down the light?"

Q: Right. It does seem that they [the IDA] are dedicated to education. (Editorial aside excised from record). Do you think that the light-at-night and cancer link, particularly in regards to melatonin suppression could be proved wrong in the future?

A: Sure, it could. You caught me there. The word "proof" I have to define the word "proof" for you. And that is a consensus of experts. There will be no proof in any absolute sense that it's right or wrong, ever. But, yes given that definition of proof—a consensus of experts—including myself, the evidence may accumulate that says on balance I will say on the basis of the evidence, I don't think that light has much or anything to do with breast cancer risk. That could happen. And of course the other side could also happen.

Q: Do you think that's likely? With what you learned over the course of your scientific career, what research you have done, do you think that will happen? I know this is

strictly an opinion….

A: I am still determinedly neutral. I just couldn't give, I wouldn't try to give; I wouldn't admit to myself that it is likely, yet.

Q: All right. In your opinion, do you believe that light pollution, and exposure to artificial light should be treated like indoor air quality, which encompasses a myriad of problems, such as radon, indoor tobacco smoke? In the same vein, exposure to artificial light at night and light pollution constitutes glare, light trespass, and the hypothesis of exposure to light-at-night and melatonin suppression? Do you think if this were to go before the EPA regulatory board, it should be treated like that?

A: Your point is a good one. There are many different aspects of artificial lighting. So the first thing is to make a definition of artificial lighting. To me it is light that is made by humans somehow. I think if you look up the word "artificial" that's what it will say. It will say, "man made". So, the sun is light is the primary source of light on the planet of course. And then there's the moon and the stars to an extent. A very, very minor extent. And then there's the human stuff. So all of it's light. They're all photons. And they all have a biological effect. But the artificial light differs in a couple of extremely important ways to our evolutionary biology, our circadian physiology. One is the timing; the sun is predictable, 12 hours of light, and 12 hours of dark. Seasonal and weather permitting. It is also generally speaking, a much different intensity and spectrum. So, yes it is a broad complicated issue. However, I would think for regulatory purposes if some agency were in charge of the mandate of investigating and then perhaps regulating how light was done. There would be one office, for artificial lighting. And then under that there would be the sub-areas, some of which you just mentioned. The effects on human physiology, the effects on ecology, the effects on street lighting and safety for motor vehicles, glare, light trespass and like that.

Q: Thank you. Do you feel that light pollution should be regulated under the auspices of the EPA, per their mandate, "The mission of the environmental protection agency is to protect human health and the environment? Since 1970 EPA has been working for a cleaner healthier environment for the American people". Do you think that mandate would include artificial light?

A: Oh, yes. It should include artificial light. Yes.

Q: Do you think there are any other regulatory agencies that that could fall under?

A: I don't...you said that was EPA?

Q: Yes. That's correct…

A: Yeah, that's great. No, I think EPA is appropriate. And I am confident they will…in fact I don't know what they are doing *right now*. I know the national institute of environmental health sciences which is right across the pond from EPA down at Research Triangle Park, NIEHS is taking this area very seriously, to do research on the human health aspect. And I think also the environment in general. Although they are not charged with ecology, per se, so I'm sure, I feel very confident EPA….I hope they are investigating it now…thinking about it. And then I am confident they will get into this.

Q: It is interesting, and I have been trying to contact EPA… (Rambling discourse excised).

A: Well EPA for unavoidable reasons is a very political entity. There is tremendous political pressure on EPA, so they're gonna be….they're a public institution, and they need to respond to this, you know. But, they're going to be careful.

Q: Yep, yep. Of course, like you said it is so politicized. [Monologue excised]. All right, I think we can move on...just a few more questions. In the pantheon of environmental problems facing mankind right now, the big ones...global warming, the loss of the ozone layer, deforestation, could you tell me where you think exposure to artificial light ranks right now?

A: Right now, I'm not sure where it ranks among those. I'm really not sure. We hear a lot about each of those in the press. And there is air pollution. There is light pollution, if you will. But, in the long run, lighting the night could be as every bit as catastrophic as global warming.

Q: All right. So maybe right now, it's not a pressing concern. I realize for some of us, your research probably makes you feel differently. [Unnecessary monologue excised]. I have three more questions. Is there anybody else you think I should contact concerning

artificial lighting and its impacts?

A: I think you should check with Dave Crawford. And someone of the ecologists, someone who has really studied this area. And Dave knows who they are. I think that's important for you really.

Q: I do have one of the ecologists, Travis Longcore onboard.

A: Oh, that's right.

Q: He is one of them. And I am hoping he will get back to me. Do you feel that this topic of light exposure, light-at-night and cancer links to circadian disruption will be subject to regulation in the future? Do you think this is something that will come under the purview of EPA?

A: Yeah, I think it will. It should, but not necessarily for the potential cancer connection. But the environmental protection agency should investigate what to do about perhaps national regulation on outdoor lighting in particular, and perhaps they will be involved in indoor lighting as well.

Q: Ok, excellent, excellent. Is there any other information you would like to share? Is there anything I didn't cover, that you thought I should have?

A: No. I can't think of anything exactly. I would send you an email if something occurs to me though.

Q: Yes, that would be great. I just wanted to say thanks again. If I need to follow up with you, in the future I would hope you would be open to that.

A: Absolutely. Yes.

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A.3 Brainard Interview

Interview with Dr. George Brainard
April 10, 2007
Conducted via telephone by Tim Berthaume
6:40 PM

Q=Tim Berthaume
A=George Brainard

Q: I would like to get your approval to record this interview….

A: It is. Although I assume that it will be just used for your thesis.

Q: Yes.

A: It's not being used for public release and so forth?

Q: No.

A: OK, that's fine.

Q: And you get to review it after transcription. (Edited for clarity).

A: All right.

Q: Can you tell me a little bit about your educational background, your credentials?

A: I started life at a very early age. Many things happened, and here I am. OK, so I did my undergraduate at Wesleyan University in Connecticut. I got my bachelors in psychology…I then did a master's program at Goddard [?] college in Vermont again in psychology. I than I worked on a doctorate in neuroscience. But in that day and age there were no neuroscience programs so the official degree is in anatomy although my concentration was entirely in neuroscience and focused on doing research on the pineal gland. I got my doctorate from the University of Texas Health Science Center at San Antonio in 1982. Postdoctoral fellowship at the University of Oregon Health Science

Center in Portland and then a second postdoctoral fellowship at Thomas Jefferson University; and I am currently a professor of Neurology at Thomas Jefferson University and also a professor of Pharmacology and experimental therapeutics. How's that?

Q: That's very good. Thank you.

A: That's more than what you want to know. I am also the director of the light research program at Thomas Jefferson University medical college. Now you got the whole story.

Q: Thanks doctor. Can you tell me when you first became interested in the effect of artificial lighting on human health? (Edited for clarity).

A: Yes. Well where does anything ever begin? I became interested in the biological [and] behavioral effects of light when I was a teenager. And that was connected directly to learning that the western skink [?] lizard—the schenodon [?]—actually has an anatomical 3rd eye which is positioned on the dorsal surface of its forehead, and that 3rd eye is connected intimately to the pineal gland which regulates pineal physiology. And that fascinated me and I [have] studied it ever since even when I was doing my degrees in psychology; every chance I had to write a paper of my own choosing it was about the biological and behavioral effects of light often involving the pineal gland.

Q: So it goes way back?

A: Yeah. My entire adult career has been focused on this as well. My formal training has ultimately—my doctoral training—has put me in the position to study this professionally. So having said all that, Tim, back when my interest was first developing the classical scientific understanding was that the human pineal gland was a vestigial organ that did nothing other than serve as a good radiological landmark in X-rays of the skull. There was a developing science showing that in animals it responded to light [background noise]…but it was not 'til 1980 that a group of scientists at the National Institute of Mental Health showed that bright light exposure at night suppressed melatonin in healthy young men. That was a publication not from my laboratory that was from NIMH. The lead author was Al Lilly and it was published in Science. That finding opens the door for doing what animal researchers have been doing with animals for years. And that came out while I was doing my work in graduate school…I contacted the lead author, Al Lilly and we ultimately agreed I could do a postdoctoral fellowship with him

to train to how to learn how to do those kinds of studies and that was my first postdoctoral fellowship.

Q: Very interesting. Do you feel that exposure to [artificial] light-at-night in humans should be regulated under the auspices of the EPA per their mandate, "The mission of the EPA is to protect human health and the environment. Since 1970 EPA has been working for a cleaner healthier environment for the American people"? Or should it fall to another regulatory agency or none at all?

A: So here's the story this is my opinion, right? It's premature for the EPA or any regulatory agency to attempt such regulation. What the other agencies should do is support the necessary research so that one day regulation can be possible. It would be a nightmare if they tried to regulate on the basis of what we know. Having said that, let me qualify it. There's lots of reasons to be concerned about exposure to light-at-night as a potential risk factor for the onset of cancer. However, if you rush in and try to do that before you know all the particulars you're just going to create more problems than help. So, that's the deal.

Q: Very good. Do you think there is enough human studies done on exposure to light-at-night to quantify the health effects on humans? (Edited for clarity).

A: Yeah. This is a more sophisticated question and it's going to require a more long-winded answer. At best I'll get this answered before we have to stop and come back and revisit it, OK?

Q: That's fine.

A: It is beyond any question that light exposure in the middle of the night to a normal healthy man or woman will alter pineal physiology and melatonin production as well as other elements of the circadian system. That's an absolutely proven and established fact and I stand by that. It's rock hard. Having said that we know an awful lot about what intensities of light will cause some of these effects in the laboratory, we know an awful lot about what wavelengths of light will cause these, we know a lot about the duration of exposure and the timing of the exposure. However these are all laboratory studies and we humans live in a dynamic environment and is further dynamic by virtue of our behavior. And we know virtually nothing about on how it works in the real world environment.

We got the stuff in the lab. And the reason I advocate federal agencies study this and support research is because we need to take that critical step of understanding how it works in a dynamic real-world situation where people live and work. If you don't do that you have no basis for regulation, that's number one. Number two, knowing that light affects pineal melatonin [production] and circadian regulation does not necessarily prove the case that light is a risk factor to cancer. Now the science here is less developed. There are a host of epidemiological studies—through interviewing Dr. Stevens you know about them—epidemiology shows association but that does not prove cause and effect. There is a smaller [body of] literature—through interviewing Dr. Blask you know about his studies which show the closest thing you can get to a hybrid model of human, animal study—showing that light affects blood levels of melatonin and in turn fed (?) into a xenograft animal bearing tumor will change its tumerous growth. That's really a strong piece of evidence, however that also does not prove the case that humans in a free-behaving everyday environment has light exposures that cause risk to cancer. So I hope I have been clear here: there's a lot of evidence that make this extremely important to study because if you can change even a percentage or two point of risk to development of breast cancer or other kinds of cancer such as prostate or colon a lot of lives could be saved. However the case need to be fleshed out a little bit or it needs better proof, or proof in real-world circumstances. Does that make sense?

Q: Yes, very much so. The research that you've been doing, including Dr. Stevens and Dr. Blask, do you feel that this information has been dispersed widely enough? Are people being exposed to this knowledge in a timely fashion? (Edited for clarity).

A: In my opinion the answer is yes. And it follow in line with my opinion about should a federal agency be regulating it at this moment in time. There's been quite a lot of press on this hypothesis in major magazines and newspapers. There have been TV reports on it and so forth. So it is an area of interest. It has vital potential importance and I think there has been quite a bit of exposure to the general public about it. But it still remains a research topic; it's not something that's mature that it ought to be federal policy. And if it can't be federal policy than promoting public guidelines and so forth is also premature. That being said there are some things being developed and promoted within the lighting industry which I think are good common sense practices [?] with the emergent science. And that, we'll have to talk about it a different time as I am out of time now.

Q: Do you feel that this topic light-at-night exposure and potential health disruptions [cancer & circadian disruption] will be subject to regulation in the future especially if the scientific case becomes stronger? (Edited for clarity)

A: Yes if it gets proven out: the answer is that it will be subject to some form of regulation whether it be federal or voluntary industry-wide remains to be seen; it depends on level of proof and if the proof ever gets to sufficiency. So for example there is a well-known hazard called blue-light photo toxicity. That hazard was discovered when they noticed people that have the job of being arc-welders were ending up with a lot more damage to their eyes than the normal population. And as they investigated it they realized that the intense amount of blue light in a welding torch was actually causing photo-retinitis. So there's a known health hazard for a disease caused by light. Now the federal government does not regulate that…what has happened is academia, industry and government has worked together to define this health hazard, define the safe exposure and encourage the application of those limits everywhere they can. By and large that works pretty well. So, it's hard to say if it will ever escalate to the level of federal regulation or whether it would even be appropriate for federal regulation…

Q: Education and voluntary compliance may be the proper route for this…? (Edited for clarity)

A: Sure. It just depends on how severe it is and how likely it is people could hurt themselves without the intervention of the government. So the standard bodies that really set limits on light safety, there are two of them: one is the American National Standards Institute and the other is ACGIH (American College of governmental and Industrial Hygienists). And they set these guidelines and by and large that's how it's done. But whether or not it would need further regulation….I'll give you another example, light therapy is currently being used for people with winter depression. It's pretty well studied and understood for about 25 years. So the standard of practice is to prescribe a bank of fluorescent lights that are quite bright—10,000 lux—for a patient to use on a daily basis. And if a person is going to be responding to that light there's a high likelihood that they will improve. This is exactly the kind of device that the FDA—the federal government—could choose to regulate; currently they have chosen not to. They have allowed the marketplace and the manufacturers to use good sense marketing and standards for that medical device. But it really is a medical intervention; so it's hard to predict whether the fed needs to come in or will come in once and if criterion evidence is reached.

Q: Very good. Concerning the research that you are involved with and to an extent Dr. Blask and Dr. Stevens, do you think that this hypothesis of light-at-night exposure and its potential health effects in a negative sense could be proven wrong in the future? Perhaps another factor you overlooked or hadn't foreseen? (Edited for clarity)

A: So, again you are asking an opinion question, right?

Q: Yes.

A: My opinion is no. I think this will go to conclusion is my opinion. I think that the evidence will continue to accumulate and it will hit sufficient weight that there will be a broader scientific consensus; we are not there yet, right?

Q: OK.

A: But hazarding my best professional guess it will get there eventually.

Q: Very good.

A: I also think this is a topic by the way—it's probably important to your thesis—because just the structure of the questions you're asking; I think the public may drive…may become an important driver of this process more than the federal government or the scientific community. As the public becomes more and more informed and more and more concerned they're gonna want clarity of answers and weight of evidence to rule it out or rule it in. So I think the public will eventually begin to pressure the funding agencies to support the work that will eventually rule this in or out.

Q: Can you identify any serious gaps in knowledge right now in the body of research on light-at-night exposure and the potential cancer link? (Edited for clarity)

A: We know virtually nothing about complex polychromatic environments: that's what people live in. So right now I am driving down the road, the light sources available to me are traffic signals, streetlights, headlights and they're changing dynamically as I am driving down the road. So it's a very complex, polychromatic environment and we have no idea, no idea whatsoever, what that complex polychromatic changing set of stimuli are

doing to the melatonin generating system or the circadian system. It's completely not known. All of our studies, or the majority of our studies are laboratory-based in highly controlled circumstances and that's really the heart of the question isn't it?

Q: Right.

A: For anything in our environment that's dangerous; sure I could shine a light in people's eyes in the lab, I know exactly what intensity, what duration, and what wavelength and what timing to suppress melatonin a lot or a little, partway, whatever. But I do that in a highly controlled fashion so that I can publish data and characterize the system; it doesn't really translate immediately into what happens in our day-to-day life. And you multiply that by—you probably get up at a different time than when I get up; I get up and I am exposed to different kinds of lighting stimuli then you are, at different hours, different quantities and different durations. None of this has really been packaged together to tell us what, if any of it, might be hazardous. Huge gap.

Q: Besides the strong correlation between light exposure at night and melatonin suppression and potential repercussions as far as cancer is concerned; and I think the best evidence shows a correlation to higher breast cancer levels is melatonin suppression linked to any other cancers? (Edited for clarity)

A: There's fledgling evidence for colon cancer. If you look at the work of Schernhammer and colleagues; and this is epidemiological evidence, so that is out there showing that in shift-working populations there's an increased risk of colon cancer but that's one study. So we can't write a big story about that, but it's intriguing. One study never proves anything and epidemiology never proves anything, it shows associations. There is some unpublished work, which you can't cite, but I can tell you about that shows it's very likely prostate cancer is going to be responsive in the same way that breast cancer is. Oh, I take it back. There is one abstract out on that and you could ask Dr. Blask for that abstract. Did he mention that to you?

Q: No, I don't think…

A: He may not have presented the abstract yet. So it may have been embargoed. You don't even have a publication—you have an abstract. But I will tell you, Dr. Blask's work in my opinion—first of all what he's done is brilliant. The things I've co-published

with him it's all been under his leadership, it's his thinking. I don't want you to believe [??] the idea that he and I are equal partners in that. He's really created that set of studies. His breast cancer stuff is only a few studies deep and the prostate cancer is only an abstract deep, so you don't have a lot there yet. But I think it's brilliant and I think it will stand the test of time. It's been done meticulously well. But I could be biased because he's also a friend.

Q: [Laughing] No you couldn't be! In the overall scheme of environmental problems facing mankind, the big problems, say for example global warming, deforestation and so forth, where do you think—and this is complete opinion on your part—the artificial light exposure [and potential health & environmental effects] would rank alongside these other issues? (Edited for clarity)

A: You know I have to back up and say this. Light is absolutely critical to all life on the planet or virtually all life on the planet. Very few species can live without access to light, so the first thing you have to keep in mind is, it's responsible for our food chain and it has many beneficial and essential regulatory purposes for our species and many species. Also light can be used as a therapeutic intervention and I already gave you that example. So right there is the crux of it: anything that is capable of healing a disease, there is always two sides to that. If it can heal, it can also harm if it's used incorrectly or inappropriately. It's a double-edged sword. The studies that are around on the value of light for promoting and helping human health are tremendous. There's only a fairly small relatively speaking, group of studies showing there is a possible risk factor. That really needs to be fleshed out and until it's fleshed out it's really hard to weigh it against other problems. I mean global warming? Yes, global warming is absolutely real, it's coming it's not a good thing and it's been known for quite some time despite the political pressure to suppress it. That being said, how immediately the effects of global warming are going to be seen, boy that's anybody's guess. Because we know nobody can predict the weather, let alone geophysical cycles of heating and cooling. You know it's all done in extremely sophisticated computer models. So how big is the problem compared to other problems? Let's take on global starvation. 500 million people starve a year. A better way to encapsulize it. Three individuals starve every 10 seconds, right? It's not for a lack of mankind having the capacity to grow food, to store food and to ship food. We had the green [agricultural] revolution a long time ago. There's adequate capacity to grow, distribute and provide food for every man, woman and child on the planet right now and yet every 10 seconds three people die of starvation or malnourishment. So in my

mind global starvation and malnutrition is a far worse problem and well known and well proven and been known for decades. And the cause of that problem is more political than anything and so anyway I am at my next appointment and that's the best I can give you for now.

Q: Thank you Dr. Brainard.

A.4 Rea Interview

Interview with Dr. Mark Rea
April 18, 2007
Conducted via telephone by Tim Berthaume
2:00 PM

Q=Tim Berthaume
A=Mark Rea

Q: Hello, Dr. Rea, this is Tim Berthaume, I would like your permission to record this interview?

A: Sure.

Q: Thank you. I'd like you to please identify yourself, your credentials, who you work for and anything else that is pertinent…

A: Well I'm a professor at RPI and director of the lighting research center and do a lot of different things related to lighting.

Q: We went over this question before and I would like to get your opinion. Do you feel that light pollution should be regulated under the auspices of the EPA per their mandate: "The mission of the EPA is to protect human health and the environment? Since 1970 the EPA has been working for a cleaner healthier environment for the American People"? (Edited for clarity)

A: Well I asked you the question before, "why is the EPA the agency you're interested in?"

Q: Basically, I felt that I started this research that upon reading their mission statement—and this being such a broad discipline—in order to bring anything to bear on it I thought this would be the regulatory agency that should perhaps or perhaps not look at this problem. That's the gist of it: does it [light pollution] belong under their jurisdiction or somewhere else? (Edited for clarity)

A: Well I think in general—and I have no opinion on whether EPA is involved or not involved—but I think there are two fundamental questions about…would have to be for any sort of decision for regulation, whoever that might be. First of all you have to define light pollution…if you can't measure it you can't regulate it. So you have to say what is it: is it obscuring the stars? Is it glare? What exactly are we talking about here? So I think that any agency would have to first of all define terms. Say exactly what you mean and can you measure it objectively? How would you go about that? Do we have audience [?] participation? So than the second half of that question you refer to health and the environment and I guess…we would have to be somewhat clear what health is. And I assume you mean human health…and so what is it you imagine when you framed this question, what is it you imagine happening that you have concern…in a public health perspective?

Q: Well the epidemiology appears to show a link between people who work shift work and cancer. The exposure to artificial light appears to reduce melatonin levels and this could lead to an increase in certain cancers further down the line…. (Edited for clarity)

A: So I think you're saying that this would be mediated through the circadian system. I mean it could be for example glare from headlights would affect your health because you can't see, but you're not talking about that, right?

Q: Technically I suppose I could be, but I'm going to confine it to the circadian effects I talked about. (Edited for clarity)

A: Well I think a common misunderstanding and shorthand for this now, light is or is not the problem. The circadian system is a timing system and has to do with patterns over a 24 hour day and so darkness becomes just as important as light in that context, right? You have to have a light-dark cycle so why wouldn't you ask the question, should the EPA protect us against too much darkness?

Q: Right. That's an interesting way to look at it.

A: Well in the context of circadian it is a light-dark cycle. Darkness becomes just as important to define as light. What one could—and it's not a too far-fetched academic argument—if it turns out you need bright days then putting a roof over your head could be a problem right? Because you do not have enough light during the day. And so, until

we can resolve what do we mean by light, what do we mean by health in the context of the light-dark cycle I think it would be pretty hard to justify any sort of regulation at this time.

Q: All right, now to follow-up a bit on this…we were speaking on how ill defined the term "light pollution" is, do you feel it needs to be clarified? Do we need an "official" scientific consensus on this term? (Edited for clarity)

A: You know there are a lot of good intentions and there has been a lot written and so on. Actually we are centrally involved in the discussion of what we would call operational definitions of light pollution you know what I mean by an operational definition?

Q: No, no.

A: Well you can have a concept like justice and that's a concept that people would feel like they understood. But then you have justice in different cultures that could take very different operational definitions. You know if you steal an apple it's a capital crime and we shoot somebody…that's justice in a culture, right? But the operational definition is: what are laws define as to how we proceed with a system of arrest, incarceration, and all those issues become operational definitions of what we mean by justice in this context. But different cultures have different operational definitions of what that means. So when we come to light pollution I think we have a general concept of what that is but what we've been trying to do is to convert those to reliable, measurable aspects of the general concept of light pollution and we feel there are three concepts that need to be defined: first of all is obscuring the stars and you can measure that either by flux or by bioluminance on a defined plane and so we now can have a system measuring it. So if somebody says well you produce more light pollution in the context of reducing stars, now you can measure how much light there is and more easily quantify it. So that's one concept; the second is what we call light trespass—these are not necessarily new terms—but this is how we define it and light trespass to us is luminance on the plane of your properties; so if you have, say 5 lux on the plane of your property than that could be above or below an acceptable amount of light trespass that you are putting on someone's property—to your neighbor for example. And finally glare which has to do with perception of brightness so it's a luminance question. So we believe that—and we've been doing a lot of software development to allow anybody that would build a space, say a national park or whatever it is you can actually get past all the talk about light pollution

and can actually measure it and have a quantitative, meaningful dialogue with stakeholders with regard to that. If we're going to begin to talk about light pollution and its impact on health we need to somehow be able to quantify what do we mean by light pollution and than does it have a functional relationship to some outcome measure that we consider to be…then again health has to be operationally defined too right? So we're a long way from regulation. We're doing a lot of measurement of light exposure people have, we've developed a new type of light meter that measures how much light over a period of time a person is getting for the circadian system so we're very active in both of these questions but our focus has been measurement as you can tell. I'm not sympathetic with all the hand waving and good intentions; we're really trying to get down to quantify and this is a central research thrust for us here.

Q: In other words regulation can't be predicated upon a thought it must be measured. What gets measured gets managed.

A: Yes, you have to measure the input which is the light and the output is the health than you have to have a functional relationship between the two [and] we're a long way from that.

Q: Can you tell me what are the effects of artificial light on the circadian system in regards to your research? (Edited for clarity)

A: Well there are a couple of issues I hope are part of your pedagogical process that you are going through. The choice of the term….why would you pick the term "artificial light"?

Q: As opposed to naturally occurring light, sunlight, starlight and so forth…

A: But incandescence is a naturally occurring phenomenon…

Q: OK, let me back up a bit here. OK, artificial light actually created by man and put into the environment by him…. (Edited for clarity)

A: Well I think that no biophysical process could differentiate a photon generated by the sun or a photon generated by some electric light source, right? So why is it important to refer to it as "artificial"?

Q: Well in the context of...now you've got me confused.

A: Well how about moonlight for example? You would not consider that to be artificial?

Q: Right, right.

A: You would not consider its light to be artificial?

Q: Certainly not.

A: OK and what if they have health consequences? We're not going to talk about it?

Q: I guess I would not be looking at that.

A: I think if you want to get a scientist's view you have to distance yourself from the adjectives like "artificial" light. So the question really is what impact does light—defined in terms of spectrum, intensity, distribution, timing, and duration—what does that have to do with some measure of outcome? It should not be prejudicial in regard to artificial or natural. Those carry with them baggage that is unnecessary for scientific inquiry as to what the impact would be. And the reason why I bring that up, when you link artificial light and you ask me about deleterious effects the other question that comes up is: why just look at deleterious effects? Why not consider the impact of light on things that improve health? Do you think that's possible?

Q: Oh yeah, certainly. Don't they treat SAD with bright fluorescent light if I recall correctly?

A: Right. What I would like for you to consider—and this is your thesis obviously under the supervision of your advisor—is that if you try to step one: step back from the adjectives like "artificial" light, I think you can have a fresher look at what I'm talking about and that is: let's measure the light, let's measure the health and the outcomes we're interested in and try to establish the functional relationships without the prejudices of deciding whether it's positive or negative, artificial or natural and those other issues. And I think you can have a more objective view about what these questions might be and in so doing you can lead to your final outcome which I hope you come up with some

recommendation, that if EPA were to read this they would say we should do something about this. But if you start with artificial light and deleterious effects than you're already driving it to a regulatory question.

Q: Yes, you're absolutely correct.

A: So why don't I rephrase your question for you?

Q: Sure, OK.

A: Is there any evidence that light can impact health? Right?

Q: Right.

A: OK. So again, notwithstanding the points I've made about quantifying the light, I'll skip over that rather than bore you again. But you have to get the spectrum, the intensity, the distribution, all those things correct and than you have to tell me what health is. Like the rate of cancer growth or it could even be sleep quality or it could be cortisol, they measure hormones and begin to get an outcome measure that you're interested in. And so in that context light can modulate some of these behaviors, some of the hormones that have been linked to health. So our goal is to try to maximize the benefits and minimize the deleterious effects. So for example Bill Rashevski and Pat Wood down at the University of South Carolina have shown that the timing of thamoxicil for breast cancer treatment depends upon the circadian timing of which it is applied. And that efficacy is either 3:1 or 5:1 or somewhere in that range. So, in principle, every woman should get her breast cancer chemotherapy at the same time, circadian time, which turns out to be in the morning. Now light could for example adjust these circadian timing so every woman could get her chemotherapy at the right time. In other words if we can change your circadian clock so that the clock time at noon turns out to be that woman's circadian morning than she would have a maximum effect of that chemotherapy. So that would be a very positive outcome of how light could improve the health of women with breast cancer by applying light, OK? That'd be one thing. Now the other thing that seems to be true is that jet lag, which is a common occurrence in modern society, that is you make the light-dark cycle asynchronous with your circadian clock that can lead to apparently cardiovascular problems, there may be some other implications of that as well. So putting ourselves in concert with the light-dark cycle seems to me to have—all the

evidence seems to suggest that's a very positive thing, including night-shift nurses who seem to be asynchronous with the light-dark cycle seems to be a clear indicator of unhealthy kinds of activities. At least that's what the epidemiological evidence would suggest. So I think that it's less about light and it's more about coordinating the light-dark cycle…whether you're taking a treatment for a disease or whether you're trying to maintain positive health. That really seems to be the key concept. So yes, I believe there is a link between light and health. But, expanding that light-dark cycle with good health is what we're really talking about here. I think that's where the discussion will end up.

Q: Thank you. Can you identify any of the major gaps in the research concerning light and its impact on health? I realize this is a broad question…. (Edited for clarity)

A: Obviously there are many features that need to be addressed. The two we're doing specifically in that regard…maybe I should say three. One is defining light pollution which may or may not have an implication on this. But I think that's important too. Because it's part of the discussion right now [and] we need to get that right. But what we've really been focused on is getting light-dark cycles in the field—the pioneering work we're doing right now are developing instrumentation so we know what, for example a day-shift nurse is getting with regard to a light-dark cycle; what is the night-shift nurse getting with regard to her light-dark cycle, if there is one? And then linking it to hormone production is a project we're in now. So the ability to characterize the stimulus over this long period of time and than link it to operational definitions of health which would be hormone production seems to be a very, very important piece of that. Part of that too is really understanding how the eye converts electromagnetic radiation into those neural signals and we've been working on that too. But I don't want to say those are the two most important things you can do...these are two we're working on that we think are important in that broad question.

Q: All right. Excellent answer. Is there anything else you think I need to know about this topic to help clarify things for me? (Edited for clarity)

A: Well, I'll put on my professor's hat rather than my interviewee hat. I think you have to structure this in a way that is doable. Students often get theses and really have no clear end point, and I think when I talked with Professor Morelli and you, was is that I think it is a very interesting contrast in the context of light pollution for things like sea turtles, OK, and I think that are some clear empirical pieces of evidence that indicates sea turtles

do get disoriented in it and so on. So here you have a cause and effect relationship. People have gone to beaches and looked at which sea turtles go for example. And I think you can say, instead of trying to connect-the-dots problem you have: I'm going to look at this dot and look at that dot and I'm going to try and draw some inferences but I do recognize that I'm not going to put up all the dots on the page or connect them, right? So if you have that, it seems to be a very interesting topic. Because sea turtles only hatch at certain times of the year therefore you have the temporal dimension, you don't necessarily have to have controls over light pollution 365 days a year; you can do it when the sea turtles are hatching. You can know where you have to do it…you won't want to be 30 miles inland, all those kinds of issues can be very carefully constructed and so you can say now, "How could we approach that same problem in people and peoples health?" And than I think it gives you a platform to be able to talk about how complicated those kinds of questions can be and I think more important in the context of human health. But the principles would still be the same: how do we structure the problem, when is it important, how long does the light have to be on, what intensity, what color of light matters? All those issues can be structured in a way than you can say, "I believe we know too little about this topic to really come to some firm conclusions like we could on the story on light pollution and sea turtles." And I think it's a nice contrast, right? You got something where you have a very narrow problem, you know what you need to do, it's a bad thing to kill sea turtles and we know how to fix this, OK? But the other issue complicates lives. Are you really going to tell a hospital that it shouldn't be open 24 hours a day to protect nurses from breast cancer? So we're not going to have ER's available to us? These are some of the kinds of social questions that come up that as a student you should wrestle with. I mean, not necessarily have to solve them, you need to pose the question and say, "I thought about this"—these kinds of questions that society has to wrestle with and I think the template you apply to it, specifying the stimulus as I call it, telling me what your outcome measures are—like dead turtles is one of your outcome measures and than you say the functional relationship between those two needs to be clearly established and I think that would be a great thesis and you could do that in the context of light pollution. You know, I think that you'll find it's not a slam-dunk with regard to the relationship—as you call it artificial light —and health. I think a lot more serious work and quantification needs to be done before you can make that case. So I'll take my professor hat off.

Q: Thank you. That helps me out quite a bit. You've given me a lot to think about…

A: You know, just don’t try to solve every problem. I mean you pick one that sets the stage than you ask the really important questions—you’re asking good questions—but you’re not going to answer them! Please stress the quantification—it’s just way too much talk and not enough measurement.

A.5 Salmon Interview

Interview with Dr. Salmon
April 9, 2007
Conducted via telephone by Tim Berthaume
12:00 PM-12:30 PM

Q=Tim Berthaume
A=Dr. Michael Salmon

Q: First and foremost, Dr. Salmon I would just like to say "thank you" very much for giving me some of your time. I do appreciate it and I am hoping you will be able to enlighten me a little bit about some of the research you've done concerning artificial lighting and sea turtles.

A: OK.

Q: Very first question is, I'd like you to identify yourself, your credentials, who you work for, your current research and any other information that might be pertinent.

A: OK, the name is Michael Salmon, I am a professor in the department of Biological Sciences at Florida Atlantic University. My specialty is animal behavior and I work primarily with marine animals, especially sea turtles. And I'm interested in their sensory, biology and behavior. Is that enough?

Q: Yeah. That's fine, tell me as much or as little as you wish…can you tell me when you first became interested in the effects of artificial light on animals and in particular sea turtles? (Edited for clarity).

A: Well I got interested in sea turtles in about 1980. Largely because of the work of a colleague of mine, Dr. Jeanette Wyneken, she was a graduate student studying sea turtles for her doctoral dissertation and I was giving her a hand because she was my girlfriend at the time. And that got the ball rolling; I then switched my research from studying primarily crabs—crab behavior—to sea turtle behavior. And one of the first projects I did was an experimental study that tried to identify the stimuli that is used by [turtle] hatchlings to reach the sea. And in the process of doing those experiments and reading

the literature I saw a few publications on how artificial lighting interfered with the ability of hatchlings to locate the sea. And that sort of got me going on an experimental approach to try to analyze the problem.

Q: Do you feel that light pollution and artificial light at night should be regulated under the auspices of the EPA per their mandate "The mission of the Environmental Protection Agency is to protect human health and the environment. Since 1970 EPA has been working for a cleaner, healthier environment for the American People"? Or do you think that would fall under the purview of some other agency? (Edited for clarity)

A: Actually in response to your question I looked up the EPA webpage. There's a lot of information there on studies that they do in the environment that involve animals and plants. So while their mission is primarily to protect human health and the human environment they're also interested in the ecology of that environment; and if you look at their website there are studies that deal with toxicology, dealing with all aspects of how human activities affect the well-being of wild organisms. So on that basis I feel they should also tackle problems with artificial lighting; in fact they don't but I think that's largely because we haven't made a very good effort in this country, that is the scientific community has not made a very good effort, to inform them about the widespread effects of artificial lighting on wildlife. To a certain extent that is because the effects have only been appreciated within the last 5 to 10 years and very few people are actually working in the field. But, nevertheless to get back to your question, should the EPA be involved? My feeling is yes they should be. And it would be perfectly consistent with a lot of work they are presently doing.

Q: Moving along to the next question. In one of your papers you say that local & state governments have spent a lot of energy to "cure" this problem [turtles being exposed to artificial light]; is the EPA involved? Should they be? (Edited for clarity)

A: Well…yes they should be. Are they involved at all? I don't think…to the best of my knowledge they're not. But, I don't know this for sure.

Q: Do you feel that roadway lighting is properly regulated in Florida by FDOT? Or should this be regulated by another agency? (Edited for clarity)

A: The FDOT certainly tries its best to regulate roadway lighting adjacent to marine turtle

nesting beaches. That effort is relatively recent, and largely spearheaded now by a former graduate student who finished a Masters at Florida Atlantic, and took a job with the FDOT. The Florida Fish and Wildlife conservation commission is also involved, but does so by issuing permits—among other things—for doing sea turtle research. They are also involved in many other aspects of wildlife biology in Florida but specifically they permit all research done on sea turtles. And they work closely with state and municipalities to try and solve problems like photopollution for sea turtles on oceanic beaches. They even modestly fund a little bit of research in that area.

Q: Can you identify any knowledge gaps in the body of research involving sea turtles and artificial lighting? And if so, what further research is needed to close these gaps?

A: Well there are all kinds of gaps. One of them is sensory biology and neuro-biology of sea turtles particularly as it applies to vision. We basically have zero understanding of why it is that artificial light from a neural level—on a neural level—causes the problems it causes. And that's not only true in sea turtles it's also true in most other animals that respond to artificial lighting. Another gap, again specifically with sea turtles has to do with in-water studies and its [light] effects. There are one or two publications on that and that's about it. And by that I'm talking about how either hatchlings during their offshore migration respond to lighting once they're in the water. We have a great deal of information about how they respond on land but very little about what they do in the water and if they're affected and how. Another major gap has to do with the effects of skyglow on both hatchling and adult sea turtles. We have general ideas, a general notion that it has a negative impact both on hatchlings and on adults but no specific information because nobody has ever really done any experimental work on the topic. I think one of the most important contributions that my students and I have made towards this whole problem is to show that it's possible to do experiments and to quantify the responses of the animals to artificial lighting and to do experiments to test mitigation solutions or to propose mitigation solutions before they are implemented. To give you an example: one of the things we've been very interested in is whether the whole effort to reduce the effects of artificial lighting on sea turtles can be done by modifying light sources themselves—particularly the wavelengths of those light sources. We've developed protocols in our laboratory that are actually testing the so-called "turtle safe" lights. It might seem to be common sense that before you install "turtle safe" lights anywhere you figure out if they work. But in point of fact that hasn't been what's been done in the past. And I go into some detail about that in the paper.

Q: As far as the embedded lighting that you studied—I recalled reading in one of your papers—you seemed pretty confident that it was beneficial to both people and the turtles. Is that still the case? Has your work evolved on that? (Edited for clarity)

A: We haven't done any follow-up work on that. And yes, we still think it is beneficial. The problem is that it's a very limited kind of solution that applies in only particular circumstances; it's not going to solve the problem, it's just going to reduce it in particular places at particular times.

Q: A limited solution at best?

A: Yes.

Q: If we were to have a national lighting policy who do you think should administer that? Is the EPA the proper agency? (Edited for brevity and clarity)

A: I don't see why not.

Q: Do you think the science [research] is there, including the research done on artificial light exposure and humans? Are you familiar with that research? (Edited for clarity)

A: Passingly familiar with it. What I do know is that there have been national policies and programs implemented in Europe in particular. And they've been very successful. You don't really have to have vast amounts of scientific knowledge to know that artificial lighting affects wildlife. The data from what I understand on the effects of artificial light on humans is fairly…..the effects are very slight and there is some question whether or not they actually occur; but there is no question whatsoever that birds and insects and many other kinds of animals are harmed by artificial lighting. And knowing that and knowing the economics involved in wasting energy—producing all that artificial light—a national policy on the topic of lighting can't help but be beneficial. The problem as always is conveying information to people in positions of power the importance of doing something about it and having the resources set aside to actually implement the changes because it's not going to be cheap. The benefits are all long term and in some European countries they've already done that. You, of course, have probably already found information on that topic?

Q: Yep, it does seem like Europe is a bit ahead of the game as opposed to the US…

A: Yes.

Q: Are there any other researchers, you feel would be a good resource to interview (Edited for brevity)?

A: Well Blair Witherington is certainly someone you should talk to. He's an expert in sea turtles but his knowledge goes far beyond just turtles….he know a lot about wildlife. And any of the other authors in this book that just came out, "Ecological Consequences of Artificial Night Lighting"; any of those other authors are people you might want to get in touch with too.

A.6 Witherington Interview

Interview with Dr. Witherington
April 18, 2007
Conducted via telephone by Tim Berthaume
11:40AM

Q=Tim Berthaume
A=Dr. Blair Witherington

Q: Hello, Dr. Witherington, this is Tim Berthaume, I would like your permission to record this interview?

A: Sure, sounds great.

Q: Thank you first and foremost. I already ran this interview by Dr. Salmon and I suspect it won't take more than a half an hour. I'd like you to identify yourself, your credentials, who you work for, and your current research if you will. (Edited for clarity)

A: Well, I am Blair Witherington; I work for the Florida Wildlife Conservation Commission as a research scientist. I have graduate degrees from the University of Central Florida and the University of Florida and I principally work on sea turtles. Much of my work involves sea turtles on nesting beaches and that includes how hatchlings find the sea given the various anthropogenic challenges that we put to them like lighting and other things as well; there are a lot of conservation challenges for sea turtles on beaches. Research on sea-finding in hatchling sea turtles has many applied aspects. Because research and management are intermingled, I end up doing both as part of my job.

Q: The commission that you work for is that analogous to the department of environmental quality or is it more along the lines of strictly wildlife? (Edited for clarity)

A: Our focus is on fish and wildlife although our agency ends up providing consultation to the state's environmental agency, which is the department of environmental protection. So we work hand in hand with that agency; in fact, my research institute was formerly part of the state's natural resources department. Then we melded into the department of environmental protection and later merged with the former state fish and game agency.

We are now a wildlife and ecosystem conservation agency we've evolved.

Q: Glad to hear. Better evolution, than de-evolution. Can you tell me when you first became interested in the effect of artificial light on sea turtles?

A: That would be when I was in graduate school doing a PhD dissertation at the University of Florida. I was looking for a question to answer for my dissertation and I thought that the study of hatchling sea turtle orientation would be a good one. Mainly because it had a lot of scientific interest for me but it also had a lot of real world conservation implications. The year was about 1987.

Q: The heart of my thesis is asking the question: do you feel that light pollution should be regulated under the auspices of the EPA per their mandate, "The mission of the EPA is to protect human health and the environment. Since 1970 EPA has been working for a cleaner healthier environment for the American people"? Or another agency or not at all? (Edited for clarity)

A: Well my answer is it should be regulated as a pollutant by an agency that is used to regulating pollutants. I have some strong feelings about that and a few reasons why I feel this way. The most important reason is that light behaves like a pollutant and therefore a lot of the things we've learned about regulating and mitigating other pollutants can be applied to solving problems that are caused by artificial light in our environment. Light has both point-source and non-point source origins. For point-source light problems one can address harm from individual sources with only modest effort in education, regulation, and application of mitigating technology. One can shield the light, change its direction, and even change the quality of the light in ways that would reduce its harm. But there are also non-point source problems that require solutions on a much broader scale. In non-point source artificial lighting problems, many light sources of varying types contribute to an overall effect. Environmental regulatory agencies have learned a lot about how to use their regulatory authority to solve pollution problems on each of these scales. These agencies have had success in solving pollution problems from chemicals, noise, and even thermal pollution. Although light is different from other pollutants I think the philosophy that would govern the mitigation of its effects is similar to other types of pollution.

Q: In one of Dr. Salmon's articles he stated that local and state governments expended a

lot of energy to “cure” this problem; to your knowledge has the EPA been involved at all?

A: No.

Q: In your opinion should they be involved in mitigating this problem?

A: Well yes. If you were to talk to somebody from EPA—and you probably will—they’ll say that you know this is just one more environmental trouble that happens to be not a very significant problem compared to the other human actions they regulate. It is a popular political philosophy to scale back the size of government and to not worry about things that aren’t quite as important. But I think that light pollution IS and an important concerns and that the EPA is just the regulatory agency to address this problem. One reason that a federal agency should be involved is that the harmful effects of light on humans and other animal’s spans boundaries. It’s not just a local issue. In fact in many cases it’s an issue that can pit one local government entity against another. There are boundary effects where one local government entity has done everything within its power to solve a problem and yet the problem still exists because a neighboring entity is not doing anything. And normally when those sorts of localized disputes occur it’s time for a larger government entity to step in and that means a state or a federal entity, like the EPA. Managing light to reduce its harm is of concern to more than sea turtle conservationists and it extends to boundaries beyond the range of sea turtle nesting. It’s not just Florida and it’s not just coastal; it’s everywhere. Light pollution concerns involve endangered species, sure, but they also involve a wider range of animals from migrating birds to night pollinating insects. Some of these are charismatic and prompt us to care about their populations—and others have mere ecological importance and we might not care about them quite as much as we should. Light pollution also includes human health concerns. These concerns are as basic as someone not being able to sleep at night because light is shining in their window. Or they may involve pursuit of happiness issues, such as someone who would like to see the Pleiades or a meteor shower but cannot because there is an artificial glow shining back at them from the urban sky that comes from us—not the heavens.

Q: Very good. Can you tell me a little bit about what your research shows regarding artificial light and sea turtles? (Edited for clarity)

A: Well in the simplest sense artificial lighting that can be seen from a nesting beach causes sea turtles to move in the wrong direction. And in terms of hatchlings, this misorientation or disorientation is important as a disruption of their sea-finding behavior. Hatchling sea turtles need to enter the sea very quickly and when they move in the wrong direction it generally means that they never reach their goal of getting to the ocean. And that means that they die. So it's a mortality problem. In terms of the US Endangered Species Act this is problem of take (killing, harming, harassment, etc). In addition to effects on hatchlings artificial lighting also causes harassment and mortality in adult nesting turtles. They can be disoriented as well and move in the wrong direction—often the result isn't as lethal as for hatchlings. Artificial lighting also influences nest site choice in adult turtles so in that way light can be considered habitat degradation. You can light up a beach and turn a perfectly good nesting beach into a beach where very few turtles nest. So I guess in essence that's the problem.

Q: Is there any new research that you haven't published yet? If so could you tell me about it? (Edited for clarity)

A: There are a few things from my dissertation that I still haven't published yet that I'd like to. There are some things—some folks may consider them esoteric—some aspects of hatchling orientation that teach us how they measure their world and what type of light is important to them. For instance there's a study in my dissertation that asks questions about light color—specifically, yellow light. Yellow is a color that stands out in terms of hatchling orientation because loggerhead hatchlings do something strange when they're shown yellow light. They see it, they respond to it and depending on the intensity of yellow light they're either attracted to it or literally repelled by it. In my dissertation I've done a little bit of work, a bioassay of sorts to see how that yellow light intensity influences behavior and that hasn't been published yet. It's a little difficult to directly apply this work to solving artificial lighting problems on beaches. But it opens up the possibility for a lot of other experiments on light color and intensity that could guide efforts to change artificial light sources so that they have the minimal effect possible on sea turtles. And I think it is an interesting avenue to pursue because just like other forms of pollution we often can't solve the problem completely. We're human beings with only modest night vision and we need a little bit of light to see at night. There are legitimate concerns for nighttime safety and security. There is going to be some light used in our future. We can't just turn off all the switches. So it's worthwhile looking at the sources we use to imagine how they can serve our purpose without causing significant harm to

other aspects of our world. To this end it will help to apply the best available technology to our lighting so that we have lights that are useful to us but that have minimal effect on human beings and animals. So, just like it would be imprudent to cease use of every chemical that could do our environment harm if in the wrong place, neither should we simply try to turn off all offending light sources. We CAN however, regulate how harmful substances and energy are used and how they get released into the environment. I think that looking along the lines of how to alter light color and intensity that could give us some tools in the toolbox for best available technology to minimize the effects of artificial lighting. And there's a little bit of that in my dissertation that hasn't been published yet. But I think future research is going to be expanding on that and doing a lot of practical experiments with lots of real world light sources to see how they affect turtles on beaches.

Q: Can you identify any knowledge gaps in the body of research concerning turtles and light, and what needs to be done? (Edited for clarity)

A: Well one really big, fundamental question that I've always had is what the true mortality rate [of sea turtles] is from artificial lighting. Understanding this is important for prioritizing conservation funding and in understanding the effects on sea turtle populations in general. To have a number that says, "This many turtles die each year from artificial lighting," seems simple but it's not. We know that the number is really big [but] we can only guess at its magnitude. We may know what rate of hatchling sea turtle disorientation applies to the state of Florida for instance, but we don't have a mortality rate. Many turtles end up getting misled but still find their way to the ocean and yet they've suffered sub-lethal effects at some unknown rate. I guess that's one gap I'd point to is coming up with a pretty good estimate for mortality rate associated with artificial lighting and then it would be good to measure that over time so that as we apply best available technology to light sources and pass laws to regulate lighting we can measure how that mortality rate decreases—hopefully we'll measure a decrease, but we'll have a measure to tell us how good we're doing, how the new technology is working and whether it's worth spending money on. Those are probably the two biggest gaps that I can point to and a third field would be the development of best available technology for light management. We have some tools in the toolbox right now to use to solve lighting problems but there are many new advances in light sources that could provide better options in the future to address the effects of artificial lighting on sea turtles and other animals.

Q: In the area that you are studying in Florida, are there any laws on the books to help mitigate the light problem? Or are you more interested in educating the public? (Edited for clarity)

A: Well education is awfully important but rule of law helps a lot also. Let me see, I can direct you to a website….there are a lot of local communities in Florida, both county and municipal governments that have passed so-called "sea-turtle lighting ordinances" that actually do regulate light visible from the beach during nesting season, so if Mrs. Jones has a dusk to dawn light that is visible from the beach during the nesting season and she lives in a county or city that has one of these ordinances she would be in violation and potentially could be fined. Now, it doesn't always work out that those lighting ordinances are enforced very well. But, nonetheless they do exist and the backup enforcement for—some of the mortality caused by artificial lighting is the endangered species act—and that has been used in just a small handful of cases where someone has had a light on the beach, and its killed turtles, they've been notified, the light remains on and they've killed more turtles. Federal agencies have gone to those people and prosecuted them under the endangered species act for take. The cases that I know of have been prosecuted in several courts. Fines have been levied; no one's gone to jail. The number of cases has been extremely small. But those things have a large effect if they are well-publicized. That is to say, someone with a light that is visible from the beach can come to know that there are consequences to not turning it off. They're doing more than just killing turtles and angering their neighbors, people care about sea turtles and their really is a risk for a substantial fine.

Q: Are there any other ecologists or researchers I should contact to enlighten me in this field? (Edited for clarity)

A: Yes. Maybe the best place to steer you would be the proceedings of a nice conference that was held and the title is, Ecological Consequences of Artificial Night Lighting.

Q: Yep, I've read it. I got that one.

A.7 Crawford Interview

Email Interview
April 2007
Interviewee: Dr. David L. Crawford

1.) In my proposal presentation you stated that light should be considered a “drug”. Could you please elaborate?

As with any other drug, light can be a big help, when needed. It must be carefully matched to the specific need and then monitored as to its effectiveness. If "overdosed: (too much light) it is not good. If misused, it is not good (glare, spill light, etc). It is costly and there can be (and often is) a great waste of scarce dollars. It is much hyped by those who stand to make a profit. It can even be a killer. But that is no reason to not use it, when it is well understood and "prescribed." It can be of great value, when needed and when well matched to the need. It can be a terrible problem to individuals and to the nation when badly understood or used.

2.) You have written, “Lack of awareness, rather than resistance, is generally the biggest problem in controlling light pollution”. Do you feel that the government at the federal level should be on involved with educating people on what constitutes quality lighting?

Yes the governments at all levels should help build awareness, just as they do on so many other issues. See 5 below too.

3.) The EPA’s mission is stated thusly on its webpage: “The mission of the Environmental Protection Agency is to protect human health and the environment. Since 1970, EPA has been working for a cleaner, healthier environment for the American people.” Do you feel that a natural night sky, that is, untainted by artificial sky glow/light pollution falls under this mandate?

I think the match of the night needs are right on target with the EPA mission statement. They, as with most other organizations, have not thought of the night as part of the environment and basically ignore it and the issues attached with it, so far anyway. So, certainly the night should fall in their mandate, and the same with DOE and essentially all

agencies, federal, state, and local (and international).

3a) If so what steps should EPA do to address light polluted skies?

Research (support it and do it), education (learn about it themselves and then do whatever they can to educate all others) to many target audiences and by many means, written, oral, multimedia, etc, etc., and regulate as best one can. Work with other agencies to do the same, individually and collectively.

4.) The Czechs have passed a national light pollution law. Is this step necessary or desirable in the U.S.? Who do you feel would have oversight of this issue if it becomes a national law (EPA? DOE? Some other entity?)

Between you and me, there is no valid Czech law. It is well reported that there is, but in fact there is not an operational one. However, there are some in Australia, and they should be everywhere, for those aspects of lighting that are in the federal mandate, such as highways, etc. Likewise, could fit the energy aspects and many other issues where lighting relates to an agency mandate or mission statement.

5.) Light pollution (in the form of skyglow) bars a quality view of the night sky; obviously this is a problem for astronomers. For the general population, this means a degraded view of the natural sky as well. Can you give some rationale why this view should be preserved? And is a voluntary approach better? Rather than tying light pollution to government regulations?

In addition to all the other aspects of night lighting, the sky glow one is critical. We live not only in our town (or whatever) but in the world and in the universe. We (most people) have lost touch with that fact, to the detriment of our environment (holds for most aspects of the environment, not just the night). We need to be in touch with it, the real it, not just as seen on TV. What a crime if our children and their children never can see the Milky Way, the stars, or the real life night around them. Need we destroy nature (all sorts and all ways) for "progress"? I hope not. So, education and awareness again. Furthermore, the night has been a vital aspect of many cultures and religions and life. It still is in words, but not in reality. One note only: churches in this country (and there are parallels in other religions and cultures) that "The Heavens Declare the Glory of God." But they use terrible outdoor lighting and destroy that view. Why? Why are they not one

of the strongest allies for a viable view of the heavens and of the Night? Awareness again. Voluntary action is needed. It is essential. But so is governmental regulation. Just as in water pollution, air, electrical dangers, plumbing, toxic waste, and on and on.

6.) Is there anything else you would like to share on this topic?

The IDA website and other resources have a lot of material with more coming all the time. A great tool for those who want to learn more: individuals, businesses, organizations, and agencies, locally, regionally, nationally, and internationally. Do work in the links to Being Green, Sustainability, and all these very hot topics now.

Appendix B

This segment of the research was identified in the methodology as a short questionnaire delivered via email to persons in my mailbox. The basic premise was to obtain anecdotal evidence on light pollution/light-at-night perceptions and thoughts by other people. The objective was to help focus research questions that were to be asked during the interview phase. This short five question survey is not in any way to be construed as a scientific sample representative of the population at large. However, the researcher felt that this anecdotal evidence helped to focus questions to be given during the interviews and could also be the starting point to lead the way to some true follow-up research.

The email questionnaire was sent out on March 6th of this year. People who are contacts in the researcher's mailbox were given the exact same document attached to a standard email form which read as follows:

"Greetings:

Please find attached a small questionnaire (5 questions) as a Word Document. This is an unscientific survey to ascertain "common" knowledge on artificial light and light pollution. Please answer the questions, resave the file and send it back to me.

This is completely confidential, so no names. The only idea behind this is to track the status of light pollution, and to see if it is even on anybody's "radar" screen.

Thank you for your help in this matter. If you cannot finish this in one week please do not send it to me after March 13.

Tim Berthaume"

The complete text of the questionnaire is presented below:

"Light Pollution Questionnaire
(Please feel free to elaborate on any of these answers; I welcome your comments).

1.) Are you aware of artificial light being treated as pollution (Y/N)?

2.) Do you think light pollution is a threat to the environment (specifically to wildlife and habitat) (Y/N)?

3.) Do you feel that exposure to artificial light, and in particular artificial light at night has an impact on human safety and health (Y/N)?

4.) Do you feel the EPA (Environmental Protection Agency) has the regulatory power to enforce action on light pollution, and exposure to light-at-night (Y/N)?

5.) Are there any issues about artificial light that you feel need to be addressed by the government(Y/N)? (Please feel free to elaborate on this and add anything that you feel is pertinent).

Thank you for your help and cooperation in this matter. Your help is appreciated. Your privacy will be respected."

Of the 41 people that were contacted to provide information, 15 responded which represents approximately 37%. With such a small sample size not being truly representative of any population or sub-population, it is impossible to draw any conclusions from this survey. However, the implicit idea was to glean anecdotal data about the status of knowledge concerning light pollution and artificial light's impact on the environment and to incorporate their observations into the interviewing guides. Breaking down the comments by question, some of the more interesting remarks are listed below.

Question 1: Are you aware of artificial light being treated as pollution (Y/N)?

- No, this is the first I've heard of it
- No, I was not.

Question 2: Do you think light pollution is a threat to the environment (specifically to wildlife and habitat) (Y/N)?

- Yes, any externally introduced element has the potential to impact the ecosystem.
- I hadn't thought much about this before your question but I can understand the possibility that light pollution is a factor; however I suspect that destroying habitat by putting in man's housing and commercial buildings on the land is a bigger reason animals are suffering.
- No. Consider full moon exposure. I know its "natural," but what frequencies are considered "artificial?"
- No. As I am not familiar with what may be construed as light pollution, or what effects it may have on the environment, wildlife, or anything else I cannot claim it to be a threat to anything.

Question 3: Do you feel that exposure to artificial light, and in particular artificial light at night has an impact on human safety and health(Y/N)?

- No. It may have an impact, but in my opinion, not in the two areas mentioned.
- Yes, I think the body deserves darkness.
- Yes but I believe the impact on human safety is in the positive direction. That is having enough light to see what you are doing is good. As for impacts on health I imagine there could be negative impacts but am not sure they are significant compared to noise "pollution" interfering with sleep and relaxing.
- No. Not in a practical sense. Light exposure can disrupt sleep cycle, but this can be mitigated by shades. Lack of light during human activity at night poses the most serious risk.
- Yes. If you are talking about during sleep. Anecdotally speaking sleeping in the dark is certainly more refreshing. Thus I would consider it healthier.

Question 4: Do you feel the EPA (Environmental Protection Agency) has the regulatory power to enforce action on light pollution, and exposure to light-at-night (Y/N)?

- Maybe for a few special situations.
- No, not at this time anyway. Not enough quantitative data to support any initiative they may have.
- No, I believe that would be stepping above their rights.
- No, I am unaware of any need for this action.
- No, at least for now. The real question is if they become empowered, by what criteria would they set standards.
- Yes, I think the EPA would be a logical regulator for this issue. I do not know if they currently have "laws in place" or authority to do such.

- Yes. If these conditions are proven to have a negative effect on the environment then the EPA should absolutely have regulatory power. Whether they can enforce anything might be a different story.

Question 5: Are there any issues about artificial light that you feel need to be addressed by the government(Y/N)? (Please feel free to elaborate on this and add anything that you feel is pertinent).

- The FDA may want to be more proactive regarding artificial light/UV rays used for indoor tanning. I do not believe they promote enough public awareness as to the potential risks this may pose. They may also want to develop exposure recommendations/guidelines.
- I would assume that artificial light would have some affects on mood and mental conditions along with some physical affects, but industry is a 24 hours a day environment and due to that we are subjected to effects that are created by that environment. If certain types of artificial light have less of an effect than other types, I would expect that the EPA would have ways to encourage that type of lighting. Now that I have taken this questionnaire, I feel I need to know more about the subject.
- I think the burning of fossil fuels to create the artificial light has an impact on our environment and quite possibly our economy. So, from that standpoint, I could favor the regulation of artificial light usage.
- No, I am unaware of any need for this action.
- I think the issue is worthy of discussion and if there is a consensus that some limits or regulations are needed then Federal mandates that may be made more stringent by local entities if there are local issues would be the best approach.
- No. The government has enough to do.
- No. I don't have enough knowledge on the subject to desire any action by the government.

The overall results of the questionnaire are tabulated in table 5.1 presented on the following page.

Table B.1-Email Questionnaire Results

Question	Yes	No	Unsure/No answer	Total
1	5 (33.3%)	10(66.6%)		15 (100%)
2	7 (46.7%)	6 (40%)	2 (13.3%)	15 (100%)
3	10 (66.6%)	5 (33.3%)		15 (100%)
4	5 (33.3%)	9 (60%)	1 (6.6%)	15 (100%)
5	7 (46.7%)	7 (46.7%)	1 (6.6%)	15 (100%)

After reviewing the questionnaires a portion of the information gleaned from the answers was put into questions that were to be answered during the interviews. Specifically the researcher queried the interviewees about the press that this topic was getting. Doctors Blask and Stevens both felt that relevant information was being delivered in a suitable manner. It was interesting to see that people are aware (to an extent) of the effects that light has upon the environment. Unfortunately the leading nature of some of these questions may have prompted them to assume some sort of negative bias towards light. It would be interesting to put together a truly scientific poll to find out the country's perception of light and its attendant effects on the environment and perhaps use that as a sounding board to ascertain what the public knows about artificial light and its impact on the environment.

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