Mapping the Terrain of an Astro-Green Criminology: A Case for Extending the Green Criminological Lens Outside of Planet Earth

Abstract

Green criminological scholarship has expanded considerably in the previous two decades. However, criminologists are yet to acknowledge the space related environmental harms caused by humankind. Consequently, this article makes the case for an astro-green criminology and has two central aims. The first is to discuss the importance of astro-green criminology by examining the environmental harms related to human exploration of outer space. The second is to 'map the terrain' of future research into astro-green crimes and harms. This includes the proposal of five quintessential areas of study: space refuse and debris; space mining; emissions pollutions from space related activities; protecting extraterrestrial heritage sites; and the future uses of the extraterrestrial world by humans.

Key Words: Astro-Green Criminology; Extreme Energy Mining; Space Pollution; Orbital Debris; Astrocriminology.

Introduction

Human activities in outer space should be a concern for criminologists and, in particular, green criminologists. The pollution of Earth's atmosphere has increased exponentially since the launch of the world's first artificial satellite, Sputnik 1 in 1957. The result is an enormous quantity of space debris currently racing around the planet at thousands of kilometres per hour. While the 'big sky theory' asserted the chances of two colliding satellites as negligible,[1] such an event did occur in 2009 when the active U.S. Iridium-33 satellite collided with the defunct Russian Cosmos-2251 military satellite creating 200,000 new pieces of debris of one centimetre or greater.[2] This event, combined with China's intentional destruction of the Fengyun-1C satellite in 2007, increased space debris in the Low Earth Orbit (LEO) by 160 percent.[3]

Green criminology has highlighted the expansion of environmental harms and crimes on planet Earth since Michael Lynch's[4] appeal for a *green* criminology over thirty years ago. Since then, research on green criminological issues has "exploded,"[5] resulting in a tremendous quantity of primary research and theoretical scholarship into anthropogenically-induced environmental harms. Part of the expansion of green criminology has resulted in several typological offshoots of research that are encapsulated under the green criminological umbrella. Examples include atmospheric justice,[6] eco-global criminology,[7] species justice,[8] climate change criminology[9] and wildlife criminology[10] - although this is by no means a complete list. The development of such specialist research areas is undoubtedly due to the inclusive and interdisciplinary nature of the green criminology perspective, which encourages exploration into all environmental problems of anthropogenic origin, regardless of whether or not a criminal offence has occurred. As a result, green criminology has often been described as inter or trans-disciplinary, all-inclusive, "fluid and full of potential to link with other areas of criminology" and beyond into the "humanities, social sciences and natural sciences."[11]

In 2019, a new green criminological offshoot was proposed by Takemura - that of astro-green criminology[12] - complementing earlier work on space debris and complexity criminology.[13] The aim of this article is to conceptualize the basic foundations of an astro-green criminology and justify its inclusion as a legitimate area of study within the perspective of green criminology, and criminology more broadly. This article expands upon Takemura's[14] original work and provides an initial definition of astro-green criminology. This acts as a starting point for future research and discussion into space harms and crimes. Furthermore, this article maps the terrain of astro-green criminology by considering a variety of prospective areas of study such as the environmental impact of space junk, debris and pollution; the extraction of extraterrestrial energy and minerals from space objects through space mining; emissions

pollutions congruent with space travel; and the general usage of space for anthropocentric purposes, like space tourism and colonization. Finally, a critique of astro-green criminology, showcasing practical and theoretical obstacles that confront the discipline at its outset is put forward.

Prior Academic Research on Outer Space

As you might imagine, most research on outer space is produced by the natural sciences. However, legal studies have also tackled space issues, which largely relates to the ownership of property in space,[15] the jurisdiction of extraterrestrial matter,[16] the participation of private entities in space activities,[17] and international law on scientific, commercial and military uses of outer space.[18] Similarly, there have emerged extensions of larger social science disciplines to include space related academic study, such as astropolitics,[19] astrotheology[20] and astrosociology.[21] However, there is no astrocriminology.

A few legal scholars have attempted to enter the criminological realm with regard to human relationships with outer space. Hermida[22] for example, developed a legal and criminological approach to criminal acts in outer space, but this focused almost exclusively on the International Space Station (ISS) and did not consider other extraterrestrial environments. Furthermore, Kutner[23] and Cockell,[24] talked abstractly about the future potential of outer space as a location to house prisoners beyond public reach and view. However, this transportation presents significant moral and philosophical questions regarding the treatment of incarcerated individuals putting aside the costs associated with such an endeavour. Pass and Hearsey[25] have similarly discussed the importance of, and problems inherent, in developing a criminal justice system in future space colonies on extraterrestrial bodies. Despite all this and the criminological issues of outer space, there is currently no field of

astrocriminology, notwithstanding the problems associated with astro-green issues as highlighted in this article.

Even though the focus of this article is on astro-green issues, criminologists should also be concerned with law-breaking and criminal behaviour related to human interactions with outer space. Astro-criminological scholarship would include the study of health and safety violations[26]; intellectual property and copyright infringements; the criminality of corporations within the space industry; criminal acts committed by other powerful actors, such as national governments or militaries; and the victims of space related crimes in these areas. This is likely only the beginning foci of development and astrocriminological study will certainly discover new areas for criminological thinking and research. However, at this nascent stage it is important to discuss the existing international laws that govern outer space.

International Space Law and the Failure to Curtail Space Pollution

The need for international space law was realized after the successful launching of satellites Sputnik 1 in 1957, and Explorer in 1958, and the realization that humans in space was imminent.[27] The first recognized international space law was the *1967 Outer Space Treaty* (OST) developed by the United Nations General Assembly and United Nations Committee on the Peaceful Use of Outer Space (UNCOPUOS) in response to technological advancements fuelling the space race. While there are seventeen articles to the treaty, they cover a range of issues that essentially regulate the "use, occupation, and appropriation of space."[28] Several of these articles clearly echo the cultural and political apprehensions of the time in relation to the cold war and what the exploration and domination of outer space could mean for international peace and politics.[29] Subsequently, many of the articles reflect this and relate to the freedom to explore space without discrimination (Article I); the prohibition of

national appropriation of celestial bodies (Article II); maintaining international peace and security (Article III); and the prohibition of nuclear weapons and other weapons of mass destruction in space (Article IV).[30]

There have also been some recent developments in international space law that reflect contemporary issues in space exploration. These include the registration of objects launched into space,[31] space traffic management,[32] and the legal regime for space tourism activities.[33] In reality, the interplay between national and international laws regarding space exploration and resources is complex and often contradictory. The U.S. *Commercial Space Launch Competitiveness Act* 2015, for example, promotes the use of space resources for profit, which could be seen to contravene Articles I and II of the 1967 OST. Such issues should spark the interest of both lawyers and criminologists alike.

Despite the vast amount of legal analysis on various space laws, there is very little international law pertaining to waste management, which should be of concern to criminologists as the quantity of space debris in low Earth orbit (LEO) continues to accrue. Although there are many domestic laws and non-binding, *de facto* guidelines on the ownership of space objects and how to prevent the creation of space debris,[34] there is no universal, *de jure* international law that assigns a binding responsibility on a state or company to remove space debris that they have created. As Nevala suggests, "although strategists are advancing many possible approaches for addressing orbital debris, the lack of a cohesive and comprehensive legal framework frustrates these efforts."[35] Such matters are of concern to astro-green criminology, zemiologists, and criminologists researching crimes of the powerful.

Defining Astro-Green Criminology

The initial task of defining an astro-green criminology is challenging. There has been considerable debate between green criminologists as to some of the basics of the discipline, including the name green criminology, and how it can be appropriately defined. Halsey highlights problems inherent with the term green and ensuing political ramifications.[36] McClanahan also suggests that green is too prismatically reductive to effectively capture the interminable breadth of the Earth's ecology.[37] It is widely accepted that "environmental criminology" would better encompass what green criminology *is*, but that this term has already been adopted by, perhaps the more aptly named, place-based criminology.[38] Environmental criminology considers traditional concerns around situational crime approaches and prevention techniques, usually in urban localities.

Several authors have attempted to define green criminology. One such delineation is provided by White,[39] who suggests that green criminology is "the study by criminologists of environmental harms (that may incorporate wider definitions of crime than that provided in strictly legal definitions)." For most green criminologists, the study of environmental harms, regardless of their legality, is considered the appropriate remit for the discipline, particularly when considering that many environmental harms are perfectly legal.[40] As a result, green criminology is often described as operating in a critical,[41] or radical,[42] sphere of mainstream criminology. This is due to the focus of orthodox criminology on behaviours that specifically violate criminal laws.[43]

As a result, a true astro-green criminology must recognize these issues that are based upon the ontological reality of crime, criminals, and criminal behaviours. As a result, the focus of the definition of astro-green criminology conforms to green criminological thinking and considers both environmental harms and crimes. Astro-green criminology can be defined as

the theoretical and practical study of space-related environmental harms and crimes that are facilitated by human actions. These harms can be Earth-based, atmospheric, or extraterrestrial and may create human victims, non-human victims, and ecological victims both on Earth and in outer space. This definition of astro-green criminology identifies both the objects to be studied, the Earth, the atmosphere, and the Universe, and those who may become victims of space related injustices including humans, non-human species, and the ecologies of the Earth and outer space.

While it is accepted that there are problems with the term green, it is arguable that it should be encompassed within a discipline that considers environmental space harms to avoid the limitations associated with traditional criminological notions that consider only behaviours that violate criminal laws. This is important for astro-green criminology because many astro-green crimes committed outside planet Earth may go unnoticed or unrecognized due to the inaccessible location of environmental harms, like mineral mining on comets, meteors, or other extraterrestrial bodies. Therefore, to prevent a *dark figure* of environmental crime and harm, astro-green criminology must align with both green criminology to embrace the notion of harm, as well as to mainstream criminology.

The term space justice may be more appropriate for an emerging discipline that considers environmental harms associated with space travel and outer space. However, the term space justice or spatial justice is already applied to geographical issues in criminology, and is therefore, described as "a geographically informed version of social justice."[44] Spatial justice has links to place-based criminology that considers situational crime prevention techniques in order to overcome crime committed in particular localities, such as anti-social behaviour in inner-city neighbourhoods. Due to these issues, astro-green criminology is an appropriate

lexicon for acknowledging both the area of study; astro related to astronomy and outer space, and the links to green criminology.

It is important to note that research and discussion on astro-green criminology is not the first to consider environmental harms connected with space travel and outer space. On the contrary, there are many publications in academic journals and books that consider such problems,[45] largely emanating from the natural sciences. For example, Qizhi[46] categorizes the environmental pollution of space related activity into three areas of chemical, biological, and radiological. For Qizhi,[47] chemical pollutions relate to emissions inherent with the space industry. This includes chemicals released during launching and then powering spacecrafts. These chemicals, such as nitrogen oxide, carbon dioxide, chlorine and hydrogen chloride, are harmful to both humans on the Earth who are exposed to such chemicals, as well as other natural systems, such as the ozone layer. Qizhi's[48] reference to biological pollutions refers to the risks associated with biological contamination as a result of going into space. This can be further split into forward-contamination where terrestrial micro-organisms contaminate space environments, and backward-contamination where extraterrestrial micro-organisms contaminate Earth environments, humans, or non-human species. Finally, "radiological pollution occurs from emissions of radioactive materials from electromagnetic waves."[49]

There is a benefit to breaking pollutions down into such categories and this article promotes the use of these as a basis to begin research into astro-green crimes. However, pollution is not the only form of environmental harm produced by the space industry. Therefore, when considering the remit of astro-green criminology it is important to contextualize what issues should be encompassed within the area of study. With this in mind, the following five issues represent the main focus of an astro-green criminology.

1. The problem of space debris including the environmental implications of satellite collisions in the LEO region.
2. The extraction of minerals and energy resources by humans from extraterrestrial bodies residing in outer space; for example, space mining to fuel transportation or to power the chemical industry.
3. Emissions pollutions associated with space travel that may affect the Earth's atmosphere or matter in outer space.
4. Protecting heritage sites of cultural significance to humankind; the site of the lunar landings in 1969 for example.
5. Future usages of outer space, such as engaging in space travel, space tourism, or future extraterrestrial colonization.

Due to the significance of these five issues for the development of astro-green criminology it is important to explain how these topics can, and in some cases have, resulted in astro-environmental harm.

Space as a Junkyard: Accumulation of Space Debris in Low Earth Orbit

Space debris is a monumental problem. Currently the total mass of all space objects in Earth orbit is 8,800 tons, encompassing hundreds of millions of individual pieces of debris.[50] These debris can travel up to 35,000 kilometres per hour[51] and while many fragments are small, there are an estimated 34,000 objects greater than 10 centimetres (cm), which is a size that can generate great harms.[52]

This number has increased exponentially since humanity began space exploration in the 1950's, and industries, such as telecommunications, started to utilize the space environment for various commercial means. The ability to utilize outer space for such industries is vital for the modern functioning of human societies. As Pelton acknowledges,

> Space systems have become so very vital, that if we were suddenly denied access to our space-based infrastructure for weather forecasting and warning, for space-based navigation and timing, for civil and military communications, and for remote sensing and surveillance from space we would be in danger. We would suffer almost immediately—economically, militarily, and socially. Many of our transportation and our communications systems would go down along with our weather and rescue services and defense systems. Internet would (lose) its synchronization, credit card validation would no longer work, we would not be alerted to major storm systems, air traffic control, shipping navigation, and trucking routing services would be lost.[53]

Whist space infrastructure is clearly vital to everyday life, and furthermore, the protection of the Earth and human life from outside inference, the issues of space debris and pollutions have received no consideration from the criminological arena, green or otherwise. Indubitably several criminological scholars may consider such study as "beyond the purview of the discipline."[54] However, space debris is a growing phenomenon that has implications for the continued functioning of modern human societies. This is because space debris presents several different problems and risks.

Firstly, the more objects that orbit the Earth, the higher the likelihood of collision events. The worst case scenario regarding collisions from an astronomical perspective concerns the ability of the space industry to continue to safely launch spacecraft through "deadly rings of

debris."[55] From a safety point of view, debris also presents a significant issue to astronauts whose spacesuits could tear as a result of being pierced by debris,[56] presenting a significant risk to human life.[57] Furthermore, there are problems around enabling new objects, like other satellites, to join an orbit that is already heavily polluted with debris.

A second risk associated with space debris is the "possibility it will strike the Earth's surface."[58] Despite such risks, the re-entry of space debris into the Earth's atmosphere is a "recommended end-of-mission disposal option for LEO objects to mitigate debris orbital pollution."[59] While this can often be controlled and aimed at oceanic environments, presenting environmental risks for non-human animals in such aquatic regions, other space debris re-entries are random or uncontrolled; around 70 percent of the re-entries of intact orbital objects fall into this category and can occur from natural decay or other factors, such as drag force.[60] Albeit not all re-entry objects reach Earth and many burn-up upon re-entry with Earth's atmosphere, the random re-entry of orbital space debris presents safety risks for humans and infrastructures, and pollution risks for natural environments on Earth.

A final risk associated with space debris concerns nuclear contamination of extraterrestrial environments, what Qizhi[61] would classify as forward-contamination, or Earth environments depending on the collision in question. According to Button, "this danger was made apparent in 1978, when a Soviet satellite malfunctioned and fell to Earth, scattering radioactive debris over northern Canada... (sparking) international efforts to limit the use of nuclear materials in orbit."[62] Despite this, it is worth noting that the Safety Framework for Nuclear Power Source Applications in Outer Space (SFNPSAOS) was only formally agreed and adopted in 2009.[63] Although the purpose of this publication is to provide high-level guidance in order to "mitigate risks arising from the use of space" nuclear power sources, this is only voluntary

guidance and is not legally binding under international law.[64] The failure to legally bind the SFNPSAOS could be seen to open-up the space environment to abuse due to the lack of an effective deterrent. Therefore, the public health risks associated with nuclear uses of outer space are worthy of criminological attention.

This section has clearly highlighted that the space debris currently orbiting Earth is an environmental issue. At the same time, space has been suggested as a potential solution to other forms of human-generated waste disposals, particularly regarding non-renewable, nuclear, and radioactive wastes that are difficult to safely treat or dispose of on Earth.[65] Non-renewable wastes generated from energy extraction industries vary in type from simple airborne emissions, such as flaring waste gases at fracking sites, to highly dangerous nuclear waste solids. Airborne emissions are harmful to the Earth's atmosphere in the form of greenhouse gas emissions, but nuclear waste solids cannot be burnt safely, and therefore must be disposed of through storage. Often this transpires deep-underground, on land, or in the sea.[66] There are as well problems surrounding the impact of such wastes on public health in the present[67] and for future generations on a finite planet. Hence, launching nuclear and radioactive solid wastes into outer space may appear to some industries as an attractive solution to the problem of toxic waste disposal. As Dusek discusses, "space disposal appears to provide an easy way of permanently ridding ourselves of the waste without the accompanying fear that the waste will pollute the Earth, and leave us with contaminated land."[68] Dumping hazardous waste into outer space, however, is not yet a reality. Despite this, it is an option that is often talked about in the nuclear waste disposal literature.[69] The possibility of mining precious space minerals and energies found on extraterrestrial bodies present a more imminent problem with regard to environmental protection than toxic waste disposal.

Space Mining and Extreme Energy Extraction

The term "extreme energy extraction" refers to "a range of relatively new, higher-risk, non-renewable resource extraction processes that have become more attractive to the conventional energy industry as the more easily accessible supplies dwindle."[70] Thus far, green criminologists have researched the environmental harms involved with extreme energy extraction processes on Earth, such as those associated with unconventional hydraulic fracturing.[71] However, they have not yet explored ideas around extreme astro-energy extraction despite the emergence of this possibility within the space industry.

In terms of potential extraterrestrial locations for space mining, the Earth's Moon holds significant potential as a source of energy. In 2016, the United States Federal Aviation Administration authorized a lunar mission with the express purpose of lunar survey and exploration in order to achieve the goal of "mining the Moon for valuable natural resources and bringing them back to Earth."[72] The Moon has the shortest space travel time of any of the planets or moons in the Solar System, and represents one of the most realistic space mining locations from a logistical standpoint.

The Moon contains significant amounts of Helium-3 in the surface crust.[73] This is extremely significant with regard to energy generation from nuclear fusion. As Kim clarifies,

> Scientists have found that if Helium-3 is nuclear-fused with heavy hydrogen, it generates tremendous energy through nuclear fusion power generation with only a small amount of energy. Even better, this generation rarely produces radioactive waste because after a short half-life, the radioactivity disappears. There is little Helium-3 on the Earth, but it is abundant

> on the Moon's surface, where about 100 million tons has been created by solar wind as it flies over. This is enough for mankind to use for a very long time. [74]

Currently the logistical requirements of Moon mining remain costly, but there are now four private companies based in the United States working specifically on astro-mining development. These include: Planetary Resources Inc; Deep Space Industries; Shackleton Energy; and Moon Express.[75] Astro-mining raises pertinent questions for green criminology, and in law and socio-legal studies as well. Who, for example, should own resources and minerals extracted from space? Is extraction a free-for-all, first-come first-served venture that risks access-inequality? Should private companies be able to extract, own, transport, and sell extraterrestrial resources? These are questions of concern for green criminological discussions.

Moreover, the Moon is not the only extraterrestrial body that could be a suitable location for space mining. Volger[76] discusses the potential of mining on both the Earth's Moon and Mars with microbes capable of extracting iron, a common material used on Earth in many industrial processes including buildings and construction. Similarly, asteroids have been found to yield an array of minerals including iron and nickel.[77] In 2005, Japan's Hayabusa spacecraft successfully landed on asteroid 25143 Itokawa, successfully 'lifted off regolith grains' from its surface, and returned the samples to Earth.[78] Additionally, the two moons of Mars, Phobos and Deimos, may also contain water, carbon and nitrogen, among other volatiles.[79] Furthermore, there are thousands of asteroids that pass close to the Earth, and millions of asteroids in the asteroid belt between Mars and Jupiter, over 200 million of which are 1.6 kilometres wide or greater.[80] There are an infinite number of extraterrestrial bodies that may be suitable for future extreme astro-mining activities, and the recent emergence of

companies interested in exploring astro-mining deems this an important future area of green criminological study.

Astronomical Additions: Emissions Pollutions from the Space Industry

Consideration of emissions from rocket and satellite launches is of great environmental concern particularly regarding the expansion of the space environment for the purposes of scientific knowledge advancement, the telecommunications industry, tourism, and other commercial enterprise.[81] Emissions not only have the potential to impact human health, but also contribute to ozone depletion and contamination of the upper Earth atmospheres.[82] As a result, discussions concerning space-related emissions are not only relevant to astro-green criminology, but would be of interest to green criminologists researching climate change. This further justifies the suitability of astro-green harms as an area of study for green criminology.

The current and future impact of telecommunications is of particular interest to criminological enquiry. Space Exploration Technologies (SpaceX), for example, has permission for 12,000 new satellites each with only an approximate five year life-span.[83] Other high numbers of 900 and 1,000 are reported for OneWeb[84] and Xinhe.[85] Placed in context, as of February 2020, 9,600 satellites have ever been placed into Earth orbit since Sputnik 1 in 1957.[86] This is important for astro-green criminology due to the emissions that are concurrent with making and launching satellites, and de-orbiting them at the end of their useable life.

In terms of climate change, the emissions of submicron-sized particles from rocket launches currently in the Earth's atmosphere is already at a level where it "could become comparable

to global aviation" in the coming decades.[87] Given the number of launches already approved for the next few years described above, there are potential serious impacts for climate change.

The type of emissions created from launches depends on several factors including, for example, the companies involved and the mechanics of rocket launching. Talwar[88] discusses how launches generate emissions that "include water, nitric oxide, carbon dioxide and soot." These emissions are of concern as the number of space rocket and satellite launches expands with the growth of the space industry and future space based capitalism.[89] As such, the relationship between profit-making, private enterprises, state-corporate relationships, and environmental harm will be of interest to theorists researching ecological withdrawals (space mining) and ecological additions (space orbital debris, emissions from space launches, and space travel).

Space Heritage Sites

Just as those researching the pertinent issues of climate change will be interested in the study of space related emissions that are detrimental to human health and the Earth's atmosphere, scholars researching conservation criminology[90] will be interested in conserving extraterrestrial environments. This involves those extraterrestrial bodies impacted by human activities, but also the conservation of culturally significant heritage sites that demonstrate humankind's achievements in extending a human footprint beyond planet Earth.[91] Space heritage sites could include those on Earth that have been used for ground-breaking space advancement, such as the Apollo missions, or those that exist in outer space. The Apollo 11 lunar landing site, for example, has been proposed as a place of special cultural significance to humans, and therefore worthy of protection.[92] The question as to whether such protection can be afforded is a legal one and beyond the scope of this paper. However, it is worth noting

that the United States have taken steps to attempt to preserve the lunar landing sites through passing legislation, *The Apollo Lunar Legacy Landing Act 2011*, proposing that this site and the equipment on it is a U.S. National Park.[93] Whilst future lunar exploration is inevitable, and "although we might assume the best of intentions for such missions, they could irreparably disturb the traces of the first human visits to another world."[94] In this context, the preservation of extraterrestrial heritage sites on the Moon, and perhaps in the future on other extraterrestrial bodies, is a key concern for astro-green criminology and conservation criminology alike.

Future Usages of Outer Space for Anthropocentric Purposes

The main topic areas for astro-green criminology considered herein include space debris, emissions pollutions, the mining of extraterrestrial bodies for volatiles, and space heritage sites. However, the scope of astro-green criminology should not be confined to issues that are already pertinent, and astro-green criminology should consider future anthropocentric usages of outer space. Herein, there are several other potential topics that are grouped into a future usages category, albeit it is recognized that astro-mining could also be classed as a future use.

There are many academic speculations regarding the future use of outer space that could be of concern to astro-green criminology. For example, space tourism is likely to increase in the future as both the ability to provide space tourism becomes more likely and the cost of purchasing a ticket into space goes down opening such travel to more and more people. Of concern to astro-green criminology, are the environmental impacts of creating a space tourism industry.

A further future usage issue can be found in the concept of extraterrestrial colonization by humans, such as on Earth's Moon or Mars.[95] Astro-green issues related to extraterrestrial colonization involve the environmental harms associated with travel to and from a colony, as well as the impact of human activity on the extraterrestrial environment in question.

From a theoretical standpoint, astro-green harms can be broken down into primary and secondary issues. Primary astro-green harms include the human space related activities that currently exist and, therefore, are of immediate interest to green criminologists. These include: the space debris that currently orbits the Earth; pollutions linked to constructing and launching spacecraft; the protection of extraterrestrial heritage sites; the weaponization and militarization of space and future dangers of space warfare; and criminal acts associated with the damage or destruction of property in space. Secondary astro-green harms include those issues that have not yet come into fruition, but evidence suggests they are a human priority for the future. Such issues entail space tourism, extraterrestrial extreme energy mining, and the potential future colonization of extraterrestrial bodies.

The extent to which the five issues discussed here for astro-green criminological study continue to materialize is influenced by governments, laws, politics, economics, and cultures. As a result, it is vital to consider how our current view of outer space and our relationship with it can change, or could result in alternative understandings. One way of doing this is to consider ecophilosophy, which is a stream of philosophy encompassing a series of perspectives that guide and inform human relations with the non-human world.

Ecophilosophy Applied to Astro-Green Criminology

In his founding article on astro-green criminology, Takemura[96] made a connection between outer space environmental protection and environmental ethics, framing his argument within anthropocentric, ecocentric, and astrocentric environmentalism. Therefore, there is a recognition that environmental ethics and in particular, ecophilosophy could provide an appropriate theoretical lens through which to explain astro-green harms, and the general usage of space for anthropocentric means. The concepts of ecophilosophy - anthropocentrism, biocentrism, and ecocentrism - are longstanding perspectives within environmental ethics.[97] However, Halsey and White[98] were the first to fully apply them to green criminology when they analysed the deforestation of Australia's old-growth forests through an ecophilsophical lens. Considering philosophical approaches to astro-green criminology is incredibly important at this early stage, especially considering that space travel and exploration is likely to expand in the next few decades as technological innovations are realized.[99]

Takemura[100] posits preliminary eco-philosophical questions regarding the application of ecophilosophy to astro-green criminology,

(1) Why should we be going into space?
(2) Does Mars as a planet have any intrinsic value in and of itself?
(3) Is there less intrinsic worth in a planet which is devoid of life than in one with an active biosphere?
(4) Should we access and use the resources which are available there, or should we leave them as they are?

Such thought-provoking issues demonstrate the "deep thought" that is required to answer such questions.[101]

Ecophilosophy could be said to give us a basis for beginning to answer such questions by applying anthropocentric, biocentric, and astrocentric perspectives to space use, exploration and utilization. This section will demonstrate this by applying ecophilosophy to anthropocentric space mining and energy extraction on matter that exists in outer space, such as on asteroids, moons, and planets. Future analysis will no doubt apply ecophilosophy to other primary and secondary astro-green issues.

From an anthropocentric perspective, outer space would be viewed instrumentally as a vast source of minerals and energies that have the capability of being extracted for the purposes of satisfying human wants and needs. Anthropocentrism would advocate space mining due to the finite quantity of resources that exist on planet Earth. Protecting the extraterrestrial environment would be useful only "for ensuring the continuity of humankind."[102] Furthermore, the limits of human space travel in terms of time and distance would increase the need for astro-sustainability. However, ultimately, anthropocentrism would consider natural matter in outer space as having no intrinsic value and, therefore, exploration and extraction could occur so long as such activities enable the continuity of humankind.

Conversely, 'biocentrism views human beings as simply another species to be attributed the same moral worth as such organisms as, for example, whales, wolves and birds.'[103] As a result, energy extraction under biocentrism would view extraterrestrial bodies as having intrinsic worth. Therefore, extraction should only occur insofar as it does not prevent future humans from also benefitting from those same natural resources. Under such a perspective,

the confines of human space travel (again, in terms of the limitations of distance and time) would recognize that only a finite number of extraterrestrial bodies within human reach are suitable for energy extraction. In this scenario, extraction should only occur under biocentrism if it does not harm any microorganisms existing in space, or the future of humankind to exploit such resources.

Finally, astrocentrism is an extreme version of biocentrism whereby outer space is attributed the same moral and intrinsic worth as planet Earth and all the life contained within. Under astrocentrism, all the natural matter that has ever existed in the universe (or multiverse), whether it is visible or otherwise, because of its very existence should be treated as having the same value. As a result, extreme precaution should be exercised by humans outside of the Earth's atmosphere, and the mining of extraterrestrial bodies would not be condoned due to the intrinsic value that they hold. Furthermore, astrocentrism is closely aligned with Huebert and Block's[104] astroenvironmentalism. In this perspective, there is a realization of the destructive nature of humankind and that humans could extend such destruction into outer space. As Takemura[105] points out when discussing astrocentrism and astroenvironmentalism,

> Since mankind made such a mess of this planet and is now paying the environmental price for the damage, this topic is of extreme importance because we must avoid making the same mistakes in space as we have on Earth. At issue are the environmental consequences of the steps we are about to take in entering space. Astroenvironmentalism is another re-formulation of the associated environmental concerns involving a space wilderness to protect, rather than a frontier to exploit.

Thus far this article has identified many issues for criminology and astro-green criminology, highlighting the need for criminological engagement with space-related human activity. Concomitantly, there is a realization that there are several limitations to astro-green criminology that must be considered at this nascent stage.

Critique of Astro-Green Criminology

First, there are only several humans who have ever explored outer space. While environmental problems may exist (and several have been identified in this paper so far), the extent to which it is possible to research and quantify astro-green harms and crimes is restricted as a direct consequence of the location of outer space in which they happen. One can postulate that many astro-green crimes and harms will (and undoubtedly already have) go unnoticed. While this presents a rationale for conducting research into astro-green harms (i.e., to identify, examine, research, and theorize), there is a practical hurdle to conducting primary astro-green criminological research in outer space. Therefore, it is likely that such research will be limited, at least at the outset, to primary astro-green harms initiated on planet Earth, such as those associated with the space industry. This does not imply that it is not possible to theorize about astro-green issues in outer space, and use secondary data to provide answers to secondary astro-green problems.

Second, while technological innovations have resulted in several noteworthy achievements in recent years, developments in what the space industry can do are limited by financial constraints, politics, and the state of current scientific knowledge. As a result, space exploration can be seen to be at a very early stage as science and technology continue to advance. This has a knock-on effect for astro-green criminology as the incumbent harms may be years into the future.

Despite this, there is evidence to suggest that the development of space (particularly in close proximity to Earth) is moving quickly. The expansion of the telecommunications industry for example, has resulted in a "60 percent increase in the total orbital debris object count" in the last decade alone.[106] The militarization potential of space is also a rapidly growing area of concern in the context of twenty-first century "space warfare."[107] Additionally, enterprises interested in space tourism and other private ventures are growing in quantity. As Denis et al.[108] state,

> Development of commercial space, with start-ups and space ventures, is one of the most visible trends in space. Stimulated by the first initiatives related to space tourism, access to space and the growing use of small satellites, space activities have attracted new entrepreneurs, both start-ups and big web actors with substantial investment capacity. This revolution started in the Silicon Valley and spread worldwide. Start-ups have attracted around $21.8 billion of investment from 2000 to 2018.

In their influential book entitled *The Treadmill of Crime: Political Economy and Green Criminology*, Stretesky et al.[109] suggested that "historically, criminologists have viewed the study of environmental harm as beyond the purview of the discipline," highlighting the dispute between what green criminologists are studying (environmental harms) and what they perhaps should study in the true criminological tradition (environmental crimes). With this in mind, an astro-green criminology that considers the potential of future environmental harms, such as those apparent with space tourism or extraterrestrial colonization, may run the risk of also being considered beyond the purview of criminology and green criminology alike. Though, such study is vital in the prevention of environmental harms, taking a precautionary approach, rather than responding to environmental harms that have already occurred. The

purpose of doing this is to prevent humans "making the same mistakes in space as we have on Earth"[110] regarding pollution and extraterrestrial degradation.

A final critique of astro-green criminology resides in the object of study and whether this constitutes a worthy area of criminological enquiry. Extraterrestrial environments and their elements occupy a location far from human view. Because of this inherent problem, it may be difficult to understand how the environmental harms in such remote locations impact human life on Earth. The distinction between primary and secondary astro-green harms and crimes mitigates this shortcoming. Primary astro-green harms, such as emissions pollutions or orbital space debris, clearly demonstrate the environmental impact of human interactions with outer space. Secondary astro-green crimes, however, do not have an immediate human impact, and may never even become a reality (such as, perhaps, space colonization). Yet, it could be argued that considering secondary astro-green crimes is the sort of precautionary approach that green criminologists should be employing to the study of environmental harm (i.e., preventing its occurrence, rather than responding to its existence once harm has already occurred).

Conclusion

This article has proposed that green criminology should include the study of environmental harms and crimes associated with human-extraterrestrial interactions, building upon Takemura's[111] original call for an astro-green criminology. There have been two core aims. The first was to discuss the importance of considering astro-green issues within criminology. This has been achieved by highlighting several different forms of environmental harm that result from space-related human activity, such as emissions pollutions. The second aim was to map the terrain of future theoretical and practical research into astro-green issues. This has

been done by differentiating between primary and secondary astro-green crimes, and also by proposing five initial areas of focus for astro-green criminology: space debris; extraterrestrial mining; emissions pollutions; the preservation of outer space heritage sites; and the potential future usages of outer space for anthropocentric means. Consideration of such issues is but one form that an astro-green criminology might take. Other possible orientations may include more philosophical, political, or theoretical approaches, perhaps integrating work in eco-philosophy, treadmill of production theory or conservation criminology. Such applications are largely absent due to green and orthodox criminology's failure to engage with space related harms and crimes. As a result, there is astronomical scope for theoretical and practical developments within astro-green criminology in the future, which is particularly important in the wake of an expanding global space industry.

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