The Governance of Global Sand Mining

by

Melissa Elizabeth Mark

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

ABSTRACT

Sand mining is a global ecological and social sustainability challenge. Greater attention to the governance of sand mining is urgently required to address these challenges. Based on a Delphi survey of global experts, this thesis investigates the ecological and social benefits and costs of sand mining, assesses governance opportunities and challenges, and examines the potential knowledge gaps and solutions for sand governance. The Delphi survey was conducted over two rounds. 12 individuals participated in the first round while 11 individuals participated in the second round.

Major findings show no ecological benefits to sand mining and several impacts, including accelerated erosion and threats to wildlife. The social impacts include compromises to resource-dependent livelihoods, infrastructure collapse, health and safety risks, illegal mining networks, and corruption. The social benefits, which include infrastructure development and employment opportunities, do not offset these risks. The lack of awareness of both sand mining and its associated costs, coupled with poor enforcement and monitoring of policy, are identified as significant governance gaps and should be addressed to improve the sustainability of sand mining. Future research should prioritize studies to understand the large-scale and long-term impacts of sand mining and to investigate illegal mining activities and corruption. Finally, the establishment of a global governance framework, including standardized certification, should be established and directed by a mediating organization to work toward the collective interests of all stakeholders.

This thesis contributes to the existing knowledge of sand mining while also increasing awareness. Additionally, identifying the governance gaps may help to improve the implementation of a global governance framework. Ultimately, this research advocates for increased awareness of the ecological and social challenges and dimensions of sand mining through increased education and research, as well as an improved global governance framework to develop sustainability of the industry.

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DEDICATION

I dedicate this thesis to my friends and family that have supported me throughout this process. Thank you for listening to me go on about sand, helping me edit work, and providing encouragement.

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"In every outthrust headland, in every curving beach, in every grain of sand there is the story of the earth."

Rachel Carson

The Shore of the North Sea: Melissa Mark

1.0 INTRODUCTION

Global sand extraction is an emerging issue with major socio political, economic, and environmental implications. As such, an effective global sand governance system is a pressing need (Torres, et al. 2017a). Sand is the second most-consumed resource in the world (we consume 50 billion tonnes per year) surpassing fossil fuels, and is exceeded only by water (Beiser, 2018a; WWF, n.d.). Sand extraction is also the largest mining practice globally, and it is responsible for 85% of global mineral extraction (Pearce, 2019). Unlike other globally extracted resources such as diamonds, there are no international conventions to regulate sand extraction, its use or its trade, which disproportionately and negatively affects the ecosystems and lower class of sand-exporting developing countries, while often benefitting the elite (Bieri, 2009; Torres et al., 2017b; UNEP, 2019). The global demand for sand resources is also increasing faster than it can be replenished by natural processes, which creates an increased demand that can lead to rising prices on the commodity in large urban areas. The rising prices, in combination with limited regulation, has resulted in an extensive illegal sand mining industry (Beiser, 2018a).

Unregulated sand extraction negatively affects ecological integrity and local livelihoods, and also has the potential to seriously harm coastal villages through increased erosion (Popescu, 2018; Subramanian. 2017; Torres et al., 2017b). Trading of illegally mined sand is facilitated where local regulations are not enforced, corruption within the government is prevalent, and global enforcement regimes do not exist (Beiser, 2018a). Even where regulations exist, sand may still be illegally extracted and traded in countries such as India, where capacity (e.g., monetary resources) to enforce environmental policies regarding resource extraction is limited (Torres et al., 2017b; UNEP, 2019). Illegal sand mining operations are lucrative given that of the 40 billion tonnes of sand extracted globally per year, only an estimated 15 billion is thought to be traded legally for a market value of USD $70 billion (Mahadevan, 2019). However, these figures are estimates; establishing accurate quantities of extracted sand is difficult due to the illicit activity that may forge documents or dismiss them all together.

The global issue of sand mining is inherently multi- and interdisciplinary and involves different actors such as government, fishers, and miners. Research must reflect these realities. For example, much of the literature focuses on the mining impacts such as habitat destruction, shifts in livelihoods towards mining, and illegal trade (Beiser, 2018a; Popescu, 2018; Salopek, 2019; Torres et al., 2017b; UNEP, 2019). Significant gaps in knowledge remain about the magnitude of global sand extraction, and the unknown ecological and social impacts of depleting sand resources which hinders progress towards environmental sustainability (Beiser, 2018a; Bendixen, 2019; Lamb, 2019). As a transboundary, global issue, current global governance of sand mining has proven challenging and insufficient to foster ecological and social sustainability. My research aims to address the knowledge gaps that exist with sand governance using a global lens. I intend to identify and address the drivers of sand mismanagement that has led to

unsustainable and illegal sand trade and provide recommendations to improve the global sustainability of the industry through enhanced governance.

1.2 Governance of global sand resources: a brief summary

Given the challenges outlined above, my research aims to address the knowledge gaps concerning the governance of the global sand extraction and trade industry. To better understand the social and ecological challenges associated with sand mining and to learn how to minimize these challenges, we must define sand governance. In this research, I define governance as

> "the interrelated and increasingly integrated system of formal and informal rules, rule-making systems, and actor-networks at all levels of human society (from local to global) that are set up to steer societies towards preventing, mitigating, and adapting to global and local environmental change and, in particular, earth system transformation, within the normative context of sustainable development" (Bierman et al, 2010: pg 279).

Governance is the core theme of this research as it influences both the social and ecological impacts of sand mining and how the resource is used, transferred, and monitored through local to global institutions (e.g., the rules and norms that mediate decision making about sand). As a transboundary, global issue, governance of sand (i.e., its mining, use and trade) is poorly understood. A recent report from the United Nations Environment Programme (UNEP 2019: pg 6) stated that, "*Sand extraction and use is defined by its local geography and governance context and does not have the same rules, practices and ethics worldwide."* The inconsistency across borders and jurisdictions regarding the mining, use and trade of sand has led to gaps in the governance of global sand resources.

A lack of, or poorly conceived governance framework for sand places little to no restrictions on sand mining, allows extraction to run rampant in many contexts, and causes many ecological and social challenges. Increased erosion and habitat alteration as a result of sand mining affects fisheries and wildlife, while also forcing people to evacuate their homes (Beiser, 2018b). A lack of governance also enables corruption and violence within the sand extraction and trading business which is seen mainly in developing countries. In the context of South Asia, hundreds of people being beaten or murdered over sand mining have been documented, including local citizens, police, and government officials (Beiser, 2018a; Bendixon et al, 2019). The fear of this violence can make monitoring sand mining operations and trade practices challenging and dangerous. Moreover, existing resource flow and trade documentation (i.e., accounts of formal exports using licensed transportation and shipping companies) is an unreliable monitoring technique. Significant quantities of sand that are traded are undocumented (Lamb et al., 2019). The process of extraction itself can often occur in unmonitored and under-regulated waters, and then shipped across borders, all of which further contribute to the challenge of monitoring mining activity (Bendixon et al, 2019; Lamb et al., 2019). These myriad challenges make sand

mining a complex transboundary issue in need of a global governance approach (Bendixon et al, 2019; UNEP, 2019).

1.3 Research Goals & Objectives

As noted above, governance is a crucial part of efforts to address issues of global sand mining and trade. Thus, the overarching goal in this thesis is to identify the key challenges and opportunities to improve global governance of sand resources. The specific objectives of this research are to:

(1) Characterize the ecological and social costs and benefits of global sand mining;

(2) Assess opportunities and challenges associated with the current approach (or lack of approach) to the governance of global sand resources; and

(3) Identify potential recommendations to improve the sustainable governance of global sand resources.

By characterizing both the ecological and social costs and benefits of sand mining, we can then map out significant gaps in governance and devise strategies for better outcomes (see Chapters 4 and 5). To support this process, I explicitly address research objectives 1 and 4 in Chapter 4. Objective 5 is then addressed in Chapter 5.

1.4 Methodology & Methods

My research uses a qualitative survey-based methodology (see Chapter 3) that is informed by a literature review. Specifically, a policy Delphi process was used involving 12 experts with knowledge of sand mining and governance issues. These experts were engaged through two rounds of the policy Delphi and through a mix of open-ended and structured questions. The policy Delphi is a methodological tool which aids in the understanding of complex policy issues (de Loe et al., 2016). A traditional policy Delphi explores policy issues or options before enactment or integration but can also be used to research previous policy action (Manley, 2013). I used the policy Delphi to identify the most important gaps in sand governance according to a panel of global experts. Further information on the methodology and methods are provided in Chapter 3. This research consisted of two rounds of survey that were presented to a panel of global experts on sand and sand mining. The global panel was used to create a broad scope on the current global sand governance structures.

1.5 Thesis Structure

This thesis will present an assessment of the current global governance gaps concerning sand mining as it relates to sustainability and social challenges. As noted, global sand resources are facing many challenges including ecological and social sustainability, corruption, and illegal mining. In the following sections, I identify and address the drivers of these challenges and

highlight factors that have contributed to the unsustainability of the industry through a panel of global experts. The conclusion of this highlights potential recommendations to improve the global sustainability of the industry through a governance framework.

Specifically, Chapter 1 introduces the broad overview and objectives of this research. Chapter 2 consists of the literature review which provides the conceptual foundations for my research. Chapter 3 explains the methodological approach and the methods that were used to conduct this research. In Chapter 4 an in-depth analysis of the findings is presented, with a discussion of how the results align with the research goals. Lastly, Chapter 5 concludes this thesis by addressing the third research objective and highlights key insights, contributions, and possible suggestions for steps to move forward and future research.

2.0 LITERATURE REVIEW

Sand is a natural resource that is over exploited by humans (Beiser, 2018a; Mahadevan, 2019; Marschke et al., 2020; UNEP, 2019). This over-exploitation has a wide range of socio-political, economic, and environmental implications (Hirsch, 2016; UNEP, 2019). These impacts are largely the result of inadequate governance. I begin this chapter by introducing sand and its uses, then discuss various extraction methods. Next, I summarize the ecological and social impacts of mining, paying particular attention to coastal sand resources and the scale of extraction efforts. Finally, I define and discuss governance of sand resources with reference to my research objectives.

2.1 Sand and its uses

Understanding what sand is and its importance is fundamental to reducing impacts of extraction (see section 2.2) and improving governance of the resource (see section 2.3). Sand (known as "aggregate" in the industry) (Bridge, 2017; Owen, 2017) is a mined resource that accounts for the largest volume of solid material extracted globally, between an estimated 40 billion to 50 billion tonnes annually (UNEP, 2019). By definition, sand is:

> *"a loose granular material that results from the disintegration of rocks, consists of particles smaller than gravel but coarser than silt, and is used in mortar, glass, abrasives, and foundry molds"* (Merriam-Webster, n.d.).

Sand consists of quartz, most commonly silica, and other components vary depending on the location (Owen, 2017). However, geologists define sand not only by composition, but by grain size: between 0.0625mm and 2mm across (Owen, 2017). Sand is formed by several geomorphological processes among which are bioerosion, and erosion from moving water, rocks, or wind (Chilamkurthy, 2016; Morgan, 2016;). Bioerosion is the result of an animal feeding on corals or animal shells and producing sediment as a result. For example, the Parrotfish feed on corals and are a main contributor to carbonate sediment in the oceans (Morgan et al., 2016). Riverine sand is formed by the constant movement of water over rocks over time which disintegrates rocks and produces sediment (NOAA, 2017). Desert sand forms by the same process as beach or river sand but before an area became arid; currently, desert sand is the result of years of wind shaping and smoothing the grains (Beiser, 2018a).

Modern life is made possible by sand, and in particular, global infrastructure development using concrete (of which sand is the main ingredient) such as roads and buildings (Beiser, 2018a; Lempriere, 2017). Moreover, sand mining and affiliated industries such as construction provide a means of livelihood for communities located near a mine, especially in developing countries (Husrin et al., 2017; Mngeni, 2016). Human activities including land reclamation, construction, and technology are increasing the demand for sand. There are a few known cases of land

reclamation, including Malaysia, Singapore, and Hong Kong, that have been using sand to grow their land mass by depositing it in bulk along their shores (Subramanian, 2018). In the last 50 years, Singapore has increased its land mass by 22% using sand and has plans for further expansion which will produce increased demand (Meynen, 2017).

According to Subramanian (2018, as cited in Beiser 2018a), sand is an essential ingredient in many materials, including concrete, glass, computer chips, and soap. It is also used in the production of glass vials used for vaccines (Baraniuk, 2021). Borosilicate glass is traditionally used for vials, it consists of mainly silicon dioxide which is a major component of sand (Hogue, 2020). The two-dose Covid-19 vaccinations are causing a vial shortage due to the surge in demand, which is placing an unexpected additional pressure on sand resources (Bai, 2020; Baraniuk, 2021). In order to vaccinate the global population against Covid-19 and variants, the vaccine requires 15 billion doses (2 doses for 7.5 billion people), which creates not only a medical challenge but an industrial one (Blais, 2020). According to Prashant Yadav at Havard Medical School, if the manufacturing of vaccines and vials along with the distribution of the vaccine are not well coordinated, a vial shortage will occur as the sand resources will be insufficient to provide the number of vials needed (Blais, 2020). While the medical industry is seeing a surge in sand consumption, the greatest consumer is the construction industry (Tweedie, 2018; UNEP, 2019). In 2012, this industry alone consumed 29.6 billion tonnes of sand (UNEP, 2019), and this number continues to increase on an annual basis (UNEP, 2014). However, the total global consumption ranges from an estimated 30 to 50 billion tonnes annually, primarily for use in construction, glass, and electronics (Bendixon et al., 2019). The rate that sand is being consumed is likely surpassing the rate of replenishment (Chilamkurthy, 2016; Lamb et al., 2019; Peduzzi, 2014).

Sand is a deceptively abundant resource. The Sahara Desert alone accounts for 8% of Earth's land area, approximately the same size as China (Hall, 2020). However, not all sands can be used for the previously mentioned purposes like construction or in other manufacturing applications. Coastal, estuary, and riverine sand are the most sought after for construction, whereas desert sand is unsuitable for use as concrete because the grains have been smoothed and rounded by years of wind (Beiser, 2018a; BNEF, 2020). As a result, coastal and riverine communities and ecosystems are among the most directly affected by sand mining operations.

2.1.2 Sand Extraction

Sand resources are obtained through mining extraction, and sand mining is the largest mining endeavor globally, accounting for 85% of material extracted from the earth (Hall, 2020; Pearce, 2019). The four locations from which sand is extracted include: the seabed, coastal areas or beaches, rivers, or quarries. The extraction phase of sand mining can take on several different forms depending on the size and location of the operation. The extraction methods include dredging, other mechanical methods such as bulldozers and excavators, and manually by hand.

The most common extraction method of industrial grade sand is dredging (Beiser, 2018c). This method uses a dredging boat in which sand is sucked up and pumped out from the sea or riverbed and onto a barge (Tweedie, 2018). When the barge becomes full, it discharges the sand into dumper trucks to be transported to its destination (Tweedie, 2018). Other mechanical methods use machines such as bulldozers, scrapers, and loaders, and can be used for the wet (extraction from below a body of water) or dry extraction of beach sand and dry intermittent stream beds (Padmalal, 2014). These methods are intrusive and negatively impact the environment and harm ecosystems (see section 2.2.1 below – further elaboration on ecological impacts is provided).

Manual methods of sand extraction occur more frequently where large machinery is unavailable or unaffordable, including small, illegal mining operations (Hezekiah et al., 2020). This method consists of an individual extracting the sand using tools such as buckets, bags, or shovels; it is the least environmentally destructive compared to the previously mentioned mechanical methods due to the lack of heavy machinery or dredging equipment that affects habitats (Hezekiah et al., 2020; Padmalal, 2014). However, this method is much less efficient, and therefore likely not preferred if mechanical options are available, despite causing less harm to the ecosystems.

All sand extraction methods have impacts on ecosystems as well as communities; the frequency and severity of these impacts increase with sand demand (see section 2.2 below – further elaboration on the social and ecological dimensions and impacts are provided). Many forces are driving sand extraction, demand, and trade. A major one is that the global population is continuing to grow, with more people migrating to urban areas than has been seen in previous years (Edwards, 2015). This population and economic growth correlate with the demand for sand resources (Gomby, 2017; Marschke, 2016, pg. 166). For example, Hong Kong is supporting the growth in their population by creating artificial islands via land reclamation (Graham-Harrison, 2019). The artificial island project is meant to help manage the housing crisis but will likely cause environmental problems as the project will be developed using land reclaimed from the sea (Graham-Harrison, 2019). The land reclamation, infrastructure and housing development on the artificial islands will significantly increase Hong Kong's sand needs.

Moreover, global sand demand is increasing faster than can be replenished by natural processes; this growth in demand combined with increasing sand scarcity and mining bans has led to a rising price on the commodity (Edwards, 2015; Goldberg, 2019). For example, India has seen a sharp price increase on sand (of up to 40% in some districts) due to the construction boom the country is seeing as incomes rise and their cities expand (Edwards, 2015; Hindustan Times, 2021; Mohan, 2020) The global construction industry is also booming from the increase in infrastructure and development that has resulted from the migration towards urban centers, subsequently resulting in the increased consumption of sand (Edwards, 2015; Beiser, 2018b). Despite urbanization being a global trend, rapidly developing countries such as China and India,

have an especially high demand for sand in order to meet physical infrastructure development goals (Sverdrup et al, 2017).

For example, China plays a significant role in the sand industry as both a consumer and a producer, consuming more sand for construction purposes between 2011 and 2013 than the United States did throughout the entire 20th century (Beiser, 2019). In 2017, China was importing one billion tonnes of sand annually, five times its annual coal imports (Meynen, 2017). Despite its massive sand imports, China is not the top consumer. In 2014, Singapore held that position (USD $279 Million), likely due to the land reclamation projects, and was followed by Canada (USD $223 Million), and Belgium (USD $279 Million) (Gavriletea, 2017).

Canada's position on this list may be unexpected; however, according to the Observatory of Economic Complexity (OEC), in 2018 Canada was the top importer of sand, at USD $287 million. This was likely due to a rebound in oil and gas drilling (Bickis, 2017). Crush-proof silica sand is used in fracking to keep the cracked shale open and allow oil and gas to flow out (Bickis, 2017; Kyger, 2019). The recovery from a downturn in the Canadian oil and gas industry compounded with the discovery that using more sand would increase efficiency has led to a sharp rise in sand demand for Canada; Calgary-based Source Energy Services saw a 91 percent increase of sand being used per well in 2016 (Bickis, 2017). Moreover, higher use of high-quality sands claims a higher price, which explains why Canada is listed as the top importer of sand by dollar value, but not necessarily by volume (Bickis, 2017). The top importer of sand by volume could not be identified and is beyond the scope of this thesis.

Meanwhile, the greatest producer of sand and gravel according to Gavriletea (2017) is the United states, followed by Italy, France, and Germany. Surprisingly, China was not listed as a top producer; however, according to the USGS (2018), China is the largest producer of cement (of which sand is the main ingredient), generating an estimated 2.4 billion tonnes in 2017 to support the country's rapid growth. This cement production is a good proxy variable for understanding sand and gravel production.

Additionally, China possesses the largest sand mine in the world - Lake Poyang (Pearce, 2019). Previously, sand mining was largely taking place in the Yangtze River. However, after a policy was enforced to protect the river, extraction shifted to Lake Poyang (Bravard et al., 2013). The rate of extraction from the lake was estimated to be 236 million cubic metres per year in 2005 and 2006; this was believed to be the highest in the world at that time (Bravard et al., 2013). Development, growth, and infrastructure in China and globally have only grown since then, applying further pressure on the resource. Through a combination of production at Lake Poyang and the country's development needs, China is a significant actor in facilitating the massive demand for sand. This demand is putting pressures on mines and is encouraging illicit mining activity.

The sand mines that support the growth of infrastructure development (sand mines that may supply cement companies) are often located in developing countries where labor is cheap, and regulations may not be enforced. However, there are also sand mines in other parts of the world including Canada, the United States, Australia, and parts of Europe (Roos and Van Der Warf, 2010; UNEP, 2019). According to Roos and Van Der Warf (2010), approximately 25 million cubic meters of sand was being extracted from the North Sea offshore of the Netherlands annually. This sand was being used for large-scale infrastructure projects, land reclamation, and beach nourishment (Roos and Van Der Warf, 2010). According to current growth and development projections, the global volume of sand extracted each year is an estimated 30 to 50 billion tonnes, however, the accuracy of these estimates is difficult to obtain due to the issues in trade documents (See section 2.2.2 where the effects of corruption and document forging are further discussed) (Bendixon et al., 2019; Mahadevan. 2020). Sand mines that currently exist will soon be depleted as demand continues to increase at an insatiable and unsustainable rate. Moreover, sand mining is exacerbated by keeping up with the growing global population that is trending towards a higher quality of life.

Products of which sand is a main ingredient, including concrete and glass, are difficult and sometimes impossible to recycle to their original quality, however, research is being done to try and accomplish recycling of sand products to create a more sustainable construction industry through investigation into concrete alternatives (Chen et al., 2016; Jones, n.d.). The recycling of construction and demolition waste into new concrete is referred to as recycled aggregate concrete (RAC) (Chen et al., 2016). Research has found that the quality of RAC is generally lower in a number of qualities including strength and durability compared to natural aggregate concrete (NAC) and is therefore not often used (Chen et al., 2016). This limited life cycle of sand products further perpetuates the need for NAC and therefore increased mining (Beiser, 2018a). Legitimate sand mining companies such as US Silica are aware of the unsustainability of the industry and produce sustainability reports outlining their efforts on environmental protection, however, regardless of these efforts, any mining operation affects the environment (Lempriere, 2017).

In addition to infrastructure development, the tourism industry is a significant contributor to the demand for sand in some countries. For example, in Morocco sand is extracted, often illegally, to build hotels and other tourism related infrastructure. In this context, sand is typically taken from the beaches that draw tourism in the first place (UNEP, 2019). This phenomenon is seen in coastal destinations globally. The demand for tourism to support a community can often create *"sand wars"*. For example, in the case of Surfside Florida, residents were noticing their sand disappearing and being deposited in a beach north of the town for replenishment (Bakkalapulo, 2019; Vassolo, 2020). Florida's beaches are essential to their economy, drawing millions of tourists each year and generating an estimated commerce valued at USD $67 billion

(Bakkalapulo, 2019; Berman, 2019). However, approximately half of the states' beaches are considered critically eroded due to the impacts of climate change, including rising sea levels and increased storm events (Florida Department of Environmental Protection, 2020).

Florida communities have found themselves battling in "sand wars" to secure the resource for beach replenishment - a project that Florida authorities have spent nearly USD $1.3 billion on over the past 50 years (Bakkalapulo, 2019). According to the executive director of the South Florida Wildlands Association, Matthew Shwartz (see Bakkalapulo, 2019), depositing sand onto a beach destroys the ecosystem within it, crushing and suffocating the wildlife. Due to a federal law prohibiting local governments from importing foreign sand, local sources are transported from central Florida, which is being exhausted, making coastal counties in the state protective of sand they do have, to keep it from being excavated and deposited elsewhere along the coast (Bakkalapulo, 2019; Vassolo, 2020). As sand is the first line of defense against the increasing frequency of storm damage in Florida, these coastal communities will become more protective, and inevitably lead to further conflict (Bakkalapulo, 2019).

2.2 Ecological and Social Dimensions and Impacts of Sand Mining

As previously stated, the increasing demand for sand resources has created a thriving sand mining industry, attended by two overarching challenges: 1) ecological and 2) social. This global extractive industry provides a fundamental resource that supports coastal protection, construction, and technology, but it also inflicts harm on the environment and humans (Hezekiah Oluwole, 2020; Marschke et al., 2020; UNEP, 2019). At this point, the long-term and large-scale impacts of this harm are unknown. Moreover, these impacts become social challenges by nature, in that sand mines impact local communities and affect those who rely on natural resources for their livelihoods. To manage sand in such a way that minimizes these impacts, we must first understand what those impacts are specifically, how they occur, who might be primarily responsible, and how they are dealt with. In this section, I describe the ecological and social challenges that result from global sand mining. I then explain illegal sand mining and how the corruption it has caused tends to undermine opportunities to effectively govern sand resources. Previous research has identified certain ecological impacts as well as those that subsequently become social (e.g., a sand mine that causes fish stocks to decline and impacts the livelihoods associated with a fishery), however, my research assesses the governance gaps that have resulted in both ecological and social sustainability impacts. In the following subsection, I focus first on the ecological impacts.

2.2.1 Ecological impacts

Sand mining causes a wide range of ecological impacts including those related to erosion and wildlife (Lamb et al., 2019); Pearce, 2019). First, sand mining has caused increased and accelerated erosion in areas such as riverbanks, coastal shores, and agricultural lands (John, 2009; Lamb et al., 2019; Masalu, 2002). When it is dredged from the seabed, sand from the shore

is pulled towards the trench by gravity and currents, which causes erosion and shore expansion (see Figure 2.1).

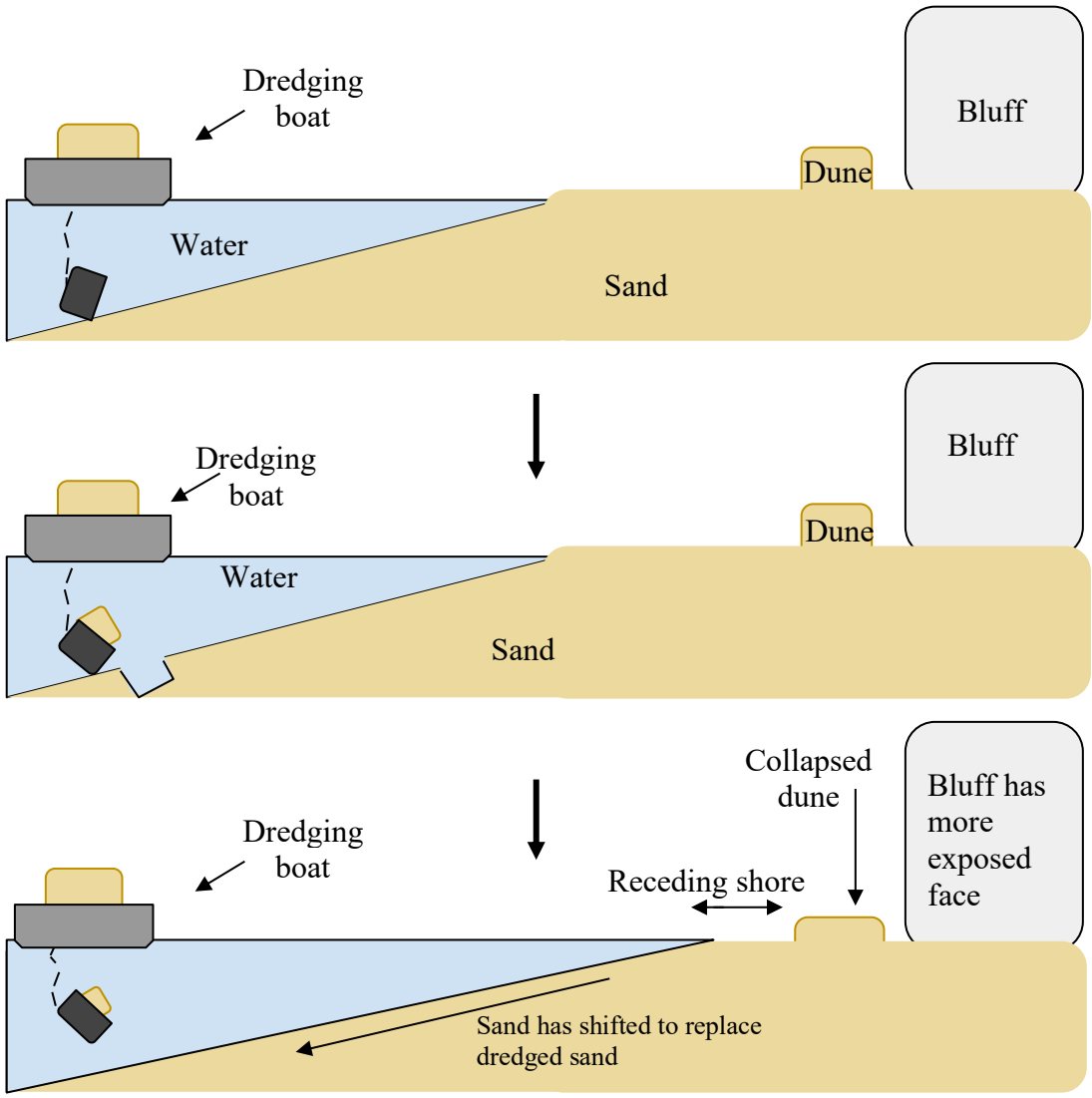

Figure 1: Diagram of Sand Extraction Causing Erosion.

Corals and seagrass are an important component of an aquatic ecosystem and act as a natural erosion buffer (Larson, 2018). Dredging boats can damage or completely destroy corals and seagrass, compounding these ecosystems' natural vulnerability to erosion (Pearce, 2019). In some areas, sand dunes, which are also an erosion buffer, have been completely depleted from mining, which has triggered cliff collapsing in coastal areas including the Azores islands (Borges et al., 2002). According to Borges et al (2002), constant mining from the sixties to the eighties removed 950,000 m3 of beach sand, and the impacts of accelerated erosion persisted into 2002 (the time of publishing) as a result. This case is an example of the importance of understanding the impacts of sand mining so that ecosystems do not surpass their natural resilience or reach

maximum vulnerability (Borges et al., 2002). Furthermore, dredging in rivers undermines the structural integrity of the riverbanks and alters the morphodynamic processes of the channel (Erftemeijer et al., 2012; Meynen, 2017; Yuill et al., 2015). The extraction of river sand causes damages to the river by deepening and widening of the basin and causes the collapse of riverbanks and bridges (John, 2009; Meynen, 2017). This erosion is creating a dangerous environment for coastal communities (Torres et al., 2017b).

Second, wildlife is also impacted by sand mining. When sand is extracted from a location and deposited elsewhere (for example, in beach replenishment), wildlife and their nesting habitats can be suffocated or crushed (Larson, 2018; Sheldrake, 2013). The heavy machinery that is used in mining on beaches or riverbanks compacts and crushes the sand and earth beneath it, while the depositing of sand (e.g., in beach replenishment) suffocates wildlife, and disrupts habitats and nesting areas which can have an impact on local fisheries (see section 2.2.1 below) (Erftemeijer et al., 2012; Sheldrake, 2013). Furthermore, the lowering water levels that are a result of sand mining impacts the aquatic vegetation that is a food source to migratory birds (Larson, 2018) Without access to this food source, the birds may not have sufficient energy for egg laying or migration (Larson, 2018).

The cascading effects of transporting sand include introducing invasive species and predators from the extraction location to the local species in the deposit location, as well as carbon emissions from the vessels (Torres et al, 2017a). While dredging is the most common method of extracting sand, it is often environmentally destructive (Pearce, 2019; Tweedie, 2018). Dredging creates sediment plumes that can stay suspended in the water and travel for several miles; these plumes can choke aquatic species and obstruct sunlight therefore reducing photosynthesis causing stress for corals and wildlife (Beiser, 2018; Erftemeijer et al., 2012; Obura, 2019; Pearce, 2019). This stress can interrupt the food chain and subsequently affect the coastal livelihoods that depend on fisheries or farms. These examples demonstrate how detrimental the ecological impacts of sand mining can be.

2.2.2 Social Dimensions and Impacts

Sand mining also results in a wide range of social dimensions and impacts including those related to erosion, health hazards, loss of livelihoods, and illegal mining (Hammond, 2019; Mahadevan, 2019: UNEP, 2019). First, coastal communities are especially impacted from the erosion due to mining, as their livelihoods and homes can collapse into rivers that have been exploited for their sand (Beiser, 2018c; Hammond, 2019). When land collapses due to erosion, it brings down homes, farms, shops, and livelihoods with it (Beiser, 2018a; Torres et al., 2017b). The Mekong River is one example of an area experiencing rampant sand mining, as the erosion has caused an estimated 500,000 people in the Mekong Delta to evacuate (Beiser, 2018b).

Secondly, sand mining can introduce health hazards such as malaria, or increased pollution (Popescu, 2018). The still pools of water left behind from mining provide a breeding ground for malaria carrying mosquitoes, possibly exacerbating the rate of infection in the surrounding area (Popescu, 2018). Moreover, working as a miner can be very dangerous. According to Chandran (2019), a 2017 Thomson Reuters Foundation investigation found that miners of illegal mines were drowning in some parts of India. There are other reports of workers in illegal mining who have died after a sand dune collapses on top of them (PTI, 2019). Miners take the risks that come with mining sand due to the wages which are often higher in similarly skilled jobs (Mahadevan, 2019).

Thirdly, these coastal communities are often resource-dependent villages that rely on natural resources for their livelihoods (such as farming or fishing) (Marschke et al., 2014). Farms can experience sea water intrusion into the soil as a result of erosion, threatening not only livelihoods but also food supplies (Popescu, 2018). As previously discussed, sand mining causes severe environmental destruction including erosion and habitat loss (Pearce, 2019; Lamb et al., 2019). These impacts significantly affect fish stocks and has led to many fisheries and aquaculture systems to experience low productivity (Husrin et al., 2018; Marschke et al., 2014). Fish stocks decline to a point that many fisheries are forced to halt operations, forcing fishers to fish more intensely and further away, such as the case in Cambodia in Marshke et al (2014), or turn to sand mining which is often much more lucrative (Husrin et al., 2018; Rege, 2016). Oftentimes, illegal sand mining operations who violate any existing regulations, will destroy fisheries through mining, and then pay these fishers higher wages than they previously earned. This was the case in Lontar Village, Indonesia, where many abandoned fisheries were found to be converted into sand mining quarries (Husrin et al., 2017). Sumaira Abdulali of environmental advocacy group Awaaz Foundation stated in Chandran (2019) that “Communities are losing their land and their homes because of sand mining, but they are split over the issue because some people make a living from it, while others say it is ruining their lives.”.

Fourth, a serious challenge in the sand industry, as well as its’ governance is illegal sand mining. Sand can often be seen as a freely available resource, and the demand from the construction industry has created opportunities for entrepreneurs in the formal and informal sectors across the supply chain (Barwell, 2016). Increasing demand has made sand a highly valuable resource that has become a multi-billion-dollar industry due to its widespread availability, combined with minimal regulations, enforcement, and monitoring (Beiser, 2018a). This expanding network and growing trend is perpetuating the associated social and environmental sustainability challenges, while simultaneously obstructing the implementation of solutions. Sand is the least regulated resource globally, despite being the most extracted solid material by weight and volume (UNEP, 2019). The lack of regulations and enforcement has enabled illegal sand mining activity to run rampant, also infiltrating legal trade (Gavriletea, 2017; Torres et al., 2017a). According to Padmalal and Maya (2014), approximately one third of sand imported to Sri Lanka is from an

illegal source. A significant governance challenge is this mixing of legal and illegal sources, creating difficulty in tracking how sand is moving across borders. Additionally, there is a lack of reliable data as researching the illicit sand industry is dangerous due to the threats from mine operators (Mahadevan, 2019; Rege, 2016). Therefore, much of the data used for this literature review was collected online from newspaper articles, government and NGO documents, and few journal articles.

Illegal sand mining activities can be categorized into two types: (1) stealing and; (2) corruption, both of which often occur in tandem. Stealing sand can refer to the practice of extraction from explicit no-take areas including private land not belonging to the miner, or areas in which policy exists to protect the area (for example, a marine protected area) (Beiser, 2018a; Tweedie, 2018). Corruption refers to the insider network made up of miners, police, and government officials facilitating illegal trade of sand with tactics including forgery of documents that alter the export/import amount or the extraction location; or bribery of enforcement officials, government officials, and other stakeholders (Beiser, 2018; Mahadevan, 2019; Rege, 2016). Having defined what is meant by illegal sand mining, I will now move on to discuss the group behind the largest network of illicit activity, the Sand Mafia.

Illegal sand mining is often driven by "*Sand Mafias"* across the globe, mainly in developing countries (Salopek, 2019). However, the most well-known example is the Sand Mafia in India - a violent crime group illegally extracting sand resources and causing rampant social and environmental degradation (Beiser, 2018a; Mahadevan, 2019; Salopek, 2019). Defining an individual who is a part of the Sand Mafia is challenging as there is no evidence to suggest these groups are religiously or ethnically defined (Mahadevan, 2019). However, in India the media uses the term "*Sand Mafia"* to identify illegal sand mining groups who threaten those that oppose the illegal extraction of sand, and the threat of violence comes to anyone trying to stop or probe information about the organization (Beiser, 2018a; Mahadevan, 2019). Therefore, an illicit sand mining group is considered a "Sand Mafia" once they begin to threaten any opponents (Mahadevan, 2019). Moreover, illegal sand mining is not exclusive to Sand Mafias; it occurs across the globe and those who steal sand are sometimes referred to as "sand pirates" (Beiser, 2018a).

Illegal mining operates on an opportunistic basis and can occur wherever a suitable sand deposit can be found (Mahadevan, 2019). Due to the expansive and diffuse locations of deposits, the monitoring and enforcement of any regulations has proven to be challenging (Popesco, 2018). Both the legal and illegal sand mines have been increasingly reported to be extracting from established biodiversity reserves and protected areas where subsequent impacts on habitat and wildlife have been reported (Koehnken, 2018). Pearce (2019) discusses seeing sand mines in Cambodia within national parks and internationally recognized wetlands that are home to rare animals, as well as truckloads of sand pass park officials in the Abijatta-Shalla National Park in

Ethiopia. According to UNEP (2019: pg 5), these are *"areas that society has agreed are so ecologically and culturally significant that they cannot host economic activities that are not compatible with the biophysical integrity of these ecosystems."*

Illegally obtained sand is often sold to construction companies (Mahadevan, 2019; Salopek, 2019). However, sand can also be stolen from one beach and sold to another for replenishment. This is common in the tourism industry where resorts rely on sandy beaches as an attraction as previously mentioned. There have been instances where significant portions of beaches have been stolen, such as the case in Coral Spring Jamaica in 2008 where an estimated 500 truckloads of sand were stolen from the site of a planned resort and believed to be sold to rival resorts (Carroll, 2008). According to Carroll (2008), corruption within some members of the local police force was believed to be involved. This situation is similar to the Surfside Florida case as previously mentioned (see section 2.1.2) where wealthier counties were attempting to replenish their beaches with sand taken from the poorer counties.

The sand industry is very lucrative; India is projected to be the third largest construction market while the illegal Sand Mafia generates approximately 17 million USD per month in revenue (Mahadevan, 2019; Rege, 2015). Despite destroying environments that support farming and fishing, sand mining provides employment. India's construction industry (which is mobilized by sand) employs approximately 51 million people (Prakasan, 2020). Furthermore, many fishers and farmers who lose their jobs due to sand mining often go to work for the very mine that destroyed their previous profession (Husrin et al., 2017). While some may be forced to leave fisheries due to a collapse in stock, many make a pivot towards sand mining as a means to earn a livelihood as it is often more fruitful than other employment options (Husrin et al., 2018; Mahadevan, 2019). In India, working in a sand mine can provide an income four times as much as a field hand, and can be less physically demanding depending on the position (Husrin et al., 2018; Salopek, 2019). These factors make employment in sand mining very enticing which exacerbate it even further.

Some impacted communities protest against both legal and illegal sand mining and look to their government for support, often to no avail (Fritts, 2017). In Kenya, local communities use social media to draw attention to and to protest illegal sand mining (Obura, 2019). The mining off the Waa coral reefs on Kenya's south coast is creating ecological damage to the reef, sea grasses, and shoreline (Obura, 2019). Illegal sand mining can occur globally, however, it is especially noticeable in many developing countries the resources to monitor or enforce regulations are less common (Barwell, 2016; Besier 2018a; Torres et al., 2017a). In turn, officials are therefore perhaps more easily bribed to look the other way in exchange for a cut of the profits (Beiser, 2018; Popescu, 2018; Mahadevan. 2020). There are often cases of corruption and partnerships between illegal mining operations and government officials or other authorities, adding to the challenge of managing illegal mining (Beiser, 2018; Peduzzi, 2018; Popescu, 2018). As a result, illegal sand miners have acquired significant power. Protests often erupt into violence and even

death with many instances of protesters and journalists being beaten or killed (Beiser, 2018; Lamb et al., 2019; Meynen, 2017). According to Rege (2016), an officer who had arrested three men for illegal mining was stopped by thirty men from the illegal organization en route to the police station. They threatened to burn the officer alive if he did not release the three men. The fear mongering and corruption that the Sand Mafias have created makes it difficult to research, as well as manage the sand industry.

A lack of research on the sand industry has resulted in the unknown magnitude and scale of global sand mining - a knowledge gap that contributes to unsustainability and poor governance of the industry (Lamb et al., 2019). Moreover, there is currently no tracking of the paths that sand travels through importing and exporting, making the scale and scope of the issues challenging to assess (Benedixon et al., 2019). Sand can be mined from one country, then cross several borders to another and there is no official method of tracking, thus leaving much of the trade undocumented. For example, between 2006 and 2016 Singapore claimed to have imported 80 million tonnes of sand from Cambodia, who confirmed exporting less than 4% of that (Lamb et al., 2019). These compounding challenges have made sand mining an ecological, economic, and social issue globally that is difficult to effectively govern (Desiderius, 2010).

2.3 Governance

The social and ecological impacts as well as illegal mining that exacerbate them are the result of poor governance of sand (Chandran, 2019; Torres et al., 2017). Government regulations are failing to keep pace with the rising demand of the resource (Chandran, 2019).

2.3.1 Governance Challenges

Without effective governance, sand mining will remain unsustainable, creating more unknown impacts in the future. However, where the governance gaps exist is unknown. Much of the previous research on sand mining has focused on the ecological and hydrological impacts, and not necessarily with a sustainability lens. My research addresses the governance knowledge gap in order to effectively address the social and ecological sustainability challenges that exist in the sand mining industry. Exploring each gap in depth is beyond the scope of this thesis yet may be carried out in the future by another researcher. In this section, I will define the term “governance” as it is used in this study. I will then broadly discuss the challenges of both local and global sand governance.

This thesis defines governance as:

> *"the interrelated and increasingly integrated system of formal and informal rules, rule-making systems, and actor-networks at all levels of human society (from local to global) that are set up to steer societies towards preventing, mitigating, and adapting to global and local environmental change and, in particular, earth system transformation, within the normative context of sustainable development."* (Bierman et al, 2010).

The current governance of sand mining is challenging and insufficient at both the global and local levels (Marschke et al., 2020; Torres et al., 2017; UNEP, 2019) Often in developing countries, governments do not formally designate locations or guidelines for sand extraction (Obura, 2019). The UNEP (2019, pg. 6) report, "*Sand and Sustainability",* noted that, "*Sand extraction and use is defined by its local geography and governance context and does not have the same rules, practices and ethics worldwide".* The lack of a global governance framework for a globally traded resource is problematic. The current development trends indicate that demand for sand is going to increase in the coming years, emphasizing the pressing need for an effective global governance system (Torres et al., 2017).

2.3.2 Framework

The inconsistency across borders regarding the use and trade of sand has led to governance gaps. The UNEP Sand & Sustainability Report (2019; pg. 9) outlines five priority areas of concern which are discussed in detail. These five priority areas are used as a framework to guide the formulation of the survey questions used for this study which are discussed in Chapter 3 (see Figure 2.2).

The first priority area of concern is "Awareness". National governments, and producers in the sand industry, as well as the general public are unaware why the state of the global sand resources and mining impacts are relevant to them. Due to the resource being freely available, cheap, and widely used, the general public has little perception of sand as a limited resource. The idea that there is an endless supply must be changed. Jianguo Liu stated in Popescu (2018) that "the community researching sand mining is still very small.". Those that are researching the topic are trying to raise awareness through the papers that they publish (Popescu, 2018). However, the general public is still largely unaware that sand is an essential component of everyday life (Beiser, 2018a). There is a need for increased awareness campaigns on the topic of sand mining (Asabonga et al., 2017). Raising awareness around the sand industry is a foundational step to improving global governance of sand (Torres et al., 2017b).

The second priority area is "Knowledge and Science". Basic information about sand resource flows and the extraction impacts are scarce, despite being essential for effective governance. According to Torres et al. (2017a) the over-consumption of sand and the respective impacts are

not often seen in scientific discussions, nor has it been systemically studied. This lack of data has led to the unsustainability and poor governance of the industry (Bendixen et al., 2019). Much of the existing knowledge on the impacts of sand mining relates to large scale pits, rather than smaller scale, illegal mines (Roos and Van Der Warf, 2010). Prior to mining, an environmental impact assessment should be carried out to inform the designation of suitable mining locations and guidelines (Obura, 2019). Information such as the amount of sand that would be required for future demand scenarios (Torres et al., 2017a), the long-term and large-scale ecological and social impacts, who are the key actors in the industry, and who owns the rights to these resources are the most crucial governance questions.

The third priority area is "Transparency and Accountability". There is currently no accountability across governments, companies, contractors, or other actors in the sand value-chain. *"Accountability is something that needs to cross boundaries and borders, right down the value chain."* (UNEP, 2019, pg. 9). As previously mentioned in section 2.2.2, there is a lack of reliable data, given the corruption found along the sand value chain, to be able to identify how sand moves across borders (Mahadevan, 2019; Rege, 2016). Not knowing where sand is being imported and exported is a barrier to holding accountability, and a significant obstacle in reaching effective governance. Additionally, current legal frameworks have not been sufficient in managing illegal mining challenges, allowing them to continue (Chandran, 2019). There must be an increase in transparency as well as information sharing by, and between companies and governments.

The fourth priority area is "Stakeholder Relationships and Platforms". The relationships between stakeholders in the sand industry are fundamental in building transparency and accountability. Currently, there is no international body that can mediate between the different interests as well as recommend policies and other governance measures to satisfy a collective interest. The absence of a global monitoring programme perpetuates the governance challenges in the sand industry and therefore, the ecological and social impacts as well (Chilamkurthy et al., 2016). Organizations such as the UNEP or the World Trade Organization (WTO) are required to assist in a global framework to achieve a collective interest (Bendixen et al., 2019).

The fifth priority area is "Fragmented Participation by Key Actors". Governments, local and indigenous communities, and industry players of all related sectors must be brought together to co-produce constructive governance. A governance structure that uses a middle ground in which companies, local communities, and impacted stakeholders are involved to understand where practices need to be adjusted. According to Asabonga et al (2017), the community, policy makers and managers should engage in environmental awareness campaigns as well as siting sand mining sites outside sensitive environments. These campaigns should also include other stakeholders such as mining groups and community members who reside near sand mines.

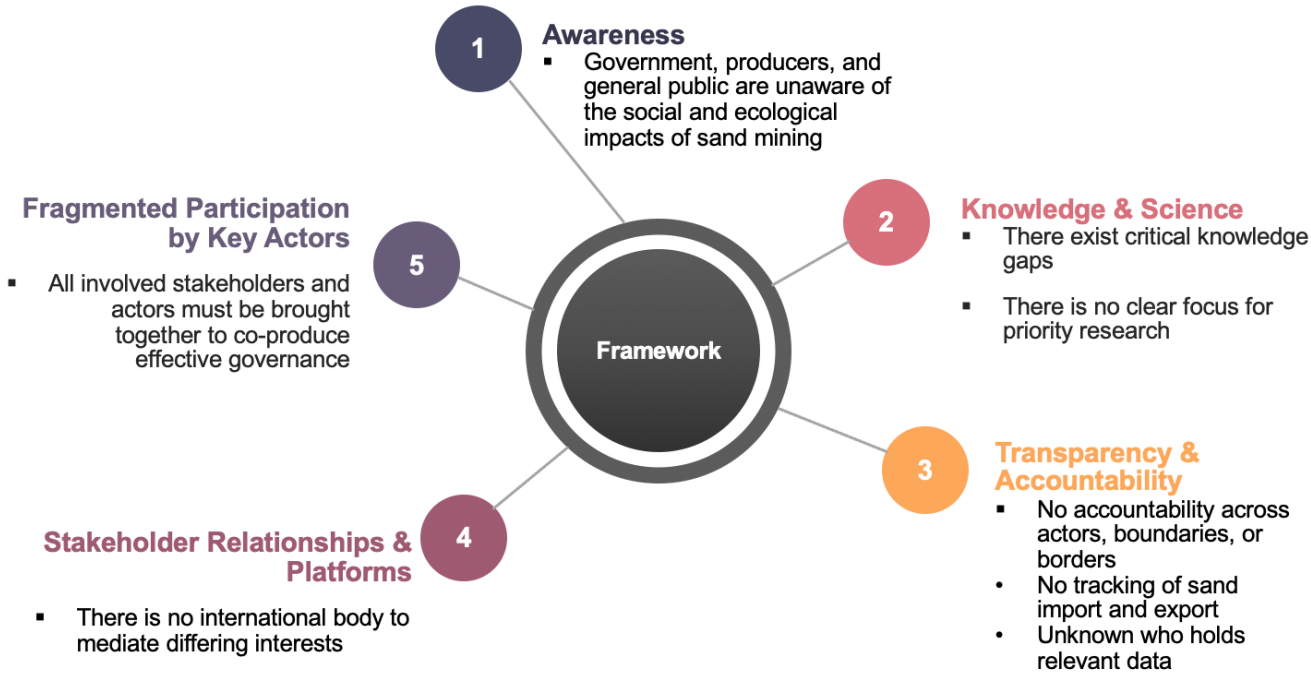

Figure 2.2: Global Sand Governance Framework.

There is currently a lack of awareness about sand resources and the associated environmental and social sustainability challenges. Journalists are bringing awareness to the extent of the issue, yet scientific studies and evidence-based policies to base sustainable extraction, consumption and regulatory frameworks are lacking (UNEP, 2019). There is a significant need for an effective global sand governance system (Torres et al., 2017a). Connecting stakeholders together is difficult but extremely valuable in providing various insights on governance challenges (Baird et al., 2018) However, including many stakeholders with diverse perspectives can often lead to conflict in environmental governance over resources by creating a tragedy of the commons dilemma (Baird et al., 2018; Berkes et al., 2006; Torres, 2017a). Sand resources are scarce in some parts of the world, but it is unclear if global sand demand exceeds global supply (Torres et al., 2017a). To develop effective governance for global sand mining, these five priority gaps listed above should be the focus in the development of a global governance framework.

3.0 METHODOLOGY AND METHODS

3.1 Introduction

The aim of this research is to understand the current state of the global governance of sand mining and to uncover where the governance gaps lie. A potential outcome of this research is to contribute to current knowledge and identify which steps should be prioritized to improve the sustainability of sand mining through a global governance framework. A qualitative research approach was used to conduct this research. Qualitative research is broad and difficult to define. However, it is often described as:

> *"a set of interpretive, material practices that make the world visible. These practices transform the world. They turn the world into a series of representations, including fieldnotes, interviews, conversations, photographs, recordings and memos to self… qualitative researchers study things in their natural settings, attempting to make sense of or interpret phenomena in terms of the meanings people bring to them*." (Ritchie et al., 2013; pg. 3).

A qualitative approach to research was considered the appropriate option for this study because there is incomplete knowledge on the global governance of sand and these governance gaps cannot be assessed by quantitative means of research. Additionally, using a qualitative method could help to draw more information than was set out to discover, which may lead to interesting findings (Hammarberg, 2016).

A Delphi survey method (see section 3.2) was used as the primary form of data collection, and was conducted using two rounds of survey questions:

(1) The first survey round consisted of questions which gathered information on the demographics of the participants and used this context to collect data on contributing factors of the governance challenges of sand and the issues within the sand mining industry. These included: awareness, knowledge and science, priority research areas, transparency and accountability, stakeholder relationships and platforms, and fragmented participation by key actors.
(2) The second round of survey facilitated a shift towards consensus by asking the participants to rank their agreement on a Likert scale of statements that were collected and condensed from the first round.

Additionally, research involved an analysis of how these consensus statements compared with some aspects of the 2019 UNEP report *Sand and Sustainability*. As noted in section 2.3.2, I synthesized the UNEP (2019) priority gaps as a framework to further guide my methods i.e., the Delphi survey. This framework highlights five themes: awareness; knowledge and science;

transparency and accountability; stakeholder relationships and platforms; and fragmented participation by key actors (see Figure 2.2).

3.2 The Delphi Survey Method

A Delphi study is a qualitative research method in which an expert consensus is achieved on a topic (Slade, 2014). This method is an appropriate choice as a research tool in situations having incomplete knowledge of a phenomenon (Skulmoski, 2007). As research in the governance of sand resources is relatively new, the Delphi is a well-suited research method for this study. Sand mining is a global sustainability challenge with few global experts and limited scientific reports focused the topic.

The United Nations Environment Programme (UNEP) released a "*Sustainability and Sand"* report in 2019. Globally, there are a limited number of experts, most of whom are siloed in their own discipline within the sand industry (e.g., ecology, crime, or social challenges). Therefore, having variation of profession and locations in the Delphi panel was useful in creating a diversity of perspectives on the current situation of sand mining. In this emergent problem context, "Group decisions are necessary when the scope of the problem is such that no individual has sufficient expertise and knowledge to affect a solution" (Tersine, 1976). Since no one person is an expert in all aspects of the sand mining industry, using a panel assisted in filling knowledge gaps that may have otherwise existed using another method.

The Delphi method was developed in the 1950s with the goal to distill expert opinions with little apparent bias which is often difficult to achieve in qualitative research (Skulmoski, 2007). There are four key features that outline a Delphi study method. The first is the anonymity that the method provides. Participants do not answer in a group setting, and their identities are kept unknown to each other to eliminate bias (Rowe, 1999). This method of surveying reduces the likelihood that a participant alters their opinion compared to an in-person group setting where a respected individual might be present and influence others (Tersine, 1976). In addition, eliminating the group atmosphere reduces the *bandwagon effect* which encourages participants to agree with the majority of the group (Tersine, 1976). The second key feature is the iteration which allows participants to refine their views at their own pace despite the progress of the group (Rowe, 1999). The third key feature is that there is controlled feedback (Rowe, 1999). This allows the researcher to share the participant's views amongst the study group and allows the participants to clarify or change their opinion (Skulmoski, 2007). The fourth key feature is that there can be (depending on sample size) a statistical aggregation of the responses to allow for quantitative analysis and interpretation of data (Skulmoski, 2007; Rowe, 1999). The Delphi method has been used in ways that deviate from the original method but are still classified as a Delphi study.

The Delphi survey method was chosen over other qualitative methods such as semi-structured interviews, to achieve a broad understanding of the current state of the sand industry on a global scale. By including participants of different occupations and locations, I was able to gain a more interdisciplinary consensus, without having the participants' field of expertise overshadow their answers as might occur in a semi-structured interview method.

3.3 Data Collection methods

In this section, I describe the data collection methods used to conduct this research, including a review of the literature and a Delphi survey.

3.3.1 Literature Review

A review of the literature is an essential component of the research process. A review of peer-reviewed technical literature and technical reports provided the base of background knowledge on the sand mining industry and subsequently guided decision making throughout the research study. This literature was sourced from the University of Waterloo online Library, as well as search engines such as google and Web of Science and included reports such as the UNEP Sand & Sustainability report, as well as peer-reviewed journals, and news articles. Key terms included but were not limited to: sand mining; governance; illegal sand mining; sand mafia; and beach replenishment. This background knowledge from the literature provided insights to help with the creation of appropriate and effective survey questions and led to the identification of possible survey participants. Similarly, non-technical grey literature such as news articles and TedTalks provided contextual data and supplemented technical literature. Sources such as newspaper articles or Vince Beiser's book "The World in a Grain" provide an overview of the world of sand mining and the social-ecological impacts in a way that is more easily digestible to the general public. These non-scholarly sources are important avenues to increase public awareness on the topic of sand mining and can help introduce points of entry for research topics.

The current availability of literature on sand mining is limited, particularly in social science or governance analysis in academic journals (Lamb et al., 2019). Academic articles that are available are focused in silos such as ecological, economic, and social impacts, however, most of the literature is focused on ecology. The global issue of sand mining is inherently inter- and multidisciplinary, and as such, requires research that understands and reflects this. Non-academic articles tend to give a broad overview of the issue and bring it to light, but do not delve into further depth of the cause or provide steps for improvement. As a result of the global scale and interdisciplinarity of sand mining governance, an international and interdisciplinary panel of participants is desired for the study so as to include the ecological, social, and economic impacts from sand mining.

3.3.2 Delphi Survey

The first step in designing a Delphi study is to select a panel of experts to be the respondents of the questionnaire (Tersine, 1976). For this study, those who were contacted include but are not limited to: mining groups, government actors, researchers, and NGOs. Those who were selected to be contacted for participation in the study were required to have some background knowledge in the field in order to contribute. Tersine (1976) outlined five criteria for choosing participants as follows (and which were accordingly used as criteria for participant selection in this study):

> (1) They must have a basic knowledge of the problem area and be able to apply that knowledge.
> (2) They must have a good performance record in their particular areas.
> (3) They must possess a high degree of objectivity and rationality.
> (4) They must have the time available to participate until the conclusion of the study.
> (5) They must be willing to give the amount of time and effort to do a thorough job of participation." (Tersine, 1976)."

There are different actors who are involved in, or directly impacted by sand mining practices. Global participants that were the target for the Delphi panel of this study include, but were not limited to the following:

1. **Mining Groups**
    1. Legal sand mining corporations - Representatives from Orca Sand and Gravel LP located in British Columbia, Canada and U.S. Mine Corporation located in California for example.
    2. Illegal sand mining operations (not being contacted for safety concerns).
2. **Governing Bodies/Legislation**
    1. Actors within Federal, Municipal, or Local government.
3. **NGOs (Non-Governmental Organizations)**
    1. Those who hold positions at UNEP.
    2. Actors who are the founders of sand-based NGOs.
4. **Coastal and Shore Communities**
    1. Members of the public who reside in coastal or shoreline communities (global).
    2. Fishers
5. **Academia and Research**
    1. Researchers
    2. Professors
    3. Authors

Involving the mining groups in the study would have been beneficial in gaining a perspective that focuses assumingly on the economic benefits of sand mining rather than environmental

degradation, unfortunately, they declined to participate. The mining groups that I requested to participate in the study were from North America, Europe, and Oceania. These locations were chosen as their governing bodies are likely to possess the resources to create, enforce, and monitor extraction policies and laws to minimize or eliminate illegal mining practices compared to many mining locations in Asia. Each mining group I contacted is likely legally bound to an environmental policy regarding extraction yields, which may or may not be followed within the limits (Beiser, 2018a). The perspective these organizations have on the effectiveness of their domestic governance compared to international governance would have been valuable insight. Furthermore, insight from affected fishers and the public could have spoken to their experiences of sand mining in their communities in greater detail than what I was able to find in literature. Due to travel restrictions as a result of Covid-19 and the online nature of this survey, affected fishers and public were not included in this study.

3.4 Participant Recruitment

Potential participants were found through the literature review and referrals from established contacts. During the initial research stage, names of those who had published articles on topics within sand mining - including ecological impacts, economics, geology, and politics - were recorded as well as those who were quoted in these articles. The majority of the contact information of those from the literature review were publicly available either within the literature piece or on a public profile such as LinkedIn. Some participants that had already been established reached out to their own contacts that they believed to be well suited for this study and obtained permission before sharing their personal information with me. 44 potential participants were recorded and then organized into an email list in Gmail.
Potential participants were recorded in an Excel spreadsheet with their name and contact information, as well as any other applicable or available information including location, profession, and the source at which they were found.

Once the list of potential participants was chosen, they were contacted via email (script in Appendix A) requesting their participation. Those that did not have an associated email were sent the same script via LinkedIn Messenger. The email included the information letter (in Appendix B) regarding the study as well as how their contribution would supplement the study. Once a participant agreed to join the study were marked on the spreadsheet and added to a Google Gmail mailing list. The potential participants were given four weeks to respond to the invitation email. A reminder email was sent to those that had not responded one week after the initial invitation email, and then each subsequent week until the time frame to respond had ended. After the participants had agreed to the duties of the study the first questionnaire was sent. A total of 12 individuals participated in round one of the Delphi and 11 participated in round two.

3.5 Survey administration and analysis

Both surveys were hosted on the Google Forms platform. Google was the platform used to host this study for its privacy measures as well as intuitive interface making the survey pleasant and straightforward for participants to navigate. By using Google, I was able to create a mailing list specifically for each round of survey and the initial invitation. The surveys were both created using Google Forms. Once the survey was sent out to the mailing list, I could see who had completed the study and who had not; for those who had not I could easily send the reminder email.

The Google Forms platform allowed the surveys to be accessible to any participant so long as they had internet access. In order to keep track of the data collected, each participant received an individual survey link via email that is associated with their contact to support anonymity. The participant names are not shared or published. The first survey included the consent form which participants choose one out of two radio buttons to give or deny consent to participate. If they chose to give consent, they were automatically brought to the beginning of the survey. If they choose not to give consent, they were asked to close the web page. The survey questions were organized by sections: Awareness, Knowledge & Science, Transparency & Accountability, Stakeholder Relationships & Platforms and, Fragmented Participation by Key Actors.

3.5.1 Survey Round One

The first round of survey questions aimed to gain insight on the challenges and opportunities within each section outlined in the framework, while the second round aimed to achieve a consensus on the responses from the first round.

Survey round one consisted of 11 questions organized according to the framework (see Figure 2.2) exclusive of the questions related to the participants personal information. Each question was accompanied by unlimited space to allow participants to respond with as little or as much detail as they wished. In order to keep the topics of responses bounded, there was no additional space for participants to write supplementary comments. The questions from survey round one can be found in Appendix C.

Of the 44 experts who were invited to the study, 15 agreed to participate and 12 completed the first round of survey. The level of detail in the responses varied by each participant and question, ranging from single sentences or bullet points to short paragraphs. Some gave detailed responses, some referred to an earlier response, and one participant wrote “no opinion, as I lack detailed information” to four questions. Some participants may have had more or less difficulty when answering depending on their profession and related knowledge. There were often similar opinions when identifying issues such as whether awareness is lacking, but the solutions or actions were varied. This is discussed in-depth in Chapter 4.

An open coding process was used to analyze the responses to the first round of survey. I reviewed the responses by question rather than by participant in order to identify repetition or commonality in the responses. 132 responses were condensed into 61 statements to be used as the basis for the second round of survey. Similar responses were grouped together to determine the range of responses. For example, the first response in the first section 'awareness' is "There is indeed a lack of awareness". I created the grouping "yes, there is a lack of awareness" and any further responses that also described that there was a lack of awareness were grouped together. If a response stated differently from the available groupings, another would be created. A response would be considered different depending on its context. For example, "There is a lack of awareness however, awareness is increasing" was considered different than the response "awareness is lacking". Each grouping of responses was then condensed into a single statement; those statements were then put back to the expert panel in round two to determine their level of agreement or disagreement with those statements.

These statements were submitted to the University of Waterloo Research Ethics Committee to be used in the second round of survey. The participants were invited to the second survey after ethics clearance was obtained.

3.5.2 Survey Round Two

The second survey round was composed of the statements which were representative of the responses to the first round of survey. Specifically, this round included nine sections consisting of six to nine statements each, totaling 61 statements for participants to rank. Each statement was accompanied by a Likert scale of 1 to 5 (1: Strongly disagree 2: disagree 3: neutral 4: agree 5: strongly agree). Each section included a response space for any additional comments or explanations. In each section, the participants were asked to rank their agreement with the statements which they believed to be the most important or most crucial. One participant did not rank several statements as they felt they did not have sufficient knowledge on the context of the statements to respond. An analysis of the responses to round two are discussed Chapter 4. The statements for survey round two can be found in Appendix D.

3.6. Advantages, Disadvantages, Assumptions, and Limitations

A significant benefit to the Delphi is that it can achieve a broad consensus without a physical meeting; therefore, the survey can take place and include participants from across the globe and allows them to complete the round of survey at their leisure while also inflicting little to no expense to the researcher. This study benefitted from this characteristic during the Covid-19 pandemic when travel was restricted. Without the need for a physical meeting, data collection was able to proceed no alterations were required to continue the study. This is a factor to consider for future qualitative studies as the Covid-19 pandemic continues to limit travel in many countries. Another assumption was that the possible participants that were invited to the study had access to the internet and to an internet capable device. This was also a limitation as the

study was an online survey, and an individual would not be able to participate unless they had access to the internet. It was also assumed that participants who responded to the study invitation had sufficient proficiency in the English language; this would mean that they understood what the survey questions were asking and could provide an answer.

Moreover, in this study the participants can remain anonymous to one another; this anonymity minimizes the likelihood of the panel influencing each other's responses which is seen as an advantage (Tersine, 1976). If the study was done using a physical meeting of the panel and an esteemed expert was present, other participants may curate their responses to align with the esteemed expert rather than providing their true opinion (Tersine, 1976). However, this was also an inherent limitation as there was no opportunity for the panel to collaborate or discuss opinions through open-ended discussion, therefore, other possible theories or knowledge gaps may not have been explored. The responses were all weighted equally so as to not have the results skewed by one or more specific participant's opinions (Dufresne, 2017). Additionally, weighing each response equally and the attribution of numeric voting in the second round provides the potential for statistical aggregation of responses and enables the researcher to conduct a quantifiable analysis that is not always possible with qualitative data (Wilder et al., 2019).

A disadvantage to using the Delphi method is that the multiple rounds of survey can be time consuming. This time requirement can lead to lack of continued commitment from participants part way through the study (Dufresne, 2017). Another significant disadvantage to using a Delphi study is that there are no clear methodological guidelines and many recent Delphi studies follow a “modified Delphi” style that consist of fewer survey rounds (as was the case in my own research) (Wilder et al., 2019). Furthermore, a consensus from a Delphi study does not necessarily translate to a correct or accurate answer or information on the subject, it merely offers a consensus to be found in the opinions of the panel (Dufresne, 2017). This study consisted of two rounds of survey. These survey rounds were sufficient in providing rich data and a consensus on the statements. However, a third survey round would have been beneficial in providing clarity in the prioritizing of statements. For example, in the section *“Strategies to improve awareness”,* several strategies received agreement consensus from the panel. The inclusion of a third round of survey may have had participants prioritize which of these strategies were the most critical.

3.7 Ethics

This project obtained full ethics clearance from the University of Waterloo Office of Research Ethics on February 28th, 2020 (ORE# 41742) (see Appendix A for ethics clearance notice). An amendment was submitted to include the statements to be used in the second round of survey. This amendment was approved on September 8th, 2020.

4.0 RESULTS AND DISCUSSION

The objective of my thesis is to assess the opportunities and challenges of the governance of global sand resources. In this chapter I present my findings of the expert panel's perspectives (i.e., the results from the Delphi process) of the governance challenges and opportunities as they relate to each dimension of the framework (see Figure 2.2; Chapter 2.3.2) used to guide my data collection. The framework themes are: 1) awareness, 2) knowledge and science, 3) transparency and accountability, 4) stakeholder relationships and platforms, and 5) fragmented participation by key actors. When referring to a statement in this chapter, I will use the corresponding section and statement number. For example, section 1 (awareness) statement 3 would be referred to as statement 1.3. In each sub-section below, I will give a general introduction, and then a summary of the main points. I then follow with a presentation of the survey data with the support of reflective statements. Furthermore, I note opportunities to improve the governance of sand mining which are discussed in further detail in Chapter 5.

4. 1 Introduction

The goal of this study was to identify which statements the expert panel reached a consensus, and whether they agreed, disagreed, or were unsure about the statement. In the analysis of the results below, I considered consensus to be when 100% of participants ranked a statement within one of the three options (e.g., 50% of participants voting for 4 and the other 50% voting for 5 would be considered consensus agreement). However, given the broad range, sample size, and qualitative nature of this study, statements in which eight or more participants ($\geq$70%) of the expert panel ranked $\geq$ 4 on the Likert scale are significant and are considered consensus agreement in this study. The number of statements that received agreement from eight or more of the participants increases the total number of consensus agreement statements significantly. In the second round of survey, 100% agreement yielded four statements total while 70% (8 out of 11) agreement yielded an additional 34 out of the 61 statements. The statements which received agreement consensus across all five sections in the survey are outlined in Tables 4., 4.2, and 4.3. These statements were considered the priority concerns and strategies as they relate to governance in each section and should be considered in a future sand governance framework.

In the following subsections, I address the results of each section of the second round of survey as it contains the condensed responses from the first round. The results are interpreted mainly from the second round of survey to reduce redundancy but will also include some statements from the first round in order to provide context (See 3.5.1 and 3.5.2 for clarification).

During the preliminary phases of this research, I found that much of the current academic literature regarding sand mining is focused in disciplinary silos, such as ecology (Larson, 2018; Meynen, 2017; Torres et al., 2017b), economics (Duncombe, 2019; Hirsch, 2016), and social impacts (Mahadevan, 2019; Popescu, 2018). I found relatively few sources which discussed the

gaps in the governance of sand, allowing my research to contribute knowledge in this under-studied area.

I began this study by asking the expert panel to provide a definition of "governance" in the context of their profession and location. By asking the panel to define governance, I can better understand the context in which they are viewing the survey questions. Individual definitions may help to explain why an expert responded in the way they did. The responses from the panel largely aligned with the definition outlined in the literature review (see section 2.3.1 for the governance definition used in this thesis). I provide some reflective responses of the definitions received below:

> *"How the government of a country makes decisions on focus matters through regulations, policies and guidelines, and ensures that they are adopted and enforced to affect the lives and activities of their people."* (Expert 7 – Academic Researcher)

> *"Governance (to me) = the entirety of policy and legislation surrounding the management of marine/coastal water systems (e.g., North Sea), which affects various stakeholders in society."* (Expert 6 – Academic Researcher)

> *"The collective action/responsibility of all stakeholders (e.g., industry, governments, organizations) involved towards a more sustainable use of marine raw materials."* (Expert 12 – Academic Researcher)

> *"The overarching management of a resource keeping the needs of future generations in mind."* (Expert 5 – Author)

These definitions of governance are all applicable to the global governance of sand.

4.2 Awareness

Awareness and knowledge on the challenges of sand mining are required in order to guide research that will inform governance to manage the social and ecological impacts of sand mining and shift towards sustainability. In the first round of the survey, I asked the expert panel if they believed there to be a lack of awareness in the context of their profession and location, and to identify the contributing factor. Examining the factors that contribute to lack of awareness can guide new research as well as education and governance strategies towards improvement. In this section I will discuss awareness from the view of the panel and highlight the challenges and opportunities in relation to governance. In the first round of survey, the expert panel collectively agreed that there is a lack of awareness, although it may be increasing among global actors.

> *"Absolutely [there is a lack of awareness]. I've been writing on the topic for 4+ years by now, and while awareness is definitely growing, it's still at a very low level. Some reasons: not a very media-sexy topic. LOTS of other competing news - between Trump, Covid and (in the US) the Black Lives Matter movement, it's hard to get attention on anything. Also, in the US and other developing countries, sand mining isn't nearly as damaging or destructive as it is in much of the developing world".* (Expert 11 - Journalist)

There is currently a lack of research and subsequently data, on the social and ecological impacts of sand mining. A lack of available data inherently leads to a lack of knowledge and understanding. Poor governance is one result of these awareness challenges. According to the expert panel, and as reflected in the literature (Beiser, 2017a; UNEP, 2019) awareness regarding the social and ecological impacts of sand mining is low, although, it is slowly increasing.

> *"Yes, there is a crucial lack of awareness across government and public spheres. The issue is compartmentalized (i.e., not considered cross-sectoral), with serious unawareness of how economic development and 'improvement' is causing literal and figurative deleterious downstream change. Political and socio-cultural factors are the main reason for this knowledge gap, followed by poor understanding of the connectivity of biophysical systems."* (Expert 7 - Academic Researcher).

The experts identified three critical factors that most influence awareness (see Table 4.1 below). The three statements which received the highest agreement (highest mean value) in descending order were: (1) peoples disconnect between sand sources (a beach or riverbed) compared with the materials made from sand (glass, concrete); (2) the belief that sand mining is only an issue in developing countries; and (3) the misconception that sand will not run out. Understanding that sand is a finite resource and that its sustainability is a global issue should be basic natural resource knowledge. Prioritizing education to disseminate this information was one of the strategies to improve awareness outlined by the panel (Table 4.1).

Section	**Agreement consensus**
1) Factors that contribute to The Lack of Awareness	1) People's disconnect between sand sources (a beach or riverbed) compared with the materials made from sand (glass, concrete). 2) The belief that sand mining is only an issue in developing countries 3) The misconception that sand will not run out.

Table 4.1: Consensus Agreement Contributing Factors to Lack of Awareness.

These misconceptions about sand further exacerbate the lack of awareness by brushing the issues under the rug. For example, the recognition of where products such as glass, concrete, and electronics come from could help consumers understand the scale to which sand is used and grasp the magnitude of the social and ecological issues that result from mining the resource. Once this is known, understanding that sand is a finite resource can help consumers to recognize that if the current rate of extraction and consumption of sand products is not curbed, the resource may soon become depleted (see Chapter 2.1). As well, a paradigm shift from believing that sand mining and the associated issues are only prevalent in developing countries, to understanding that the impacts are felt globally can be a wakeup call, especially to those who rely on tourism for an income (see 2.2.2 for impacts on tourism) (Bakkalapulo, 2019; UNEP, 2019).

Localized sand demand negatively impacts many beaches in the United states (Bakkalapulo, 2019) as well as Caribbean and other beach holiday destinations where sand is mined from beaches to be used in development or beach replenishment elsewhere (Bakkalapulo, 2019; Carroll, 2008). The loss of key species and beach erosion that result from sand mining negatively affect eco-tourism in coastal areas (Kondolf, 1997; UNEP, 2019). The sandy beaches that are being extracted and the wildlife that they support are main attractions of a beach holiday and if they disappear from unrestrained mining, tourism will significantly decline (Carroll, 2008; UNEP, 2019). If this occurs, the industry of sand mining could severely impact an entire other lucrative industry, affecting many livelihoods and the local economies.

Having defined the factors that impact awareness, panel experts were asked to reflect on awareness improvement strategies. To address these factors, I asked the expert panel what they believe to be the critical strategies required to improve the awareness about sand mining and its impacts. Six strategies obtained a consensus (see Table 4.2). The panel agreed that reflective pricing as well as an increase in education, research, cross-sector collaboration, and transparency are the most critical strategies to improve awareness of the sand industry.

For example, using reflective pricing to echo the social and ecological costs that sand mining incurs will draw the attention of direct consumers of sand to the mining issues and therefore increase awareness. In order to reach those who are not direct consumers of sand and may not be able to make the link between the increase of product costs and the reflective pricing, improved education on sand resources should be included in resource management courses at the secondary school level as public information sessions such as public lectures or presentations for those not in school. To increase education on the topic, research and funding must be prioritized so that current and accurate data can support this education.

Section	Agreement consensus
2) Strategies to Increase Awareness	1) Ensure pricing of sand commodities reflects the environmental and social costs of mining activity. 2) Increase education within schools, corporations, and the public about the environmental and social impacts of sand mining. 3) Increase education on the interdependencies between sand-based ecosystems and vulnerable communities. 5) Increase funding for research and data collection regarding the unknown environmental and social implications of sand mining. 6) Increase or start cross-sector collaboration and structured dialogue between stakeholders regarding sand mining policy (e.g., roundtable discussions to create a policy framework) 7) Improve transparency with regards to the accounting of sand needs (e.g., construction and development, technology, glass, food products, etc.).

Table 4.2: Consensus Agreement Strategies to Improve Awareness.

> *"Education is key, we need to disseminate information about the environmental and social impacts of sand mining, and this needs to cover a range of sectors (industry, NGO, humanitarian etc.). There is also a need for greater data collection around the environmental and ecosystem implications of sand mining so that we are able to better quantify and understand how these processes affect and damage the environment."*
> (Expert 2 - Academic Researcher)

The panel also highlighted cross-sector collaboration and structured dialogue between stakeholders regarding policy as a critical strategy for awareness raising. For example, roundtable discussions to create a policy framework can help all stakeholders to benefit from sand mining, or at least reduce the negative impacts. The inclusion of different stakeholders allows for a breadth of insights as to how sand mining may be affecting a certain group or community that was not taken into previous consideration. By having an external organization to facilitate these collaborative discussions (for example, UNEP), a voice can be provided to those who may not otherwise be equipped to share their opinions such as local community members that are experiencing increased erosion as a result of a sand mine. This was highlighted in the "Transparency & Accountability" and "Stakeholder Relationships & Platforms" Sections.

> *"Sustainable extraction of the resource has to start locally, with better regulation and transparency at the local scale. Providing the community with legal instruments that provides them to have a voice when their local sand is being illegally extracted."* (Expert 1 – Consultant).

> *"It comes back to good governance and the willingness to take the voices of those without power, political and economic, seriously."* (Expert 4 – Academic Researcher)

Finally, the experts agreed that improving transparency with regards to the accounting of sand needs can help researchers and other stakeholders to understand how the resource stocks are moving across borders, who the consumers are, and whether these consumers should be the priority or if they are prone to corruption to keep up with demand (i.e., will use illegal sand mining in order to develop a beach resort and supplement the beach in order to maintain or grow tourism).

> *"Increase enforcement of existing laws and policies governing sand mining. Legislation in most countries exists but is not enforced."* (Expert 1 - Consultant, additional comment in round two: Strategies to Improve Awareness).

Throughout this study, the expert panel and literature mention increasing enforcement of existing policies several times as a governance improvement. However, using enforcement as a strategy to increase awareness can also be effective. Many of the social and ecological challenges that occur as a result of sand mining are related to illegal mining operations persisting from a lack of policy enforcement (Beiser, 2018a; Mahadevan, 2019; Popesco, 2018; UNEP, 2019)

If enforcement is increased and illicit mining curtails, the demand will increase and this pressure will shift to legitimate mines and therefore, pricing will be reflective of this which will satisfy the previously mentioned awareness strategy.

> *"Putting a price on sand that reflects the actual cost (environmental and social) of the product will cause construction costs to increase, and this will immediately increase awareness. In areas where sand prices increase (because of a clamp down on illegal mining) construction costs skyrocket, projects stop, and people take notice."* (Expert 1-Consultant)

4.3 Knowledge and Science

> *"We lack a robust understanding of the environmental and socioeconomic conditions, as well as governance strategies, that lead to successful or unsuccessful outcomes in sand extraction operations. Likewise, we lack the knowledge of how and which distant factors influence the sustainability of the entire operation."* (Expert 10 - Academic Researcher)

In order to improve awareness by investing in research and education, it is important to recognize the critical knowledge gaps that exist in order to prioritize research accordingly. Scientific studies and policies on which to base sustainable extraction and consumption are lacking according to the 2019 UNEP Sand and Sustainability Report.

To address this, I asked the expert panel what they believe to be the most critical knowledge gap that pertains to sand mining. The panel reached an agreement consensus on four critical knowledge gaps (Table 4.3).

Section	**Agreement consensus**
3) Knowledge Gaps	1) The unknown large scale and long-term impacts of sand mining and its various extraction methods on other ecosystems, processes, and livelihoods, 2)The lack of data on sand resources, including assessments of sand stocks, and demand, 3) The lack of data on current mechanisms to govern sand resources, including existing regulatory frameworks, and 4) The lack of data on the relationship between illicit mining and legitimate construction.

Table 4.3: Consensus Agreement Knowledge Gaps.

The four knowledge gaps which received the consensus agreement in descending order were: (1) the unknown large scale and long term impacts of sand mining and its various extraction methods on other ecosystems, processes, and livelihoods; (2) the lack of data on sand resources, including assessments of sand stocks, and demand; (3) the lack of data on current mechanisms to govern sand resources, including existing regulatory frameworks, and; (4) the lack of data on the relationship between illicit mining and legitimate construction.

In regard to the first critical knowledge gap, one panel expert noted:

> *Sand from rivers is extracted locally, but affects the entire river system, with impacts occurring over long time periods. Understanding the large scale, long-term processes and impacts associated with sand mining, and the interaction between sand mining and other activities (dams, dredging for navigation, etc) is a major gap."* (Expert 1 - Consultant).

As reflected above, the first knowledge gap relates to the unknown large scale and long-term impacts on ecosystems, processes, and livelihoods. Without understanding the large scale and long-term impacts sand mining can inflict on ecosystems, processes, and livelihoods, the continuation of sand mining poses an unknown threat. It is important to understand and forecast these future impacts so that actions can be taken now to minimize future harm. If the risks are unknown, there is no supporting evidence to curb mining, which will allow the impacts to become further exacerbated as time moves on. This was noted by Expert 2 in the first round of survey:

> *"We need better data pertaining to the rates and locations of riverine [sand] mining, and more extensive longitudinal studies of these sites to assess how quickly systems may recover to the perturbations induced by sand mining. We have shown that sand mining can lead to riverbank collapse and increased saline intrusion in deltas, but we need now to understand what the implications of these impacts are on flood risk, livelihoods and community resilience to changing hydrological regimes. Without this underpinning data, we will not be able to develop governance structures which enable sustainable and environmentally sound practices and rates of extraction.".* (Expert 2 – Academic Researcher)

This lack of data has led to the unsustainability and poor governance of the industry (Bendixen et al., 2019). Moreover, understanding these risks can help to inform an effective governance framework. Prior to a legal sand mine starting operations, an environmental impact assessment should be carried out to better understand the environment and risks in the area to inform policy guidelines for extraction (Obura, 2019).

The second knowledge gap relates to the lack of data on sand resources.
In order to set mining limits, similar to the fishing industry, the sand stocks and demand must be assessed and known by policy makers. In addition to managing the impacts from sand mining, ensuring the finite resource is not depleted in a matter of a few years is a priority. It is important to understand current stock and where these sand deposits are located, current demand and the location and purpose of this demand. Understanding the stock and demand can help to prioritize moving towards a sustainable sand mining industry so as to not deplete stocks while also

minimizing the social and environmental impacts. One panel expert noted the importance of this data in informing governance:

> *"I think that the underpinning data on stocks and impacts (both ecologically and societally) is needed to inform the lack of regulatory frameworks i.e., the lack of environmental data on stocks and impacts should be a first order priority to inform the subsequent steps."* (Expert 2 – Academic Researcher, additional comment in survey round two, section: Knowledge Gaps).

However, there is an absence of reliable data due to corruption and ensuring that future data collected is accurate may be challenging (Mahadevan, 2019; Rege, 2016).

The third knowledge gap relates to the lack of data on current governance mechanisms including existing regulatory framework. In order to help guide governance, policy makers should be able to assess past frameworks to understand what has been successful or not in the context that they are working in. There is little data on the governance frameworks for sand resources which gives current governing bodies nothing to work with. Data on mechanisms that have failed would allow for governance to be more efficient because they would not repeat the same mistakes and could possibly identify where the past mechanisms fell short, adjust them to be an improvement, and try these methods again, or to surpass a failed mechanism altogether and move on to the next one. Time is a factor in improving the governance of sand mining as a significant amount of sand is mined every day. The sooner it is efficiently governed, the less sand will be consumed.

The fourth knowledge gap relates to the lack of data on the relationship between illicit mining and legitimate construction. There exists a huge knowledge gap on illegal mining operations and legitimate construction due to the corruption that accompanies it. It is very difficult to acquire data on this topic due to the imminent threat of violence that is well known to be associated with researching illegal sand mining. Many journalists and advocates in local communities have been able to share their personal stories of attempting to approach or investigate illegal mining operations and being seriously threatened, or beaten, while some have not escaped with their lives. The monetary benefits are much too valuable (especially in developing countries) to allow for someone to get in the way. Therefore, with the interest in mind, strong relationships form between illicit miners and the government officials who help to facilitate it.

> *"The most important knowledge gap lies in not knowing who finances illicit sand extraction within a given community. Even if environmental laws are broken, failure to identify a chief suspect can mean that prosecutors are left only with the option of charging low-level miners for offences which would not attract a severe punishment. Lack of data regarding the relationship between illicit sand mining and the (legitimate)*

> *construction industry means that it is relatively easy for sand to be 'laundered' within supply chains and mis-labelled as having originated from a local and sustainable resource. Without information indicating that there is a measure of 'organization' behind sand mining, it is easy to dismiss such activity as being merely entrepreneurial rather than conspiratorial."* (Expert 8 - Academic Researcher).

Interestingly, I identified some contradictions in how the panel prioritized knowledge gaps. In the first round, broadly, the lack of data was identified as a critical knowledge gap. However, in the second round of survey when asked about the specific types of data, there was some contradiction. Data on the impacts of sand, sand stocks and demand, governance mechanisms and illicit mining all received agreement from the panel (all experts voted 4 or 5). However, 54% (6 out of 11) of the panel experts either disagreed (3 experts) or were unsure (3 experts) that the lack of data on sand mining operations including the organizational structure of a mine and its relationship with consumers was a critical knowledge gap (statement 3.4). This percentage of the panel seemed less concerned with how a sand mine operates but were interested in data on sand as a resource, the effects sand mining can create, how it is governed, and how illegal mining operates. However, as increasing research was highlighted as a core strategy to improve awareness, this could apply to all aspects of sand mining. Moreover, understanding the operations of a sand mine including the internal organizational structure, methods of extraction, trading, etc., could lead to insights within the other knowledge gaps that were voted highly. For example, understanding the internal organizational structure could provide insight into the current governance mechanisms and how successful or unsuccessful they are. As one panel expert noted:

> *"First, understanding the organizational structure, operations (modus operandi), and partnerships (modus coordinati) of the activity itself. Second, understanding the cultural and economic context of the nations where this activity occurs. Third, understanding the 'demand': sources, quantity, alternatives, etc. Fourth, understanding existing regulatory and enforcement strategies and why they do/not work. Finally, understanding how 1-4 work in unison to get the larger picture and understand how these various parts fit together and engage, resulting in this activity."* (Expert 3 – Academic Researcher)

Highlighting the critical knowledge gaps is key in determining where research efforts must be focused to improve the social and ecological sustainability of the sand mining industry.

In the second round of the Delphi survey, the expert panel reached consensus on six areas of priority research. The priority research areas which received highest agreement in descending order were: (1) examining the downstream impacts of sand mining on livelihoods and ecosystems; (2) quantifying sand budgets to identify a 'sustainable extraction rate'; (3) understanding how the high environmental and socio-economic costs of sand mining are passed

on to local communities and broader civil society; (4) creating a framework to outline what best practices look like in the sand industry; (5) assessing the scale of global sand mining both legitimate and illegitimate; and (6) critically examining the operations of illicit mining activities.

These areas of priority research reflect the critical knowledge gaps that the panel had previously highlighted. A first step in a revised governance system should be to address the critical knowledge gaps and prioritize the research areas so that current and accurate data can be used to educate as well as create an effective and efficient governance framework.

The panel identified these areas of priority research to better understand sand mining and impacts as a whole, the associated impacts, and paths to improvement. Knowing that these are areas of priority research, they can be advertised to researchers and academics to pursue studies within these fields and contribute to the knowledge base. This knowledge base can then be used in education as well as creating governance strategies. Moreover, despite the global demand for sand, the sustainability is rarely discussed in scientific studies (Torres et al., 2017b). Therefore, it is not known which immediate and distant factors influence the sustainability of the industry in different environments. As previously mentioned in the "Knowledge and Science" section, one panel expert noted:

> "*Understanding the large scale, long-term processes and impacts associated with sand mining, and the interaction between sand mining and other activities (dams, dredging for navigation, etc) is a major gap."* (Expert 1 - Consultant).
> The unknown large scale and long-term processes and impacts from sand mining are a significant knowledge gap.

> *"We lack a robust understanding of the environmental and socioeconomic conditions, as well as governance strategies, that lead to successful or unsuccessful outcomes in sand extraction operations. Likewise, we lack the knowledge of how and which distant factors influence the sustainability of the entire operation."* (Expert 10 - Academic Researcher)

4.4 Transparency & Accountability

Transparency and accountability within industry, governments, and multilateral organizations are required for effective governance of a resource: sand governance currently lacks these traits (Mahadevan, 2019; Rege, 2016; UNEP, 2019). Without transparency and accountability, corruption becomes rife within an industry which is what has happened with sand (Peduzzi, 2018; Popescu, 2018). Below, I review the obstacles that the experts agreed were impeding effective transparency and accountability measures, as well as the factors that should be included in an ideal framework.

In the first round of the survey, the expert panel agreed that the lack of awareness and resources, corruption, and poor regulation were obstacles to transparency and accountability.

> *"Depending on the country in question, typical issues/obstacles (in no particular order) could include corruption, poverty, greed, limited resources & training (to keep track of activities and impacts), silo-based operations (are different entities working together to address the issue)."* (Expert 3 - Academic Researcher).

In the second round of survey, the panel agreed on five specific obstacles. These obstacles in descending order of agreement are: (1) lack of awareness and knowledge about sand mining and the impacts, making it difficult to communicate among stakeholders and the public; (2) poor regulation and lack of resources; (3) sector-based corruption among government officials and a focus on short term benefits; (4) the diffuse locations of extraction sites which makes managing the cumulative effects of sand mining challenging; and (5) an overall lack of data, different data collection approaches and material definitions (no standardization).

First, in order to have transparency, stakeholders must be able to communicate with each other about their needs and concerns. This is not possible if stakeholders are uneducated on the social and ecological impacts from sand mining. Reports such as the UNEP Sand & Sustainability (2019) report can help to disseminate knowledge to stakeholders and ensure uniformity of awareness at a roundtable stakeholder discussion. Furthermore, stakeholders from different disciplines, levels of education, and geographic locations may use different language or jargon that can be miscommunicated and lack shared understanding. For example, a fisher that has been impacted by sand mining in a developing country may not be able to understand the language used by a mining company or policy maker. Similarly, mining company representatives and government officials may use jargon specific to their profession that will not be translated between the two actors. Recognizing this, roundtable discussions and collaborative communications should use a standardized language and provide clear definitions of jargon when it is not possible to avoid.

> *"Through my experience in SE Asia I am aware there is a lot of corruption in the sector with government officials holding stakes or backing extraction operations. This is a major obstacle to fair and accountable governance and regulation. Many larger companies are also multinational and so may operate under different structures based on their organisations registered country. The lack of global regulatory framework for this resource makes it difficult to enact effective regional and local governance."* (Expert 2 - Academic Researcher).

Poor regulation is the result of a lack of monetary and physical resources, as well as corruption (Beiser, 2018a). The "sand mafia" in India is an example of how these three factors can lead to

unsustainability and rampant illegal mining (Mahadevan, 2019). Funds are required to hire monitoring agents to perform downstream checks on sand mines. Many sand mines operate with official licenses to do so, however, the illicit activity often includes operating beyond the bounds that is mandated (i.e., greater extraction than the license allows for and no enforcement of obeying quotas). This is more common in developing countries, where regions lack the resources to hire monitoring agents and are perhaps more easily persuaded into corruption as is often seen in the Sand Mafia (Mahadevan, 2019; UNEP, 2019).

Many regulations for sand mining are not enforced or are overlooked by officials who are paid a portion of profits by an illicit sand mining operation (Beiser, 2018; Popescu, 2018; Mahadevan. 2020). This mutually beneficial relationship has impeded transparency and accountability in the governance of sand resources significantly and will continue to do so until serious change is made (Rege, 2016). This relationship has set up a system which benefits illicit sand mining activity that requires significant efforts to stop or reverse. If corrupt law enforcement does not stop the illegal activity, it becomes difficult for government officials to do so. This is a reflection of a greater societal issue that includes sand mining as part of the elite capture of a series of resources including trees, fish, and other wildlife. In turn, the more corrupt officials that exist, the more illegal mining activity is overlooked. This process impedes transparency and accountability in the governance of sand resources. The corruption that results from a lack of resources has government officials focusing on short term benefits such as infrastructure development for their country or creating powerful beneficial relationships. This focus on the short-term was noted by a panel expert:

> *"The view that short term benefit (money-making, development, social upliftment, 'progress') outweighs the long-term (intangible) costs (ecosystem dysfunction, biodiversity loss, habitat destruction, loss of goods and services climate change mitigation). Dissociating the effects of the practice from the gains does not promote novel thinking into new, green engineering practices using alternate and sustainable building methods. Without a prior inventory of the full socio-ecological value system of the extraction location, communities and countries are left with non-functional ecosystems that need to also carry them through a highly uncertain climate change-influenced future*." (Expert 7 - Academic Researcher).

Furthermore, as noted by another panel expert, the sheer amount of diffuse sand mines creates a challenging situation to manage and track the cumulative effects of extraction both locally and globally.

> *"The regulation of the industry falls to local agencies with inadequate funding or expertise to manage the mining in a sustainable manner. The management of the resource and its trade needs to be handled at a higher level, but this is difficult because*

> *of the large number and diffuse locations of extraction sites. The areas in the world where sand mining is having (probably) the largest impacts and being completed in the least sustainable manner are areas where governance and transparency are poor."* (Expert 1 – Consultant).

The regulation of the sand industry should be funded by the larger, better funded agencies that can disseminate resources to a local level for enforcement. Monitoring and tracking of every sand extraction site is a difficult task, especially in an expansive country with many remote riverine or coastal areas.

> *"The most pressing issues around sand mining are in the developing world, especially fast-growing economies including India, China, Nigeria, Indonesia etc. There is very little regulation of the industry in those places, generally speaking, and the regulations that do exist are often ignored by illegal miners who pay off public officials to leave them alone. So we need both better regulations and more effective enforcement. Endemic corruption is therefore a major obstacle*." (Expert 11 - Journalist).

Moreover, the overall lack of data makes transparency and accountability challenging (Bendixen et al., 2018). Different data collection approaches, material definitions, and lack of standardization within the industry across borders creates a communication barrier and can act as a scapegoat for corruption to take place.

Surprisingly, I began to see some disagreement in this section. Four statements in particular did not reach a consensus and had disagreement amongst the panel.

Statement 4: *Companies (often multinational) that may operate under different governance and reporting structures based on their registered country.* 50% of the panel agreed with the statement while the remaining 50% either disagreed (20%) or was unsure (30%).

Statement 5: *The challenge of regulating a resource that is 'transboundary' (i.e., commodity flows across countries and regions).* 40% of the panel agreed with the statement while the remaining 60% either disagreed (20%) or was unsure (40%).

Statement 6: *Proprietary data which industries are currently not compelled to share but which are needed for transparency and accountability.* 50% of the panel agreed with the statement while the remaining 50% either disagreed (10%) or was unsure (40%).

Statement 7: *The lack of common terminology which is key to understanding and governance.* 40% of the panel agreed with the statement while the majority (50%) voted that they were unsure.

The commonality between the above statements is that they relate to entities working in different siloed bubbles and not fostering effective communication which is likely impeding effective governance. The response to these statements is interesting because improved communications between these siloed entities was previously highlighted as a transparency and accountability obstacle, as well as in the Awareness section as a critical factor for improved global governance of sand. These results likely occurred because the panel was prioritizing the other statements which they voted with high agreement (voted 4 or 5) as the most critical and to be addressed first. The statements above perhaps held different levels of urgency amongst the panel, resulting in disagreement, or panel experts themselves are focused in varying silos and scales in which some will not see transboundary commons as an issue and others will see these as flows. Additionally, profession and location may have influenced this disagreement. Profession and location are contributing factors to these silos, and may have an influence on language and use of 'jargon' which also may have been reasons for the disagreement. Terms such as "transboundary" may not be present in some participants language or may hold different meaning (i.e., seen as a flow versus seen as a commons issue).

The social and ecological sustainability of sand mining is a complex issue comprised of varying influencing factors, and therefore achieving effective governance of the industry is challenging. However, given the transparency and accountability obstacles outlined by the panel, several complementary opportunities arise. For example, improving documentation of trade data, and including local communities in communications.

Governance improvements and creating a framework to outline what best practices look like in the sand industry were previously highlighted as areas of priority research. To specifically look at how to improve governance of sand resources, I asked the panel what an ideal transparency and accountability framework for the sand industry would include. The opportunities outlined by the panel complemented the challenges that were also previously mentioned. The factors that should be reflected in an ideal transparency framework according to the expert panel included: (1) improving documentation; (2) a global certification standard; (3) material flow analysis; (4) making data available and accessible to the public; and (5) allowing the community to be involved in communication.

> *"The following factors might be reflected in a transparency framework that aims to promote awareness about sand-mining: requiring that all sand shipments should be accompanied by documentation certifying the places they originated from, the number of miners contracted, what machine tools were used, projections of future mining activity in the region, lists of purchasers together with their status (in terms of whether a business is registered or not). This is all only possible in an ideal scenario but would be fiercely resisted in real life."* (Expert 8 - Academic Researcher).

The implementation of a set of certification standards developed by an external organization (e.g., the UNEP) for the global sand industry similar to other commodity-based industries would help to improve accountability as all countries would have to meet the same global standards. As one panel expert noted in the second round of survey as an additional comment regarding statement 6, "Increase or start cross-sector collaboration and structured dialogue between stakeholders regarding sand mining policy (e.g., roundtable discussions to create a policy framework)":

"Perhaps a system comparable to the Kimberly System for diamonds i.e., legitimate mining (with provisions for mitigation & restoration) for legitimate construction." (Expert 7 - Academic Researcher).

This approach has been successful in other natural resource industries such as the Kimberley Process (KP) for diamond mining (Kimberley Process, n.d.). Similar to the global sand trade, diamonds can be involved in illegal activities. What are referred to as blood diamonds were traded by rebels to finance armed conflict against governments and were estimated to account for up 20 percent of global diamond trade in the 1990s (Bieri, 2010). The combined efforts of the United Nations and other NGOs brought awareness of this issue to policy makers and the public, which led to the Kimberley Process (Bieri, 2010). The KP consisted of states, NGOs and industry to create the Kimberley Process Certification Scheme (KPCS): an international agreement to regulate the diamond trade through certifications, which now has 75 countries complying with the scheme (Bieri, 2010). The success of the Kimberley Process within the diamond trade makes the approach appropriate for niche areas in the sand industry to work towards.

However, having to comply with a global standard would likely be resisted due to the benefits that government officials receive as a result of corruption, but also in terms of inequity. For example, it is likely that a sand mine in Texas can more easily reach the certification standards compared to a sand mine in an underdeveloped area of India. One could argue that this inequity is not a level playing field and demand exemptions be made which would make the certification standards a moot point.

> *"Sustainable extraction of the resource has to start locally, with better regulation and transparency at the local scale. Providing the community with legal instruments that provides them to have a voice when their local sand is being illegally extracted. Ideally, the global industry should have standards similar to forest products or aquaculture or wild fisheries that demonstrate sustainability, but the industry is so poorly regulated at the local level it is difficult to envisage a pathway for this to occur."* (Expert 1 - Consultant).

Regulations and monitoring were highlighted as challenges to an ideal transparency framework. Statement 3: *"increased and improved regulation as well as adequate funding for regulatory agencies"* received agreement consensus as expected, identifying it as a factor for an ideal framework. Improved regulation and downstream monitoring could help to curb corruption and stop some illegal mining activity.

> *"Accurate and robust estimates of volumes extracted and traded (import/export). Stringent and accountable licensing of extraction sites along with routine monitoring. This also extends to the financial flows operating behind the corporations and organisations conducting and operating the mines to avoid corruption and circumventing the governance structures."* (Expert 2 - Academic Researcher).

The collection of accurate and transparent import and export data, monitoring of mining operations and documentation, and documentation of volumes of sand extracted and traded is important in order to maintain transparency and accountability. This tracking data could help to identify where illegal activity may be occurring along the chain if documentation does not reflect the data. This way, tracking and closing an illegal mine may be much more efficient which would help minimize the associated social and ecological impacts.

Finally, improved engagement between the government and stakeholders can foster meaningful communication that could identify points of weakness in the framework, or areas to be reassessed. Understanding stakeholder needs is an important component of prioritizing a shift towards a sustainable sand industry. Local communities who reside near a sand mine and are directly impacted play a key role in the governance of sand resources and should be involved in awareness campaigns and round table discussions to provide insight (Asabonga et al., 2017; UNEP, 2019). In the second round of survey, I asked the panel to select their agreement with statement 5.1 *"Communication with the local communities to understand their thoughts and concerns in regard to sand mining.",* as a crucial factor to improve the transparency and accountability of sand mining. This statement received an interesting response. Two participants disagreed that this is a crucial factor to improve transparency and accountability, another two were unsure while the rest of the panel (seven) agreed. I expected stronger agreement for this statement as improving transparency and accountability inherently involves local communities. Communication with local communities would also enrich research regarding the social implications of sand mining which was voted as a strategy to improve awareness as previously mentioned.

> *"Sand mining is almost universally managed at the local scale, so these 'actors' have the most important role. Higher level (state, national) bans on mining in specific areas may be useful for setting the broad directions (e.g., most western countries have ban mining in*

> *rivers, so locals regulate sand pits or crushing activities), however it depends on the overall governance situation in the country. for example, in several developing countries, the federal or state governments have banned sand mining in some locations, but these bans are not enforced at the local level due to corruption and fear."* (Expert - 1 Consultant).

The experts that did not agree with statement 5.1 were likely prioritizing other factors that they believed to be more crucial for a transparency and accountability framework (e.g., statement 5.3: "Increased and improved regulation as well as adequate funding for regulatory agencies." Which received consensus agreement). Further discussion of these factors is provided in Chapter 5.

4.5 Stakeholder Relationships & Platforms

Corruption, lack of a global framework, enforcement, and communication have collectively led to the ecological and social issues caused by sand mining. The relationships and communication between governing bodies and other stakeholders of sand has been inadequate and has fostered a great deal of corruption (Beiser, 2018; Peduzzi, 2018). This leaves room for many opportunities to improve governance.

Throughout this study, partnerships, stakeholder relations, and communications have been highlighted as challenges within governance. This is due to the transboundary nature of the resource, corruption, and lack of a governance framework. I asked the expert panel what governance processes (i.e., at local or global levels) for sand resources are needed to improve relationships among stakeholders and/or address critical impacts (e.g., communication, codes of conduct). The panel agreed that improved regulations and enforcement, data collection, and improved partnerships, collaboration, and communications are needed.

> *"Greater enforcement of existing regulations in many areas would improve the situation, as would making 'guidelines' regulations and providing resources for enforcement."* (Expert 1 - Consultant).

To elaborate, I draw attention to the several statements around which consensus was achieved. For example, Statement 7.2, "*Establish greater enforcement of existing regulations",* was one of four statements in the second round of survey that received 100% agreement consensus. Based on the literature review (Gavriletea, 2017; Torres et al., 2017a) and the Delphi process, it is recognized that improving the enforcement of regulations would be an important governance process to prioritize. The lack of enforcement has likely led to distrust between governing bodies and other stakeholders and gives the illusion that regulations are there for show only (Obura, 2019). Such is the case in the southern coast of Kenya, where the government has remained silent while residents protest sand extraction from the Waa coral reefs (Obura, 2019) Moreover, the corruption between government officials and illegal mining has created distrust (Beiser,

2018a). Government officials cannot be trusted to own accountability of the challenges that arise from sand mining. If improving regulation is agreed to be the critical process in improving these relationships, then it should be prioritized. Then, other processes can work towards improvement once relationships have been established.

Furthermore, increased enforcement and monitoring will help to address the critical impacts of sand mining by limiting the frequency of illicit mining activity which will then have less of an impact on the ecosystem and livelihoods. In order to facilitate increased enforcement, the existing regulations should be revised to create a clear and robust regulatory framework. This framework will improve governance by having a concrete structure to follow rather than ambiguity that may have facilitated a lack of enforcement. By creating a robust regulatory framework while improving enforcement and monitoring, governing bodies can improve relationships by ensuring transparent reporting of operations which will help to build stakeholder trust.

> *"Better partnerships and streamlined communications between various stakeholders to allow for better data collection, monitoring practices, and assessment/evaluation for both short-term and long-term impacts."* (Expert 3 - Academic Researcher).

Once improved enforcement and monitoring has been established, further improvement of relationships by streamlining communications to allow for better data collection, monitoring, and assessment for short- and long-term impacts can proceed. These processes must be implemented when working towards improved governance of global sand resources. Improving partnerships and stakeholder relations is key to fostering sustainability in the sand industry.

Statement 7.7 *"Improved arrangements for co-governance to be adopted including different spheres of government fostering communication"* received the least agreement. Four out of 11 experts agreed while five were unsure, one disagreed, and one did not answer. I expected more agreement for this statement because statement 8.3, *"Improvement in communications within and between government spheres and stakeholders",* received a high amount of agreement (only two experts were unsure). The panel seems to agree the improved communications are crucial but were unsure that the creation of an arrangement to foster this communication is crucial. This assumes that stakeholders are able to improve communications without the use of an arrangement. The experts may believe that communication is easier to achieve than creating a robust regulatory framework and therefore prioritized that process instead.

After identifying what governance processes are required, I asked the expert panel to identify critical governance arrangements (e.g., new rules, governing organization) that are needed to improve stakeholder relationships and/or address critical impacts.

> *"A solution could be to have UNEP or the World Trade Organisation to set up and oversee a global monitoring programme."* (Expert 9 - Academic Researcher).

> *"Neutral statutory agencies that are better funded and resourced. Many in the UK and elsewhere have been weakened over the years."* (Expert 5 - Author).

The panel responded that the creation of a global program by a neutral agency including clear guidelines and policies to remove ambiguity in operations is needed with continued enforcement and monitoring. Additionally, structured communications with all stakeholders on a regular basis to assess the processes and make changes as needed is also required.

> *"I think overarching international or multilateral regulations and governance frameworks are required. Good practice guidelines are also needed to be drawn up to an international standard to ensure that there is uniformity in practice to reduce impacts on society and the environment.".* (Expert 2 - Academic Researcher).

These governance processes and arrangements should be considered in research objective 3 (Identify potential recommendations to improve the sustainable governance of global sand resources.) and are discussed further in Chapter 5.

4.6 Fragmented Participation by Key Actors

Throughout the governance process, key actor groups and stakeholders (e.g., local communities, and government officials) remain a consistent factor in governance. In order to achieve effective governance and to improve the social and ecological sustainability of sand resources, all those involved or affected must be considered and have their voices heard (Asabonga et al., 2017). This can be through public hearings or by including a representative at roundtable discussions. This collaborative approach will be beneficial in creating a well-rounded governance framework to achieve a collective interest (Baird et al., 2018). In any case, these crucial groups (local communities directly impacted from sand mining) have experienced fragmented participation throughout the governance of the sand industry (Beiser 2017c; Popescu, 2018).

In the first round of the survey, I asked the panel to identify which key actors and stakeholders have a crucial role in the governance of sand mining. One panel expert noted that these roles vary depending on the governance structure of the country.

> *"Sand mining is almost universally managed at the local scale, so these 'actors' have the most important role. Higher level (state, national) bans on mining in specific areas may be useful for setting the broad directions (e.g. most western countries have ban mining in rivers, so locals regulate sand pits or crushing activities), however it depends on the overall governance situation in the country. for example in several developing countries,*

the federal or state governments have banned sand mining in some locations, but these bans are not enforced at the local level due to corruption and fear."

Below is the list of key actor groups and stakeholders who have a crucial role in the governance of sand mining as submitted by the expert panel, which has been condensed for simplicity. One panel expert noted that the actors and stakeholders will vary depending on the governance structure of the country. The list of actors and stakeholders included groups from various points along the value chain. First, those at the extraction point of the sand value chain include local actors (e.g., local residents, communities that are directly impacted from sand mining), and mining companies. Next, those involved in sand trade including law enforcement agencies, government officials, and financial institutions. Then the construction industry and other consumers at the end of the sand value chain. Finally, there are those who are investigating different aspects of the sand industry including journalists, academics and researchers, and non-government organizations (NGOs).

This list was not included in the second round of survey to obtain consensus as all of these stakeholders have a role and one cannot necessarily be prioritized over another. Each actor's role plays a part, and it is difficult to parse which groups would be more crucial than others as this varies by location and context. This list of actor groups and stakeholders are all involved with or impacted by sand mining and play a role in the governance of the resource. Improved governance that involves these roles requires improved communication and perhaps round table discussions that have not yet occurred. It is important to highlight this list of stakeholders to ensure they are involved when creating a governance framework for sand resources. Involving those who have not previously been involved with sand governance could provide insights as to where the current structure is lacking and options for improvements. This way, a more well-rounded framework can be created. As one panel expert noted:

"The problem is not with the governance but with the absence of governance. So the focus needs to be on those without roles, but should have them. Especially local residents.". (Expert 4 – Academic Researcher).

The above quote highlights the need to include the considerations and insights from impacted communities in the formulation of a sand governance framework. Throughout this study the governance challenges that have been revealed have also had complementary solutions provided by the panel. If the solutions to the challenges are known, why have they not been implemented? Improving communications and effective governance were frequently discussed solutions but they remain as only figurative solutions and have not been implemented. Due to this discrepancy, I asked the expert panel what they believe to be the constraining factors of participation and co-production of effective governance among stakeholders involved in sand mining. The panel

reached an agreement consensus on three constraints that have impeded effective governance: (1) corruption; (2) fear; and (3) lack of awareness of the scale of the problem.

Corruption and fear severely constrain a more integrated or less fragmented governance approach due to the power that illicit mining has collected (Mahadevan, 2019; Torres et al., 2017a). For example, the fear mongering that the Sand Mafia has created stops enforcement officials from ceasing the illegal operations (Beiser, 2017a; Rege, 2016). Corruption and fear that has resulted from illicit sand mining in combination with lack of awareness impedes governance improvement. Moreover, the importance of awareness has been highlighted throughout this thesis (see section 2.3.2) as a foundational factor of governance. The lack of awareness is part of a positive feedback loop with lack of research and data. Without research and data, there is a lack of knowledge, and therefore lack of awareness. Without awareness of the issue, researchers do not know to collect and communicate data on the issue. This lack of awareness of the challenges of sand mining allows for it to continue as there is not enough pressure on governments from the public to take action and enforce policies (see section 4.2 above).

Until awareness is improved and illicit mining is under control, sand mining will continue to be a socially and ecologically unsustainable industry. Statement 9.4 *"Limited scientific evidence."* received a significant amount of disagreement: 45% of the panel disagreed and 18% were unsure while only 36% of the panel agreed. Seeing this, I come to two conclusions. One conclusion is that the panel believes there is sufficient scientific data that it does not pose as a constraint. The expert panel previously identified a lack of data as a knowledge gap and mentioned the need for more research. Therefore, having sufficient scientific data is likely not the case as to why this statement received a dispersed response. It is likely that the panel is prioritizing the other factors as more constraining to governance than a lack of scientific data, so this constraint was not voted with as much agreement.

5.0 CONCLUSION

I begin by reviewing the research objectives for this thesis, including the relevant points from Chapter 4 where objective one and two were addressed. I then discuss specific suggestions from the Delphi panel for governance improvements (objective 3). Building on these insights, I will then discuss the contributions from this study. Finally, I conclude this chapter with a discussion of the opportunities for future research.

5.1 Thesis Context

The social and ecological sustainability of sand mining is limited by inadequate local and global governance. As a result, coastal communities are experiencing the impacts such as food insecurity, loss of livelihood, homelessness, and dangerous threats from sand mafias (see 2.2.2) (Husrin et al., 2018; Mahadevan, 2019 Popescu, 2018). Furthermore, there have been significant implications for the environment and wildlife, including accelerated erosion and habitat loss (see 2.2.1) (Lamb et al., 2019). In order to manage these and future impacts, the governance of this globally traded resource must be improved. Through the use of a Delphi survey method, **t**his study set out to address three research objectives: (1) characterize the ecological and social costs and benefits of global sand mining; (2) assess opportunities and challenges associated with the current approach (or lack of approach) to the governance of global sand resources drawing from the most recent UNEP report, Sand & Sustainability (2019); and (3) identify potential knowledge gaps and solution oriented approaches to global sand governance through the Delphi survey of global experts.

5.2 Thesis Summary

In this section, I summarize the main findings for each research objective of this thesis (Table 5.1). In order to address these objectives, I adopted a qualitative approach using a Delphi research method. This approach incorporated both inductive analysis in the first round of survey, and deductive analysis in the second round. Specifically, the methods I used for this research included the literature review and two rounds of semi-structured survey (see Chapter 3).

Objective	Chapter(s) Where Addressed
1) Characterize the ecological and social costs and benefits of global sand mining.	2, 4
2) Assess opportunities and challenges associated with the current approach (or lack of approach) to the governance of global sand resources.	2, 4
3) Identify potential recommendations to improve the sustainable governance of global sand resources.	4, 5

Table 5.1: Research Objectives and The Chapters Where Each Objective is Addressed.

5.2.1 Understanding Context

The first objective of my research was to characterize the ecological and social costs and benefits of global sand mining. Within the literature review and results from both rounds of survey, I identified no ecological benefits to sand mining. However, there were several costs or impacts. The first ecological impact identified was the increased and accelerated erosion in riverbanks, coastal shores, and agricultural lands. (John, 2009; Lamb et al., 2019; Masalu, 2002). Erosion caused by sand mining is a significant problem to the environment, wildlife, and livelihoods through destruction of habitat and infrastructure. This erosion is causing shore recession and was identified as a trigger for cliff collapses in the Azores islands (Borges et al., 2002). Furthermore, sand mining can alter the morphodynamic processes in water bodies and undermine the structural integrity of built infrastructure such as bridges (Erftemeijer et al., 2012; Meynen, 2017; Yuill et al., 2015). Lastly, sand mining impacts wildlife by disturbing habitats, nesting and feeding sites, interferes with photosynthesis, crushes wildlife with machinery or sand deposits, and introduces invasive species.

This study found that there are significant social dimensions and costs from sand mining, including those related to erosion, health, livelihoods, and corruption (see 2.2.2) (Hammond, 2019; Mahadevan, 2019: UNEP, 2019). The accelerated erosion from sand mining directly impacts communities by destroying homes and buildings (Beiser, 2018c; Hammond, 2019). When sand is extracted nearby a resource-dependent community, the impacts are magnified. Mining operations can lead to fish stock decline and saltwater intrusion of agricultural soils causing food insecurity for the local communities (Marschke et al., 2014; Popescu, 2018). Those impacted include persons whose livelihoods depend on fishing, farming, or buildings that collapse due to sand mining. I found that sand mining could also lead to health implications by fostering disease carrying mosquitoes and increased local noise pollution (Popescu, 2018). Reports indicate that miners have died from drowning or having a sand dune collapse on them

while working (Chandran, 2019; PTI, 2019). The network of illegal sand mining and the Sand Mafias in India exacerbate these challenges by continuing to extract sand while not adhering to any existing policies which protect the environment and citizens.

5.2.2 Understanding Governance

The second objective of my research was to assess the opportunities and challenges associated with the current approach (or lack of approach) to the governance of global sand resources. In assessing challenges within the current structure of sand governance using the Global Sand Governance Framework (see Figure: 2) outlined in Chapter 2, several significant insights emerged: (1) the lack of reliable data and research concerning sand stocks, flows, and current regulatory frameworks (see table 4.3 for knowledge gaps); (2) limited regulations coupled with poor enforcement and monitoring; (3) the number of diffuse mining locations which make tracking resource flows difficult; (4) illegal mining and corruption within government and authoritative positions; and; (5) a lack of communication within and between governments and stakeholders (see Chapter 4).

By outlining these challenges, complementary opportunities to improve sand governance were identified: (1) increasing and improving research and accurate data collection and making this data accessible to the public; (2) increase the enforcement and monitoring of improved regulations along the entire value chain; (3) improve documentation of material flow analysis; (4) increase and improve collaboration and communication between stakeholders; (5) encourage the collection and sharing of best practices; (6) develop a global standard certification framework similar to the Kimberley Process for global diamond trade (Bieri, 2010), and; (7) establish a global governance which is overseen by a neutral, well-funded agency (see Chapter 4, and section 5.2.3 below).

5.2.3 Recommendations for sustainable governance

The third and final research objective of this study was to *"Identify potential recommendations to improve the sustainable governance of global sand resources."*. I address the third research objective primarily in this chapter and combine these findings with the insights from the first two objectives. This study has identified several recommendations to address this objective, some of which were noted in Chapter 4. First, improving the enforcement of any existing regulations for sand mining at both a local and global level is needed. Statements from survey participants reflecting this perspective include:

> *"Increase enforcement of existing laws and policies governing sand mining. Legislation in most countries exists but is not enforced."* (Expert 1 - Consultant, second round of survey additional comment).

> *"Permits do include stipulations for mitigation of impacts and rehabilitation of environmental damage. However, they are hardly commensurate to the scale of rehabilitation required for these operations. The entire mining process including transportation (roads and vehicles) and the extraction method adopted (digging, dredging) requires compliance monitoring and enforcement of regulations. Local governance must ensure that the activity does not impinge on other regulations and better arrangements for co-governance must be adopted. In the South African context, sand mining falls under the Department of Mineral Resources (mining) and is a national competence, where on the ground local (provincial) regulation is required from Departments of Water and Sanitation and Environmental Affairs - thus there is no functional arrangement for these different spheres of government to communicate."* (Expert 7 - Academic Researcher).

The lack of enforcement and monitoring was highlighted as a challenge within the second research objective and directing resources to improve it at a local and global scale will be significant in improving sand governance.

Next, the results of this study show that a global governance framework including standardized certifications should be established and directed by a mediating organization, such as the UNEP or WTO, to achieve a collective outcome for all stakeholders (Bendixen et al., 2019). As one panel expert noted in the second round of survey:

> *"[Concerning statement] No. 6 Perhaps a system comparable to the Kimberley System for diamonds i.e. legitimate mining (with provisions for mitigation & restoration) for legitimate construction."* (Expert 7 - Academic Researcher, round two additional comment).

The Kimberley Process was successful in improving the regulation of the global diamond trade and would be suitable for sand governance to take the same approach for niche sand types that are globally traded (see section 4.4). Panel experts also noted that the collection of accurate data should be available and accessible to the public to improve governance transparency. One panel expert responded:

> *"Information needs to be in the public domain and accessible over the internet as much as possible. Asking the mining company to pay for an EIA makes the EIA consultancy eager to please them. They highlight problems but give the go ahead anyway. (See interview with Joanna Thomson, Goodwin sands). Ideally it should be paid for and managed by an unbiased body from the government." (*Expert 5 - Author, Survey Round One).

5.3 Contributions

This thesis has provided insights into the realm of global sand mining and the governance gaps associated with sand mining. The most central finding to emerge from this study is that awareness of the challenges and potential solutions to address sand mining are limited. The expert panel in this study collectively agreed that awareness on sand mining and the associated ecological and social challenges is lacking. In the literature review, it was noted that researchers are contributing to awareness through published articles (Popescu, 2018). This work contributes to existing knowledge of sand mining simply by increasing awareness through research and discussion, which may inspire further research in the field.

However, the analysis of the global governance gaps undertaken here has extended our knowledge of why these gaps are continuing to impede effective outcomes, as well as which factors to prioritize when working towards sustainability. This new understanding may help improve the implementation of a global sand governance framework by outlining the key challenges and opportunities within the industry. While this study focuses on governance gaps, the findings may well have a bearing on improving awareness and cascading effects such as habitat protection.

Ultimately, this thesis offers three key insights into the global governance of sand mining:

1) Awareness of sand mining and the associated ecological and social dimensions and challenges must be improved; this awareness could lead to a call to action which could expedite the establishment of a global governance framework.
2) A global governance framework which is managed by a mediating organization that improves the enforcement and monitoring of policy is needed to improve the sustainability of sand mining.
3) Corruption between illegal mining operations, government, and other officials (such as police) and the illicit monetary flows as a result, are a main barrier in achieving a more sustainable sand industry.

The framework from the UNEP (2019) report was used as a tool to collect and analyze the data for this thesis which was organized into the five priority gaps. By organizing the survey questions according to the framework, the clarity of the surveys was improved and perhaps helped the expert panel understand the context of each question. This organizational approach was then useful in the analysis as it kept the discussion of results bounded and allowed me to cross reference between categories to identify interesting findings. Additionally, this framework provided a guide to create the survey questions that would enrich and add to the knowledge already gathered from the literature review.

However, while the framework touches upon many elements related to the illegal mining of sand (such as 4.4 the transparency and accountability section), illegal sand mining activity is an extensive topic that should be its own priority gap included in this framework rather than an element throughout all the sections. This could amplify the severity of illegal sand mining and the associated impacts. Additionally, there are significant social issues that the framework does not explicitly account for, such as labour issues and power dimensions. The use of a pre-existing framework to address these issues would be beneficial in work towards improving the social dimensions of sand mining.

Finally, the way in which the five priority gaps outlined in this framework are intertwined is a dimension of this framework that requires some explanation. The framework currently presents the priority impacts as siloed, but by presenting them as dynamic and intertwined, it invites a different perspective from readers and researchers allowing them to develop appropriate solutions.

5.4 Future Research

These findings highlight a plethora of areas for future investigation. Opportunities for future research include:

1) Research to better understand sand stocks including a sustainable extraction rates, a global material flow analysis to understand how sand stocks travel globally, and to better understand the scale of global sand mining.
2) Further research to understand the social and ecological impacts of sand mining in more detail including how livelihoods and illicit activity intersect with species decline as well as trying to identify currently unknown impacts.
3) Studies to understand 'virtual sand': how sand moves through products similar to the concept of virtual water (i.e., sand-rich products such as concrete or silicon chips that are produced in China, and then shipped to other countries).
4) Case studies (including collaborative case studies carried out by researchers and journalists) to examine illegal mining operations and corruption.

First, further research might usefully explore a global material flow analysis to understand how sand stocks are being traded. This type of material flow analysis should be undertaken with the intent of including illegal sand sources and should be done with great care to ensure researcher safety. Moreover, assessing global sand stocks and rates of replenishment to identify a sustainable extraction rate would be useful data in the creation of a global governance framework.

Second, further work is needed to fully understand the social and ecological implications of sand mining. This work might advance the current knowledge on known impacts or may undertake

exploring the unknown long-term and large-scale impacts. Comparing 'virtual sand' to the concept of 'virtual water' may be beneficial in assessing the global trade of sand. Virtual water is the concept that water is embodied in food and non-food commodities (Allan, 2020; Chen, 2013). When these commodities are exported, the embodied water travels as well (Allan, 2020). Sand that is used in products such as silicon chips for computers and the glass of vaccine vials that are produced in China, but exported globally are not accounted for in global sand resource flows but should be. Assessing and understanding sand consumption from this perspective may provide insight on where sand resources are travelling and the rate at which countries are consuming sand at the end of the value chain rather than on intermediate importers of the raw resource (Chen et al., 2017).

Finally, further studies need to be carried out in order to establish a stronger understanding of illegal sand mining and corruption as it is such a critical barrier to effective governance. Research in this field would be great help not only in improving sand governance, but also protecting those who are threatened by illegal mining. Case studies of different experiences would be beneficial in providing different insights. For example, case studies on manual versus machine operated extraction or illegal versus illegal sand mining operations in a location specific context. In addition to these research opportunities, the expert panel agreed on six areas of priority research which can be found in section 4.3 that should be explored.

5.5 Final personal reflections on sand

Navigating the completion of this thesis during the Covid-19 Pandemic leaves me with a bizarre and accomplished feeling. By using an online survey, my research did not have to pivot as was the case for many of my colleagues. However, trying to keep focus as a researcher while also trying to capture the attention of potential survey participants was challenging at times.
My biggest takeaway from this process is that research needs to be flexible, and researchers need the ability to adapt efficiently to evolving situations. While my thesis outlines its contributions (see section 5.3), the most tangible one is the awareness that has increased through conversation with friends, family, and colleagues about my research. The intrigue that is sparked when I mention I study sand mining complete with quick facts on consumption rates, uses, and the Sand Mafia has sent people to research the topic further on their own. It is this type of discussion that helps to improve awareness of the public and can lead to further research and improved governance.

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Appendix A
Study Invitation Script

Hello,

My name is Melissa Mark and I am a Masters student working under the supervision of Derek Armitage in the School of Environment, Resources, and Sustainability (SERS) at the University of Waterloo in Canada. I am conducting a study to identify the gaps in the governance of global sand resources as a basis for my master's thesis. We are currently seeking global volunteers who have some knowledge of the sand mining industry, and whom are willing to participate in a survey. The research objectives of this study are as follows:

(1) To characterize the ecological and social costs and benefits of global sand mining.

(2) To assess opportunities and challenges associated with the current approach (or lack of approach) to the governance of global sand resources

(3) To identify potential recommendations to improve the sustainable governance of global sand resources

Participation in this study involves completing up to three (3) rounds of an online survey following the Delphi method which involves surveying a panel of experts using multiple rounds of an adaptive survey. Each survey will aim to develop a consensus on the governance gaps that have contributed to unsustainability in the sand mining industry. The second and third surveys will be developed based on the results of the first and second survey, respectively.

If you choose to partake in this study, your identity will not be published. However, with your permission, some selected quotes may be used. Participants will be referenced generally by occupation (e.g. government, non-government). The anticipated time to answer the first survey round is approximately 20-30 minutes. Subsequent survey rounds will require no more than 20 minutes, resulting in a total of approximately 1 hour of your time. This research study has been reviewed and received ethics clearance through the University of Waterloo Research Ethics Committee.

However, the final decision about participation is yours. We plan to begin the first round of survey on May 25th, 2020 and request that it be completed June 8th, 2020.

Please read the attached Information Letter for more details regarding what participation involves. If you would like to participate, or you require additional information to assist you in reaching a decision about participation, please contact Melissa Mark at memark@uwaterloo.ca and Derek Armitage at derek.armitage@uwaterloo.ca.
Sincerely,

Melissa Mark
University of Waterloo

Appendix B
Information Letter

Title of the study: The Gaps in the Global Governance of Sand Mining

Principal Investigator/Faculty Supervisor: Derek Armitage. Canada, The University of Waterloo, Faculty of Environment, School of Environment, Resources, and Sustainability, Environmental Change and Governance Group. Email: derek.armitage@uwaterloo.ca Phone: 519-888-4567, ext. 35795.

Student Investigator: Melissa Mark. Canada, The University of Waterloo, Faculty of Environment, School of Environment, Resources, and Sustainability, Environmental Change and Governance Group. Email: memark@uwaterloo.ca.

To help you make an informed decision regarding your participation, this letter will explain what the study is about, the possible risks and benefits, and your rights as a research participant. If you do not understand something in the letter, please ask one of the investigators prior to consenting to the study.

Invitation to participation/What is the study about?

You are invited to participate in a research study about the global governance of sand mining and the sustainability implications associated. The objectives of this study are: (1) To characterize the ecological and social costs and benefits of global sand mining; (2) To assess opportunities and challenges associated with the current approach (or lack of approach) to the governance of global sand resources; (3) To identify potential recommendations to improve the sustainable governance of global sand resources. This research is important as sand resources continue to be consumed at an unsustainable rate. In order to support future sand needs, improved governance of the resource is needed. This research aims to address the knowledge gaps that exist in sand resource management through a global governance lens. I intend to identify and address the drivers of unsustainable and illegal sand trade. This study is for the completion of a master's thesis.

I. Your responsibilities as a participant

What does participation involve?

Participation in the study will consist of up to three rounds of survey in which you will be asked to answer questions regarding the governance of sand resources. There will be up to three rounds of survey facilitated on Google Forms and it is estimated that the completion of one round will take approximately 30 mins. Therefore, the total time for participation in this survey should not exceed 1 and a half hours.

The method of surveying being used for this study is the Delphi method. The Delphi study is a qualitative research method in which an expert consensus is achieved on a topic. Thus, the second and third surveys will be developed based on the results of the first survey. This method is an appropriate choice as a research tool in the case of having incomplete knowledge of a topic

which makes the Delphi an appropriate choice for sand resource governance research. Sand mining as a global environmental concern is a relatively new issue with few global experts and scientific reports featuring the topic.

Participation Process

If you choose to participate in this study you must reply to this email to confirm. Once the participant panel has been confirmed you will receive a link to the initial survey which includes the consent form and the choice between two radio buttons to confirm or deny consent.

If you deny consent, you will not be brought to the survey and asked to close your browser. If you confirm consent you will be brought to the initial survey. In the surveys, you will be asked to provide your knowledge and/or opinion regarding an aspect of sand resource governance.

You will be asked to submit your answers within one week of receiving the survey link. It is estimated that 2-3 weeks after receiving the data from the first survey that the second survey will be sent out in the same process as the first. You will receive a reminder email which includes the information letter, and link to the second survey. The process is the same for the second and possible third survey as the first. It is estimated that the first survey will be sent via email on March 2nd, 2020. These surveys will be created and emailed from Canada but may be completed anywhere and at your leisure within the time frame.

II. Your rights as a participant

Is participation in the study voluntary?

Participation in this study is voluntary. You may decline answering any question(s) you prefer not to answer by leaving them blank. Further, you may decide to end your participation in the surveys at any time by advising the researcher and by simply closing your browser.

Will I receive anything for participating in the study?

You will not receive payment for your participation in the study.

What are the possible benefits of the study?

Participation in this study will not provide any personal benefit to you. Data collected from surveys will contribute towards available knowledge and a better understanding of sand resource governance.

What are the risks associated with the study?

You will be completing the study via an online survey operated by Google Forms. Please note that Google Forms may temporarily collect your computer IP address to avoid duplicate responses in the dataset. Additionally, when information is transmitted over the internet, privacy cannot be guaranteed. There is always a risk your responses may be intercepted by a third party (e.g., government agencies, hackers).

Will my identity be known?

Your participation will be considered confidential. Individual results will not be shared. Only the research team will have access to study data. Identifying information will be removed from the data that is collected and stored separately. Your name will not appear in any paper or publication resulting from this study, however, please note that anonymous quotations may be used from your open-ended responses, and you may be referenced generally by your occupation and country of residence (e.g. Journalist, U.S.A.)]. Collected data will be securely stored for a minimum of one year in an encrypted file on a password-protected computer. You may withdraw your consent and request that your data be removed from the study by contacting the researcher within this time period. Please note that given the group format of the Delphi method, it may not be possible to withdraw all data associated with you. Additionally, it will not be possible to withdraw your data once the findings have been submitted for publication.

Has the study received ethics clearance?
This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE#41742). If you have questions for the Committee contact the Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore- ceo@uwaterloo.ca.

Who should I contact if I have questions regarding my participation in the study?
If you have any questions regarding this study or would like additional information to assist you in reaching a decision about participation, please contact Melissa Mark by email at memark@uwaterloo.ca or Derek Armitage at derek.armitage@uwaterloo.ca.

Consent Section
(To be completed at the beginning of the first survey).

Title of the study: The Gaps in the Global Governance of Sand Mining.

I have read the information presented in the information letter about a study conducted by Derek Armitage and Melissa Mark School of Environment, Resources, and Sustainability at the University of Waterloo, Canada. I have had the opportunity to ask questions related to the study and have received satisfactory answers to my questions and any additional details.

I was informed that participation in the study is voluntary and that I can withdraw this consent by informing the researcher. This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE#41742). If you have questions for the Committee contact the Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo@uwaterloo.ca.

For all other questions contact Melissa Mark at memark@uwaterloo.ca.

By providing your consent, you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

[insert check box] Yes, I give my consent to participate in this study.
[insert check box] No, I do not give my consent. (please close your browser now).

Appendix C
Survey Round One Questions

The purpose of this Delphi survey is to identify gaps in the knowledge and the global governance of sand resources. The first round of survey questions were created using five priority governance gaps outlined in the UNEP Sand & Sustainability Report as a framework. This is a two to three round survey that will seek to build a consensus among research participants about five themes influencing the governance of sand resources.

If you choose to partake in this study, your identity will not be published. However, with your permission, some selected quotes may be used. Participants will be referenced generally by occupation (e.g. government, non-government).

a) **What city and country are you based in?**

b) **Please state your profession.**

Awareness

1) In the context of your profession and location, please briefly define "governance"

2) Based on your work and experience, do you feel there is a lack of awareness (locally, globally) about the issues of sand mining? If so, what factors or critical issues (e.g., political, socio-cultural, biophysical) contribute to this awareness gap?
3) In the context of your work and experience, what are the critical strategies required to improve awareness about sand mining (e.g., it's social or ecological impacts, significance) in civil society?

Knowledge & Science

1) In the context of your work and experience, what are the critical knowledge gaps (e.g., about the resource, ecological disturbances, technology, social-ecological impacts, livelihoods) associated with the understanding and governance of sand mining (locally and globally)?
2) What priority research questions or areas of research do you feel are required to fill critical knowledge gaps?

Transparency & Accountability

1) What factors should be reflected in an ideal transparency and accountability framework for a resource such as sand that is mined regionally and traded regionally and globally?
2) What are the main issues, obstacles and/or opportunities with regard to effective transparency measures and accountability of industry, governments and multi-lateral organizations?

Stakeholder Relationships & Platforms

1) What governance *processes* (i.e., at local or global levels) for sand resources are needed to improve relationships among stakeholders and/or address critical impacts (e.g., communication, codes of conduct)?
2) What governance *arrangements* (i.e., at local or global levels) for sand resources are needed to improve relationships among stakeholders and/or address critical impacts (e.g., new rules, governing organization)?

Fragmented Participation by Key Actors

1) In the context of your work and experience, which key actor groups or stakeholders have crucial roles in the governance of sand mining?
2) In the context of your work and experience, what are the factors that are constraining the participation and co-production of effective governance among stakeholders involved in sand mining?

Reminder Email

Hello,

This is a reminder that you have agreed to participate in the study *The Gaps in the Global Governance of Sand Mining".* Thank you for your participation in the first survey round.
The data collection and analysis from the first survey is complete and the second survey can begin. I am now sending you the link to the second survey where you will be presented with the consent form. If you click "*yes"* to consent you will be brought to the second survey to complete.
The Information Letter for the study is attached to remind you of the study's details.
Please have this survey completed by September 22nd, 2020.
Thank you again for your participation in this study.

If you have any questions regarding this study or would like additional information to assist you in reaching a decision about participation, please contact Melissa Mark by email at memark@uwaterloo.ca or Derek Armitage at derek.armitage@uwaterloo.ca.

Sincerely,

Melissa Mark

Appendix D
Survey Round Two Statements

Awareness

The most important factor influencing the awareness of the impact of sand mining is:

1. People's disconnect between sand sources (a beach or riverbed) compared with the materials made from sand (glass, concrete).
2. The limited media coverage of the sand industry.
3. The belief that sand mining is only an issue in developing countries.
4. The misconception that sand will not run out.
5. The poorly funded regulatory agencies that contribute to this awareness gap.
6. The blurring of illegal mining activity with legitimate sand mining activities.

Strategies to Improve Awareness

The most crucial strategy needed to improve awareness about sand mining is to:

1. Ensure pricing of sand commodities reflects the environmental and social costs of mining activity.
2. Increase education within: schools, corporations, and the public about the environmental and social impacts of sand mining.
3. Increase education on the interdependencies between sand-based ecosystems and vulnerable communities.
4. Increase transparent media coverage of the sand industry.
5. Increase funding for research and data collection regarding the unknown environmental and social implications of sand mining.
6. Increase or start cross-sector collaboration and structured dialogue between stakeholders regarding sand mining policy (e.g. roundtable discussions to create a policy framework).
7. Improve transparency with regards to the accounting of sand needs (e.g. construction and development, technology, glass, food products, etc).
8. Improve transparency with regards prioritization of sand uses (e.g. sand use for development in a developing country is prioritized over sand use for technology in a developed country).

Knowledge Gaps

The most critical knowledge gap which pertains to sand mining is:

1. The unknown large scale and long term impacts of sand mining and its various extraction methods on other ecosystems, processes, and livelihoods.
2. The lack of data on sand resources, including assessments of sand stocks, and demand.
3. The lack of data on system recovery after mining, and the cultural and economic context of where sand mining is occurring.
4. The lack of data on sand mining operations including the organizational structure of a mine and its relationship with consumers.
5. The lack of data on current mechanisms to govern sand resources, including existing regulatory frameworks.
6. The lack of data on the relationship between illicit mining and legitimate construction.

Priority Research

The highest priority research area to understand sand mining is (rank all seven statements):

1. Quantifying sand budgets to identify a 'sustainable extraction rate'.
2. Examining the downstream impacts of sand mining on livelihoods and ecosystems.
3. Assessing the scale of global sand mining both legitimate and illegitimate.
4. Critically examining the operations of illicit mining activities.
5. Creating a framework to outline what best practices look like in the sand industry.
6. Identifying which past governance strategies lead to successful or unsuccessful outcomes in sand extraction operations.
7. Understanding how the high environmental and socio-economic costs of sand mining are passed on to local communities and broader civil society.

Transparency Framework

The most crucial factor to improve transparency and accountability in the mining of sand resources is:

1. Communication with the local communities to understand their thoughts and concerns in regards to sand mining.
2. The creation of a set of certification standards for the global sand industry similar to other commodity-based industries (e.g., forestry).
3. Increased and improved regulation as well as adequate funding for regulatory agencies.
4. The collection of accurate and transparent import and export data, monitoring of mining operations and documentation, and documentation of volumes of sand extracted and traded.
5. Improved engagement from the government with stakeholders and more stringent monitoring across all sand operations.

Transparency Obstacles

The most critical obstacle to transparency and accountability in the mining of sand resources is:

1. Poor regulation and lack of resources.
2. Sector-based corruption among government officials.
3. The diffuse locations of extraction sites which makes managing the cumulative effects of sand mining challenging.
4. Companies (often multinational) that may operate under different governance and reporting structures based on their registered country.
5. The challenge of regulating a resource that is 'transboundary' (i.e. commodity flows across countries and regions).
6. Proprietary data which industries are currently not compelled to share but which are needed for transparency and accountability.
7. The lack of common terminology which is key to understanding and governance.
8. An overall lack of data, different data collection approaches and material definitions (no standardization).
9. Lack of awareness and knowledge about sand mining and the impacts, making it difficult to communicate among stakeholders and the public.

Governance Process

A critical governance process required to improve stakeholder relationships and/or address critical impacts in sand mining:

1. Create a robust regulatory framework.
2. Establish greater enforcement of existing regulations.
3. Prioritize improved monitoring.
4. Ensure transparent reporting of operations to build public and stakeholder trust.
5. Improving partnerships and streamlining communications between various stakeholders to allow for better data collection, monitoring, assessment for short/long term impacts.
6. Foster the willingness within government agencies to listen to those without political or economic power.
7. Improved arrangements for co-governance to be adopted including different spheres of government fostering communication.
8. Sharing and promoting good examples of past successful governance processes and exchanging best practices.

Governance Arrangements

A critical governance arrangement required to improve stakeholder relationships and/or address critical impacts is:

1. Improved policy enabling law enforcement in the sand mining industry.
2. An increase in regulations for the sand industry.
3. Improvement in communications within and between government spheres and stakeholders.
4. The creation of good practice guidelines developed to an international standard to ensure uniformity.
5. Obliging policy makers to emphasize downstream checks and monitoring.
6. Appointing a non-governmental organization (NGO) or multilateral organization (e.g., UNEP or WTOP) to establish a global monitoring program.

Constraints

The primary factor which constrains the participation and co-production of effective governance among stakeholders involved in sand mining is:

1. Corruption.
2. Fear.
3. Poverty.
4. Limited scientific evidence.
5. A dominant message of economic development associated with sand mining.
6. Lack of awareness of the scale of the problem.

Appendix E
Ethics Clearance

Subject: Research Ethics - Initial application # 41742 has ethics clearance
Date: Friday, February 28, 2020 at 2:32:33 PM Eastern Standard Time
From: no-reply=kuali.co@mx3.kuali.co on behalf of Kuali Notifications
To: Melissa Elizabeth Mark

Dear Derek Armitage and other members of the research team:

Your application has been reviewed by Delegated Reviewers. We are pleased to inform you the **Initial application for 41742 The Gaps in the Global Governance of Sand Mining** has been given ethics clearance.

This research must be conducted in accordance with the most recent version of the application in the research ethics system and the most recent versions of all supporting materials.

Ethics clearance for this study is valid until Monday, March 1st 2021.

The research team is responsible for obtaining any additional institutional approvals that might be required to complete this Expedited study.

University of Waterloo Research Ethics Committees operate in compliance with the institution's guidelines for research with human participants, the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS, 2nd edition), Internalization Conference on Harmonization: Good Clinical Practice (ICH-GCP), the Ontario Personal Health Information Protection Act (PHIPA), and the applicable laws and regulations of the province of Ontario. Both Committees are registered with the U.S. Department of Health and Human Services under the Federal Wide Assurance, FWA00021410, and IRB registration number IRB00002419 (Human Research Ethics Committee) and IRB00007409 (Clinical Research Ethics Committee).

Renewal: Multi-year research must be renewed at least once every 12 months unless a more frequent review has been specified on the notification of ethics clearance. This is a requirement as outlined in Article 6.14 of the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS2, 2014). The annual renewal report/application must receive ethics clearance before Saturday, February 6th 2021. Failure to receive ethics clearance for a study renewal will result in suspension of ethics clearance and the researchers must cease conducting the study. Research Finance will be notified ethics clearance is no longer valid.

Amendment: Changes to this study are to be submitted by initiating the amendment procedure in the research ethics system and may only be implemented once the proposed changes have received ethics clearance.

Adverse event: Events that adversely affect a study participant must be reported as soon as possible, but no later than 24 hours following the event, by contacting the Director, Research Ethics. Submission of an adverse event form is to follow the next business day.

Deviation: Unanticipated deviations from the approved study protocol or approved documentation or procedures are to be reported within 7 days of the occurrence using a protocol deviation form.

Incidental finding: Anticipated or unanticipated incidental findings are to be reported as soon as possible by contacting the Director, Research Ethics. Submission of the incidental findings form is to follow within 3 days of learning of the finding. Participants may not be contacted regarding incidental findings until after clearance has been received from a Research Ethics Committee to contact participants to disclose these findings.

Study closure: Report the end of this study by submitting a study closure report through the research ethics system.

Coordinated Reviews: If your application was reviewed in conjunction with Wilfrid Laurier University, Conestoga College, Western University or the Tri-Hospital Research Ethics Board, note the following: 1) Amendments must receive prior ethics clearance through both REBs before the changes are put in place, 2) PI must submit the required annual renewal report to both REBs and failure to complete the necessary annual reporting requirements may result

in Research Finance being notified at both institutions, 3) In the event that there is an unanticipated event involving a participant that adversely affects them, the PI must report this to both REBs within 24 hours of the event taking place and any unanticipated or unintentional changes which may impact the research protocol shall be reported within seven days of the deviation to both REBs.

Initial application ethics clearance notification: Your clearance notification will be added to the record within 24 hours. Go to "View Admin Attachments" in the research ethics system (right-hand side) to print a copy of the initial application ethics clearance notification.

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Best wishes for success with this study.

If you have any questions concerning this notification, please contact the Research Ethics Office or email researchethics@uwaterloo.ca.

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Ethics Amendment Clearance

Subject: Research Ethics - Renewed application # 41742 has ethics clearance
Date: Tuesday, December 15, 2020 at 8:08:54 AM Eastern Standard Time
From: no-reply=kuali.co@mx3.kuali.co on behalf of Kuali Notifications
To: Melissa Elizabeth Mark

Dear Derek Armitage and other members of the research team:

Your application has been reviewed by Delegated Reviewers. We are pleased to inform you the **Renewed application for 41742 The Gaps in the Global Governance of Sand Mining** has been given ethics clearance.

Note: Due to the current COVID-19 situation, research activities that require face-to-face/in-person interactions cannot be conducted until all procedures for research re-start (including safety plan approval) have been completed. For all in-person research protocols please review Frequently Asked Questions, processes and forms, and restart guidance. Direct any inquires to researchethics@uwaterloo.ca.

This research must be conducted in accordance with the most recent version of the application in the research ethics system and the most recent versions of all supporting materials.

Ethics clearance for this study is valid until Tuesday, March 1st 2022.

The research team is responsible for obtaining any additional institutional approvals that might be required to complete this Expedited study.

University of Waterloo Research Ethics Committees operate in compliance with the institution's guidelines for research with human participants, the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS, 2nd edition), Internalization Conference on Harmonization: Good Clinical Practice (ICH-GCP), the Ontario Personal Health Information Protection Act (PHIPA), and the applicable laws and regulations of the province of Ontario. Both Committees are registered with the U.S. Department of Health and Human Services under the Federal Wide Assurance, FWA00021410, and IRB registration number IRB00002419 (Human Research Ethics Committee) and IRB00007409 (Clinical Research Ethics Committee).

Renewal: Multi-year research must be renewed at least once every 12 months unless a more frequent review has been specified on the notification of ethics clearance. This is a requirement as outlined in Article 6.14 of the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS2, 2014). The annual renewal report/application must receive ethics clearance before Sunday, February 6th 2022. Failure to receive ethics clearance for a study renewal will result in suspension of ethics clearance and the researchers must cease conducting the study. Research Finance will be notified ethics clearance is no longer valid.

Amendment: Changes to this study are to be submitted by initiating the amendment procedure in the research ethics system and may only be implemented once the proposed changes have received ethics clearance.

Adverse event: Events that adversely affect a study participant must be reported as soon as possible, but no later than 24 hours following the event, by contacting the Director, Research Ethics. Submission of an adverse event form is to follow the next business day.

Deviation: Unanticipated deviations from the approved study protocol or approved documentation or procedures are to be reported within 7 days of the occurrence using a protocol deviation form.

Incidental finding: Anticipated or unanticipated incidental findings are to be reported as soon as possible by contacting the Director, Research Ethics. Submission of the incidental findings form is to follow within 3 days of learning of the finding. Participants may not be contacted regarding incidental findings until after clearance has been received from a Research Ethics Committee to contact participants to disclose these findings.

Study closure: Report the end of this study by submitting a study closure report through the research ethics system.

Coordinated Reviews: If your application was reviewed in conjunction with Wilfrid Laurier University, Conestoga College, Western University or the Tri-Hospital Research Ethics Board, note the following: 1) Amendments must receive prior ethics clearance through both REBs before the changes are put in place, 2) PI must submit the required annual renewal report to both REBs and failure to complete the necessary annual reporting requirements may result in Research Finance being notified at both institutions, 3) In the event that there is an unanticipated event involving a participant that adversely affects them, the PI must report this to both REBs within 24 hours of the event taking place and any unanticipated or unintentional changes which may impact the research protocol shall be reported within seven days of the deviation to both REBs.

Initial application ethics clearance notification: Your clearance notification will be added to the record within 24 hours. Go to "Admin Notes and Files" in the research ethics system (right-hand side) to print a copy of the initial application ethics clearance notification.

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Best wishes for success with this study.

If you have any questions concerning this notification, please contact the Research Ethics Office or email researchethics@uwaterloo.ca.

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