APPLYING THE CONCEPT OF SUSTAINABLE CONSUMPTION TO SEAFOOD: HOW PRODUCT LOSS THROUGH POST-HARVEST SEAFOOD SUPPLY CHAINS UNDERMINES SEAFOOD SUSTAINABILITY

by

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ABSTRACT

To date, efforts towards seafood sustainability have almost exclusively focused on 'improvement on the water', wherein the focus is to make the production systems more eco-efficient. Significant achievements have been made using this approach, but the emphasis on creating sustainable seafood production systems has overshadowed other opportunities to advance seafood sustainability. In particular, there is growing evidence that losses of seafood products through the supply chain (either during processing, distribution, transport, retail, or at the consumer level) may have an important cumulative impact on the overall sustainability of seafood systems. This projects aims to better understand the degree of seafood loss in North American and European post-harvest seafood supply chains (PHSSC) based on interviews with 17 key informants and a meta-analysis of current literature. The data suggest that significant waste is occurring along PHSSCs and that, cumulatively, between 1.34 and 2.37 units of seafood need to be produced for every one unit of seafood consumed. Seafood losses were found to be greater and more variable for fresh seafood than for frozen seafood, and highest loss rates were recorded at the consumer level (25-40%) and at the retail level (1.63-12%). These nodes of the supply chain are priority points for future research and management considerations. A number of short- to medium-term management strategies are provided to begin addressing the issue of seafood loss and that aim to support a broader transition towards sustainable consumption practices within of seafood systems.

Keywords: seafood loss; seafood supply chains; sustainable seafood; sustainable consumption and production; food waste

ABBREVIATIONS

ERS	Economic Research Services
FAO	Food and Agriculture Organization
FSC	Food Supply Chain
NFCS	Nationwide Food Consumption Survey
NGO	Non-Governmental Organization
NHNES	National Health and Nutrition Examination Survey
PHSSC	Post-Harvest Seafood Supply Chain
SCP	Sustainable Consumption and Production
SSM	Sustainable Seafood Movement
StatsCan	Statistics Canada
WSSD	World Summit on Sustainable Development
WRAP	Waste and Resource Action Programme
UNCED	United Nation Conference on Environment and Development
UNEP	United Nations Environment Programme

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CHAPTER 1. INTRODUCTION

The global supply of seafood has reached unprecedented scales. In 2010, a record 128 million tonnes of food fish were produced (Food and Agriculture Organization (FAO), 2012). This growth is driven in part by the growing human population, but more prominently by an increasing per capita consumption rate. The world per capita food fish supply has nearly doubled over the past half century from 9.9 kg in the 1960's to 18.4 kg in 2009 (FAO, 2012). Unfortunately, this has not come without cost as nearly 30% of global fish stocks have been deemed over exploited and another 57% are considered fully exploited (FAO, 2012). Research from the past four decades has extensively documented the numerous, widespread ecosystem impacts resulting from the industrialization and growth of global fisheries (*e.g* Hilborn et al., 2003; Jennings & Kaiser, 2002; Pauly, Christensen, Dalsgaard, Froese, & Torres Jr., 1998; Pauly et al., 2002). Many have gone as far as to argue that we have reached, or even perhaps exceeded, the global carrying capacity for fisheries (Worm et al., 2006). It is true, after all, that overall landings from world capture fisheries have remained stable since the late 1980's at approximately 90 million tonnes per year despite technological advances that have allowed for the expansion and increased efficiency of fishing fleets (Pauly et al., 2002; Pauly, Watson, & Alder, 2005; Stone, 1997).

In order to account for the shortfall in supply from capture fisheries relative to the growing demand for seafood, aquaculture – the farming of aquatic organisms – has been heavily developed. Aquaculture is now considered to be the fastest growing agroindustry in the world and accounted for 47% of all food fish consumed in 2008 (FAO, 2012). Because of this, there is great hope and growing expectations of the role that aquaculture

will play in the future of food systems, particularly with respect to food security, raising nutritional standards and alleviating poverty (Tacon, 2000; Thompson & Subasinghe, 2011). Aquaculture, however, is no silver bullet as it too has associated costs and tradeoffs. There are ongoing concerns about - and in some contexts opposition to – aquaculture as the environmental impacts of some farmed seafood become better understood (including *inter alia* habitat destruction, disease transmission, and antibiotic and chemical use).

When the anticipated growth in demand for seafood is set against the backdrop of depleting fish stocks and the environmental concerns of aquaculture, the future of seafood becomes a point of concern. Worm et al. (2006) emphasized this point of view for the future of seafood when they predicted that global fisheries would collapse by 2048 should fisheries practices carry on with business as usual. This paper has been openly criticized and heavily scrutinized since its publication (Branch, 2008; Hilborn, 2007; Murawski, Methot, Tromble, Hilborn, & Briggs, 2007). Since, Worm has came out with a less alarmist perspective after further research showed that, despite the majority of fish stocks still being below target numbers, fishing pressure had been reduced significantly in five of the ten ecosystems reviewed in this later study (Worm et al., 2009). Ultimately, the debate around the future of seafood continues with vocal critics and promoters associated with both fisheries and aquaculture, suggesting that the most certain conclusion that can be drawn is that the future of seafood remains uncertain.

There are, indeed, some clear areas of opportunity and avenues for sustainable alternatives that provide some sense of optimism for the future of seafood. The coarse-grained picture painted above, for example, fails to acknowledge that not all fisheries are

on the brink of collapse or that aquaculture can be carried out in ways that minimize its impact to the natural environment. A major part of the challenge to date, however, has been to find effective ways to provide an incentive for more sustainable fisheries practices and give appropriate recognition to those adopting such practices. The sustainable seafood movement has evolved to address this challenge. Inclusive of scientists, conservationists, political leaders, seafood producers, seafood handlers, and the public, the sustainable seafood movement, which began in the 1990's, is a diverse, international, multi-stakeholder community committed to promoting sustainable seafood systems (Ward & Phillips, 2008). The movement has primarily adopted a variety of initiatives focused at both major buyers (such as ecolabeling and certification) and the general public (social marketing techniques including labeling and wallet cards) to increase consumer awareness around the sustainability implications of seafood. After some fifteen years of active campaigning, the effectiveness of the sustainable seafood movement is becoming a point of growing debate. Many have argued that, for a number of reasons, the sustainable seafood movement is simply not creating change at the scale or speed required to meet present challenges (*e.g.* Jacquet & Pauly, 2007; Kaiser & Edwards-Jones, 2006; Tlusty et al., 2012; Ward, 2008).

One uncommonly cited, but undoubtedly pertinent, criticism of the sustainable seafood movement is the narrow approach that it has taken in the pursuit of sustainability. To date, the movement has almost exclusively promoted seafood sustainability through the lens of sustainable production; holding strong to the belief that eco-efficiency in seafood production will support a sustainable seafood system. The blind faith placed in

this belief must be questioned, particularly in light of the observed trend of increasing consumption and demand for seafood.

The need to address consumption patterns as well as production practices in order to successfully achieve sustainability is being gradually recognized across disciplines. The growing body of recent research conducted on the topic of food waste serves as a prime example. Waste is a physical manifestation of unsustainable consumption, representing not only a loss of the wasted resource, but also a misuse of the secondary resources used in the lifecycle of that product. Estimates suggest that food waste is no small issue: according to one study, some 30-50% of all food produced is wasted before ever being consumed (Gustavsson, Cedergberg, Sonesson, van Otterdijk, & Meybeck, 2011). Most estimates of food waste currently available are relatively high-level and broad, while few have focused specifically on seafood (Parfit, Barthel, & Macnaughton, 2010; Hall, Guo, Dore, & Chow, 2009). Should numbers such as those estimated by Gustavsson et al. (2011) hold true to seafood systems, however, it would suggest that there are significant opportunities to advance the economic, social and environmental sustainability of seafood systems by addressing seafood losses through the supply chain.

1.1 The Sustainable Seafood Movement

The sustainable seafood movement (SSM) gained traction through the 1990's as it became increasingly evident that seafood production practices were having significant ecological impacts and many lacked confidence in the ability of governments to implement effective management practices that would sufficiently address the issues. The cornerstone of the movement has been a sweep of social marketing techniques that aim to promote consumer awareness around seafood sustainability that drive change of on-the-

water practices through market demand (Ward & Phillips, 2008; Parkes, 2009). Ecolabels – a labelling system wherein seafood products are branded based on various sustainability criteria – have become almost synonymous with the movement. In theory, ecolabels aim to promote sustainable fishing and farming practices by fostering consumer demand for sustainably sourced seafood products, which ultimately shifts sourcing policies throughout the supply chain (Jacquet & Pauly, 2007). The concept, stemming from well-founded intentions, is attractive to many of the involved stakeholders: fishers and farmers, buyers, retailers, consumers, policy makers and resource managers all have the potential to benefit from effective ecolabeling campaigns (Deere, 1999; Ward & Phillips, 2008).

Awareness campaigns of diverse nature have also played a significant role in the movement. Educational campaigns have increased understanding and dialogue around the concept of sustainability as it relates to seafood. A prime example being the Monterey Bay Aquarium's Seafood Watch Program, which has distributed over one million SeafoodWatch pocket guides that code the sustainability of seafood products using the stop-light (red, yellow, green) system (Jacquet & Pauly, 2007). On the other end of the spectrum, species-specific campaigns and in some instances boycotts have managed to make the trade and consumption of particularly vulnerable species a social *faux pas*. The "Take a Pass on Chilean Sea Bass" campaign, for example, saw over 700 American chefs take a pledge to stop serving this species whose population is threatened by harmful fishing practices (Handwerk, 2002). Despite key successes such as these, the tangible impacts of the SSM to change market demand and on-the-water practices have been poorly evaluated (Jacquet et al., 2010; Stockstad, 2011; Tlusty, 2012). Now, after some

fifteen years of implementation, questions about the efficacy and broader applicability of the strategies employed by the SSM are becoming common within the seafood sector (Nilsson et al., 2004; Stockstad, 2011; Ward, 2008). Undoubtedly, the SSM has seen both successes and failures and has received both criticism and praise – all of which have been warranted to some degree (*e.g.* Jacquet & Pauly, 2007; Jacquet et al. 2010; Nilsson et al., 2004; Stockstad, 2011; Ward, 2008).

In addition to the internal debates about the effectiveness and success of the SSM, a broader concern is beginning to emerge: that environmental gains achieved through the promotion of production efficiency are being offset by consumption growth (Luskin & Del Matto, 2007, Clark, 2007; Jacquet et al. 2010). This phenomenon –known as the rebound effect or Jevon's paradox – has most widely been applied within the field of energy economics after first being described in 1865 by British economist, William Stanley Jevons, in relation to increased efficiencies of coal use. Jevons noted that technological efficiency gains in coal-fired engines did not actually lead to a decrease in coal use, but rather an increase in overall consumption of coal, iron and other resources (Alcott, 2005). This concept maintains applicability to, and potentially profound implications for, seafood resources and seafood sustainability given the strict focus on achieving sustainability by encouraging eco-efficient seafood production strategies. This is particularly true in light of the recent trend for large companies to adopt sustainable seafood sourcing policies as part of their corporate social responsibility platform[1].

[1] For example Loblaw's - Canada's largest seafood buyer - has committed to sourcing 100% of its seafood from sustainable sources by 2013 (Loblaw Companies Ltd., 2012). Walmart Canada made a similar commitment in 2011 stating that they would carry 100% sustainably-sourced frozen, wild and farmed fish by 2013 (Walmart Canada Corp., 2011)

Although such action holds great potential for positive change, it has also pushed the concept of sustainable seafood into the realm of large-scale market economies.

The fact that per capita world food fish supply has increased on average by 3.2% per year since 1961, reaching a historical high of 18.4 kg per capita in 2009 (FAO, 2012), highlights that the SSM has had little to no influence in curbing the overall demand for seafood. Admittedly, the goal of the SSM has been to shift consumer demand towards more sustainably produced seafood products and had no specific intention to reduce overall demand. With an ever growing global population and increasing per capita consumption, however, it is imperative that the 'consumption' aspect of seafood markets are also held to the bar of sustainability.

1.2 Broadening the Concept of Sustainability

Many have argued over recent years that the SSM has plateaued (Iles, 2007; Jacquet et al., 2010; Konefal, 2012); the current market share for ecolabeled products remains relatively small (Washington, 2008; Golden, 2010), the breadth of engaged consumers is narrow (Jacquet & Pauly, 2007; Johnston & Roheim, 2006; Teisl, Roe & Levy, 1999), and the ever-growing number of ecolabels has created confusion and sparked much debate (Washington, 2008). Tlusty et al. (2012) argue that this reality is reflected in the evolution of the language used in reference to the SSM. The authors identify that there has been a fundamental shift wherein the initial goal of the SSM was to achieve "seafood sustainability", which describes an ongoing process, but now more declarative statements such as "sustainable seafood" are used, which suggest the completion of an objective. The authors state "this change in reference from a continual

process (a journey) to a static point (it is sustainable) limits further advances in seafood sustainability and the drive for continual improvement" (p. 1).

Despite the diversity in campaigns and attempts to broaden the reach of seafood sustainability initiatives (*e.g.* development of mobile apps, growing focus on targeting buyers and retailers), the SSM to date remains narrowly focused on achieving seafood sustainability by making the production component (*i.e.* on-the-water practices) of the seafood supply system more eco-efficient. The emphasis on creating sustainable seafood production systems has arguably caused other opportunities to foster seafood sustainability to be overlooked. This issue is not unique to seafood sustainability; the past decade has seen a growing awareness that sustainability is more than just creating sustainable industrial processes, but that the concept must also account for and promote sustainable products, services and consumption (Barber, 2007; Luskin & Del Matto, 2007, Kronenberg, 2007).

The concept of Sustainable Consumption and Production (SCP) emerged from the 1992 UN Conference on Environment and Development (UNCED), which identified that the excessive consumption patterns of industrialized societies were having a direct impact on the environment. The 1994 Oslo Symposium on Sustainable Consumption formalized the definition of sustainable consumption to mean "the use of goods and services that respond to basic needs and bring a better quality of life, while minimizing the use of natural resources, toxic materials and emissions of waste and pollutants over the life cycle, so as not to jeopardize the needs of future generations" (Norwegian Ministry of Environment, 1994 as cited in Seyfang, 2004, p.324).

Furthering the concept, the 2002 World Summit on Sustainable Development (WSSD) recognized that "[f]undamental changes in the way societies produce and consume are indispensable for achieving global sustainable development" (p.7, United Nations, 2002) and, as such, made SCP a component of the second pillar in the *Plan of Implementation of the World Summit on Sustainable Development*. The *Plan of Implementation* called for

> the development of a 10-year framework of programmes in support of regional and national initiatives to accelerate the shift towards sustainable consumption and production to promote social and economic development within the carrying capacity of ecosystems by addressing, where appropriate, delinking economic growth and environmental degradation through improving efficiency and sustainability in the use of resources and production processes and reducing resource degradation, pollution and waste. **(**p.7, United Nations, 2002**)**

The ability to develop such a framework has seen mixed success internationally. In 2008, the European Union (EU) endorsed the *Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan* outlining the building blocks for the EU's policies on SCP (European Commission, 2013). In North America, the SCP movement has been defined as "a convergence of networks, organizations and individuals often committed to different environmental, social and economic issues and concerns yet linked by an understanding and effort to change at least some aspect of the production and consumption patterns" (Barber, 2007, p.1). Despite the diverse approaches taken to promote SCP, in all instances the efforts towards promoting sustainable production have heavily outweighed those in support of sustainable consumption. The two concepts, however, are complementary and are unlikely to effectively support sustainable development if applied singularly (UNEP, 1992).

The hesitancy with which the concept of sustainable consumption is being approached is not surprising; consumption and trying to define what a sustainable level of consumption entails is a sensitive subject that faces numerous debates, many of which are values-laden. Mont and Plepys state that the questions that emerge from this concept "clash with a number of personal, political and economic interests of different stakeholders and are therefore difficult to deal with" (p. 531, 2008). In few circumstances is this truer than in the context of sustainable consumption of food. Since food is a basic human need, few are willing to begin the conversation around – let alone try to define or set limits to – what might be a sustainable consumption level. Leverage into the topic may be gained, however, by addressing whether or not food resources are being used sustainably. The reality of food loss through the supply chain, which is believed to be upwards of 30% of overall production (Institution of Mechanical Engineers, 2012; Gustavsson et al., 2011; Buzby, Hyman, Stewart, & Wells, 2011; Lundqvist, de Fraiture, & Molden, 2008), suggests that the attitude of convenience and disposability with which we approach our food systems may have important sustainability implications.

1.3 Food Loss Research To Date

Food loss through the supply chain has been acknowledged for many years, but efforts to address the issue have occurred only intermittently over the past half-century. The movement to reduce hunger, malnutrition and food inequality that began in the 1960's provided the first medium through which to address the issue of food losses (Ashburner, 1998). In 1974 the Food and Agriculture Organization's Food Security Programme was launched and by 1977 the Special Action Programme for the Prevention of Food Losses was established to help operationalize the United Nations' commitment to

reducing global food losses by 50% by 1985 (Parfitt et al., 2010). Through these early years of discussion much of the focus was placed on reducing losses of durable grain, but this was later expanded to include fresh vegetables, fruits, roots and tubers (Parfitt et al., 2010). Unfortunately, there were few, if any, tangible achievements that resulted from these initial international efforts to address food loss.

Many attempts to quantify the degree of global food loss through the supply chain have been made over the past two decades (FAO, 1989; Hanley, 1991;Parfitt et al., 2010). This type of assessment is challenging, however, because the limited data available are typically collected across food supply chains at different scales and, as discussed in section 1.3.1, is subject to ambiguity in definition. One of the earliest food loss reports, published by the United States National Research Council in 1978, concluded "[i]n certain cases, it may never be possible or economically feasible to estimate losses, whether of weight, quality, or nutritive value, with any statistically significant degree of accuracy" (p.166). Although some advances have been made in the methodology of food loss research, the statement above still holds true and, as such, most of the estimates available are relatively broad and provide little resolution across or between different food supply chains.

Gustavsson et al. (2011) conducted one of the most up-to-date and detailed global food loss studies that, resultantly, has become one of the most cited pieces of literature in the field of food loss. The authors used mass flow models to analyze losses occurring along the entire supply chain in seven different geographic regions for seven

commodities[2]. The final estimate suggested that roughly one-third of food produced for human consumption is lost globally (approximately 1.3 billion tons per year), but great variability exists between product types, across geographic locations and through the supply chain.

Aside from this report, research on the topic of food loss is sporadic at best. Smil (2000) compiled much of the research completed on food intake across different countries to show that even the highest reported average per capita consumption rate was nearly 1,000 kcal a day less than the global per capita supply. In 2010, another literature review was conducted which compiled food loss rates within supply chains, specifically for rice and fresh fruits and vegetables (Parfitt et al, 2010). Also noteworthy is the sweep of research and initiatives conducted by the Waste and Resources Action Programme (WRAP), a not-for-profit organization based in the United Kingdom (UK), that partners with residents, companies and government to reduce waste and promote recycling throughout the UK. WRAP released a report in 2008 titled *The Food We Waste* that quantified and analyzed the composition of food waste from UK households. Although an extremely useful endeavour, the results do not shed any insight on the proportion of food loss relative to production, but rather provides an in depth examination of the composition of household food losses.

The other principal source of food loss data is made available through national surveys on food availability. The Economic Research Service (ERS) of the United States Department of Agriculture, for example, has records of annual per capita food availability

[2] The seven commodities included in the mass flow modeling by Gustavsson et al. (2011) were cereals, root & tubers, oil crops & pulses, fruit & vegetables, meat, fish, and dairy

dating back to 1909 for several hundred commodities. They have also calculated "loss-adjusted food availability" for each of these commodities based on two major periodic food intake surveys – the Nationwide Food Consumption Survey (NFCS) and the National Health and Nutrition Examination Survey (NHANES). These national statistics appear to be some of the most comprehensive data sets available that are pertinent to food loss, however they are not particularly robust. Smil (2000) discusses how the complexity of estimating food supply, food losses, and food intake creates an inherent weakness in any effort to estimate overall losses. Additionally, the expense of conducting such surveys and reporting the data are rather inhibitive to many developing countries meaning that only an incomplete picture can be drawn from these data.

The food loss estimates cited here represent the leading examples of food loss research to date, although is it by no means a complete list. The limited work that has been completed, however, has demonstrated that estimating food loss is by no means an easy task for many reasons from a lack of standardized definitions to varying availability and scales of data sets. Resultantly, the estimates available for food loss remain broad and relatively non-descript – especially in the context of seafood.

1.3.1 Defining Food Loss

There are a number of definitions applicable to the concept of food loss. In the crudest sense, food loss is defined as "wholesome edible material intended for human consumption, arising at any point in the [food supply chain] that is instead discarded, lost, degraded or consumed by pests" (FAO, 1981). A more recent definition by Stuart (2009) includes edible material that is intentionally fed to animals or is a by-product of food processing diverted away from human food. Further still, Smil (2004) suggests that food

loss should also include over-nutrition – "the gap between the energy value of *consumed* food *per capita* and the energy value of food *needed per capita*" (as cited in Parfitt et al., 2010, p. 3065). All of these definitions are correct in their own way, but represent a progression in stringency as to what we may collectively define as 'lost food'. The latter of the three is by far the most stringent because it actually includes individual consumption choices (*i.e.* overconsumption) to the concept of food loss.

Further confusion with respect to defining food loss results from the significant variation in the terminology used in relation to the concept of food loss; common terms include 'food loss', 'food waste', 'shrink', 'spoilage' and 'discards'. To date, there has been little consistency with which different terms have been applied, however increasing awareness of the topic and a growing body of literature has highlighted the need to adopt a clear, harmonized set of definitions. Greater differentiation is being made in the literature, for example, between 'food loss' and 'food waste' whereby the former is used to define food that is lost before it reaches the consumer due to spilling or spoilage through the supply chain, while the latter refers to food that is fit for human consumption but does not get consumed because it is discarded (Gustavsson et al, 2011). Despite recent efforts to better delineate definitions around food loss, the inconsistencies in vernacular present a significant challenge when trying to collate and compare information across varying sources.

For the purpose of this paper, 'food loss' is considered to be any product or portion of product that was intended for human consumption but is disposed of due to spill, spoilage, or degradation, resulting in the complete removal of that product from the food system.

1.3.2 Food Loss Through The Supply Chain

Food loss may occur for a variety of reasons at all points throughout the food supply chain (FSC). The complexity and length of FSCs will differ based on the type of food product, its country of origin and its destination, but in general five nodes can be identified: production, processing, distribution, retail and consumption. Food loss can (and does) occur at each of these five nodes, however loss rates and reasons for loss will vary depending on the FSC in question. The reasons for food loss that are most common and relevant to seafood supply chains are presented in Table 1.

Table 1: Description of possible reasons for seafood loss at each stage of a simplified food supply chain (FSC).

Supply Chain Node	Example/reason for food loss
Production	Discards from fishing, by-catch, stock loss due to disease or escapes, inadequate storage after harvest, etc.
Processing	Trimmings from processing, loss of quality due to poor handling practice, floor losses
Distribution	Spillage, floor losses, degradation of product during transport/handling,
Retail	Does not sell before 'sell by date', compromised package, loss of quality
Consumption	Not used before 'best before date', plate scrapings, poor food preparation technique

By reviewing the diversity in reasons for seafood loss through the supply chain it becomes evident that the issue of loss is not attributable to a single player. Indeed, small amounts of loss along the supply chain may potentially have significant cumulative impacts and losses that occur later in the supply chain (*i.e.* at retail or consumer level) will compound any impacts associated with the production methodology. For this reason, identifying loss rates for each node in FSC is critical because it highlights where along the supply chain lie the greatest areas for opportunity to address food losses. This also

provides the opportunity to tailor management approaches that address the specific reasons for loss at the various nodes.

1.4 Project Scope and Objectives

Estimates of food loss through the supply chain, although broad and often ill defined, suggest that losses of seafood through the supply chain may hold important implications for the overall sustainability of seafood systems. Despite the extensive amount of work that has been done to date to promote seafood sustainability, surprisingly little consideration has been paid to the issue of seafood waste and loss. As the demand for seafood continues to increase despite growing concerns about the environmental impacts of seafood production, it is imperative that broader approaches are taken to forward the goal of sustainability. In particular, seafood sustainability must account for both the sustainable production and the sustainable consumption of seafood products.

This project aims to begin the conversation of sustainable consumption of seafood products by exploring the reality of seafood losses through the postharvest supply chain. By conducting a thorough literature review and series of interviews with key informants along the seafood supply chain, the author intends to develop a better understanding of the degree of, reasons for, and variation in seafood losses both along and between the post-harvest component of seafood supply chains. This will ultimately provide important baseline information as to the potential impact of seafood losses, as well as allow for the identification of priority management areas within the stages of the seafood supply chain that will need to be addressed to reduce postharvest losses. The specific research questions that this project sets out to address are:

- Where along the post-harvest seafood supply chain are losses occurring?
- Is there a variation in loss rates between different seafood supply chains (fresh/frozen/live and shellfish/finfish)?
- What is the potential cumulative impact of seafood losses through post-harvest seafood supply chains?
- What key factors are driving post-harvest seafood losses?
- What mechanisms (if any) are currently in place to address the issue of seafood loss?

1.5 Report Structure

This report is structured into three chapters and 2 appendices. This chapter, chapter 1, serves as a general introduction to the project. It outlines the broader concepts and context for the research, primarily addressing the state of seafood production, efforts to date to promote seafood sustainability, the need to broaden the concept of sustainability to include sustainable consumption, the potential implications of food loss through the supply chain and how this may apply to seafood systems. Furthermore it outlines the research purpose, questions and structure of this report.

Chapter 2 delves into the research methods and results of seafood losses through the post-harvest supply chain across various seafood product types, as well as provides a broad discussion on the impacts of post-harvest seafood losses and identifies a number of potential opportunities to address the issue. This chapter was written as a stand-alone draft manuscript with the intent of submission to the *Journal of Cleaner Production* and as such is structured as per the 'Guide to Authors' for that journal. This paper will be submitted as co-authored by myself, Jenna Stoner, and my academic supervisor, Dr. Peter Tyedmers.

Chapter 3 concludes this project report by discussing, in further detail, some of the key reasons for including post-harvest seafood losses in the pursuit of seafood

sustainability, limitations of this research, and reiterates the available opportunities to address the issue by providing targeted short-term and long-term management recommendations.

CHAPTER 2. APPLYING THE CONCEPT OF SUSTAINABLE CONSUMPTION TO SEAFOOD: HOW PRODUCT LOSS THROUGH THE POST-HARVEST SEAFOOD SUPPLY CHAIN UNDERMINES SEAFOOD SUSTAINABILITY

2.1 ABSTRACT

To date, efforts towards seafood sustainability have almost exclusively focused on 'improvement on the water', wherein the focus is to make the production systems more eco-efficient. Significant achievements have been made using this approach, but the emphasis on creating sustainable seafood production systems has overshadowed other opportunities to advance seafood sustainability. In particular, there is growing evidence that losses of seafood products throughout the supply chain (either during processing, distribution, transport, retail, or at the consumer level) may have an important cumulative impact on the overall sustainability of seafood systems. Here, we provide information on seafood loss throughout North American and European post-harvest seafood supply chains (PHSSC) based on interviews with 17 key informants. The data suggest that significant waste is occurring along PHSSCs and that, cumulatively, between 1.34 and 2.37 units of seafood need to be produced for every one unit of seafood consumed. Seafood losses were found to be greater and more variable for fresh seafood than for frozen seafood, and highest loss rates were recorded at the consumer level (25-40%) and at the retail level (1.63-12%). These nodes of the supply chain are priority points for future research and management considerations. The article concludes by urging all individuals and organizations interested in improving the sustainability of seafood systems to start including the issue of seafood loss, and more broadly the concept of sustainable consumption of seafood, into their current initiatives, goals and visions to support a future of seafood sustainability.

2.2 INTRODUCTION

Since its inception in 1987, the concept of sustainable development has become a collective societal goal. As early as 1992, during the UN Conference on Environment and Development (UNCED), it was recognized that our ability to achieve the goal of sustainable development hinges on the promotion and adoption of *both* sustainable production practices and sustainable consumption. The two concepts are deemed to be complementary and unlikely to effectively support sustainable development if applied singularly.

In nearly all instances, however, efforts towards promoting sustainable production have heavily outweighed those in support of sustainable consumption (Luskin & Del Matto, 2007; Mont & Plepys, 2008; Tucker et al., 2008). The pursuits for cleaner production strategies and eco-efficiency have become synonymous with sustainability. Indeed, some have argued that innovations in sustainable production will be sufficient to achieve sustainable development (Department for Environment, Food and Rural Affairs, 2003; Organization for Economic Co-operation and Development (OECD), 2002). This point of view suggests that sustainable consumption will be achieved solely through the consumption of sustainably produced goods. Others have refuted this point of view, referring to it as "weak sustainable consumption", because it speaks only to changing patterns of consumption and does not address the issue of current consumption levels (Douthwaite, 1992; Fedrigo & Hontelez, 2010; Lorek & Fuchs, 2011; Schumacher, 1973; Seyfang, 2007).

It cannot be debated that sustainable production plays a key role in the pursuit of sustainable development and that, in essence, sustainable consumption should entail the consumption of sustainably produced products. In recognition that our global society needs to live within set ecological limits, however, the concept of sustainable consumption must also account for the utilization of products. This point was highlighted in 1994 by the Oslo Symposium on Sustainable Consumption when it formally defined sustainable consumption as "the use of goods and services that respond to basic needs and bring a better quality of life, while minimizing the use of natural resources, toxic materials and emissions of waste and pollutants over the life cycle, so as not to jeopardize the needs of future generations" (Norwegian Ministry of Environment, 1994 as cited in

Seyfang, 2004, p.324). This definition, like that of sustainable development, is rather ambiguous; leaving it open for interpretation and fueling debate over how rigidly the concept should be adopted. It does, however, pointedly suggest that sustainable consumption is about the *use* of goods and services. The *Plan of Implementation of the World Summit on Sustainable Development*, released in 2002, furthers the link between sustainable consumption and the use of products as it called for an accelerated shift towards sustainable consumption and production by "improving efficiency and sustainability in the use of resources and production processes" (p.7, United Nations).

How then do we begin to define what is an efficient and sustainable use of resources? This question has become increasingly common over the past decade, as many believe that the "weak" approach to sustainable consumption is not providing the scale of change needed to appropriately address the challenges that face today's society (Gonez, Skirke, Kleizen & Barber, 2007; Mont & Plepys, 2008; Seyfang, 2007; World Economic Forum, 2011). The most typical responses speak to reducing material consumption and waste, shifting towards service-based consumption (as opposed to product-based consumption), and supporting a movement towards de-growth. The topic becomes more sensitive, however, when addressed in the context of food; as a basic human need, few are willing to begin the conversation around – let alone try to define or set limits to – what might be a sustainable consumption level for food.

One point of leverage into the conversation of sustainable consumption of food is to begin by addressing food loss and waste. Waste by definition is to "use, expend carelessly, extravagantly or to no purpose" (Oxford Dictionaries, n.d.) and, hence, represents a physical manifestation of unsustainable consumption. Oelofse & Nahman

(2012) aptly describe food waste as having "a triple negative impact" (p.85) because it exacerbates the issue of food insecurity, it is wasteful of resources used in the production, processing and transportation of food, and the disposal of food waste has widespread environmental impacts. Although research into food waste is not itself new, the focus of the research has evolved over the past decade. Earlier research concentrated on reclaiming food waste and producing secondary products (*i.e.* increasing the efficiency of the system), while more recent work has considered the sustainability implications (societal, economic and environmental) of food waste. The proliferation of large international and national campaigns such as "Love Food, Hate Waste" in the United Kingdom, "Think.Eat.Save" by the United Nations Environment Programme, Food and Agriculture Organization and Mese Dusseldorf, as well as "FoodWise" in Australia are statements to the growing concerns around food waste. Indisputably, these campaigns and recent research have made great advances in bringing the issue of food waste to the forefront, but they remain relatively high-level and broad in scope. Little work has been done to date that aims to connect the issue of food loss through the supply chain to the overall sustainability of a specific food product (see Beretta, Stoessel, Baier & Hellweg, 2013; Gooch, Felfel & Marenick, 2010; Gustavsson et al., 2011; Gunders, 2012; Institution of Mechanical Engineers (IMECH), 2012).

Seafood presents a prime case study to begin exploring the sustainability implications of food loss through the supply chain. In the face of ongoing challenges to effectively manage many capture fisheries and limit environmental degradation associated with some forms of aquaculture, a variety of strategic efforts to promote seafood sustainability have been undertaken since the early 1990's. A myriad of

awareness campaigns, ecolabels and social-marketing tools have been created to educate and empower consumers and to pressure retailers to make more informed decisions about the seafood that they purchase (Ward, 2008). The underlying hope being that this would create a sufficient shift in market demand towards sustainably sourced seafood to drive change of on-the-water practices. These efforts are a characterization of taking the weak approach to sustainable consumption as they focus almost exclusively on encouraging seafood buyers (both individual and commercial) to purchase sustainably produced seafood products.

The success of these efforts to effectively shift consumer demand towards more sustainably produced seafood is a point of debate (Kaiser & Edwards-Jones 2006; Jacquet et al. 2009; Tlusty, 2012; Ward 2008), but one that is perhaps moot given that, overall, seafood consumption rates have reached historical highs and are anticipated to continue rising with the projected increase in human population and growth in wealth (FAO, 2012). This increasing demand for seafood is putting significant pressure on fisheries and aquaculture industries to grow despite ongoing concerns about the sustainability of fish stocks and environmental impacts of some aquaculture productions practices (Naylor et al., 2009; Pauly et al., 2002; Pitcher & Cheung, 2013). Resultantly, the need to question how seafood is being used becomes ever more pertinent if we wish to promote sustainability within seafood systems.

Recent studies of global food waste have estimated that 30-50% of all food produced is lost before being consumed (Gustavsson, 2011). If this is the case for seafood, then the discarding of product prior to consumption may negate all of the "on the water" sustainability gains implemented at the point of production. Unfortunately,

much of the research done to date on food loss has been conducted at broad scales and results are typically poorly resolved – especially in the context of seafood. There has yet to be an assessment of loss within seafood supply chains and how this may vary between product categories such as fresh and frozen, which impedes the ability to devise focused policy and management solutions for the issues at hand. This study aims to better understand where losses are occurring through the post-harvest components of seafood supply chains and provide insight into the variability of loss rates between major seafood product categories. The results lead to a discussion about how seafood losses pertain to the goal of seafood sustainability and the need for all individuals and organizations interested in improving the sustainability of seafood systems to adopt sustainable consumption as a central tenet of their work. Finally, some preliminary suggestions for opportunities to address seafood loss through the supply chain are presented.

2.3 METHODS

2.3.1 Goals And Scope

This study aims to gain a better understanding of the sustainability implications of post-harvest seafood losses. To address this point the following questions were used to guide the research:

- Where along the post-harvest seafood supply chain are losses occurring?
- Is there variation in loss rates between different seafood supply chains (fresh/frozen/live and shellfish/finfish)?
- What key factors are driving post-harvest seafood losses?
- What mechanisms (if any) are currently in place to address the issue of seafood loss?
- What is the potential cumulative impact of seafood losses through the post-harvest seafood supply chain?

For this study, the term 'food loss' is defined as any product that was intended for human consumption but gets disposed of due to spill, spoilage, or degradation, resulting in the redirection of the product from the human food system. Under this definition, product that is downgraded (*e.g.* made into pet food, fertilizer or some other secondary product) is not considered a loss because some benefit is still being extracted from the resource. In other words, this definition is entirely relative to edible portions of seafood and intentionally excludes by-products from processing. This definition is more lenient than that taken by recent studies on food loss. Smil (2004), for example, included overconsumption as a component to food loss. Although strong arguments have been made in support of adopting more strict definitions for food loss (Stuart, 2009; Gustavsson et al., 2011), it was determined that the more lenient definition was most applicable to seafood systems at this time due to scarcity of data and potential inconsistencies in recording and reporting other more subtle forms of losses between different companies. Taking this approach also ensures that the loss rates presented herein are conservative and can aptly be compared between the nodes of the post-harvest seafood supply chain (PHSSC).

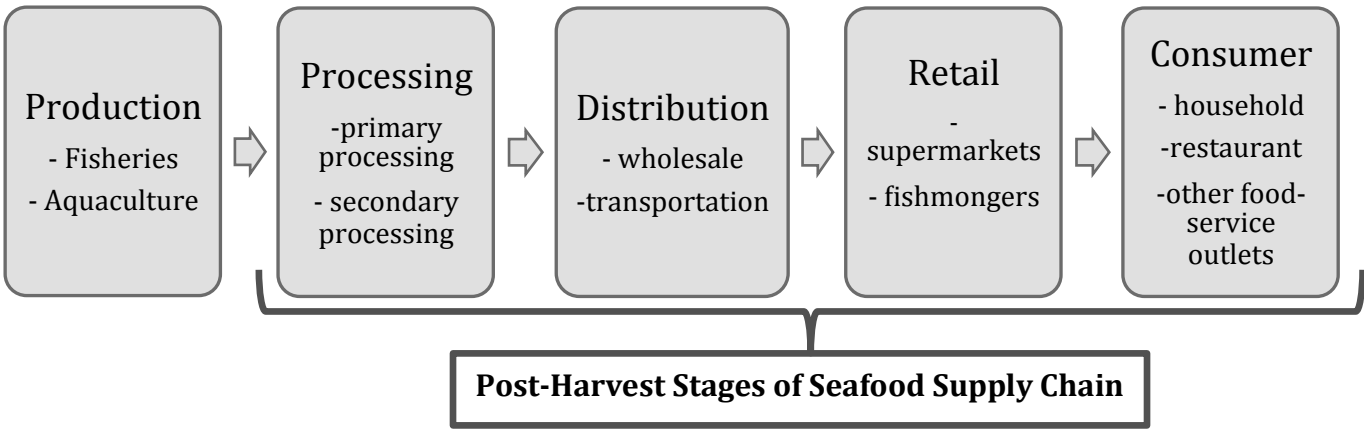

Figure 1: A simplified diagram of the seafood supply chain identifying what stages are included in the 'post-harvest' component.

The PHSSC is defined to include all stages of handling subsequent to the production of seafood, which are identified as processing, distribution, retail and consumer (Fig. 1). By focusing on the post-harvest component of the supply chain, losses that occur during production such as by-catch, improper storage and fishing discards for fisheries or loss due to disease or escapes in aquaculture are not included. Admittedly, these production losses can be significant and play a major role in overall sustainability. They were excluded from this research, however, because they are specific to production method and species, and it is very challenging to find accurate and applicable data at this level despite ongoing research on the issue (*e.g.* Alverson, 1994; Kelleher, 2005; Zeller & Pauly, 2005).

2.3.2 Literature Review

In order to consolidate existing estimates of seafood loss, compare between existing data, and identify gaps in existing literature, a thorough review of the literature was conducted. From April to June 2013, iterative searches were conducted using ScienceDirect, Web of Science, Google Scholar and Google. Search terms entered into each database included combinations of the following: 'food', 'seafood', 'loss', 'waste', 'shrink', 'estimate', and 'supply chain'. The reference lists of the pertinent literature found through this method were also searched for additional resources. Results from both academic and grey literature were deemed acceptable for inclusion, but they had to meet the following criteria:

- Contain loss estimates specific to seafood (*i.e.* estimates were distinct from other food types)
- Estimates had to be derived from original research (*i.e.* literature citing estimates from pre-existing research were not included).

Articles identified were critically analyzed to assess the methodology, scale and scope of the research, and relevancy of the data. All estimated loss rates provided in the literature and deemed as applicable to this study were recorded in a table identifying the type of product and node of the supply chain for which the estimate was made.

2.3.3 Interviews

In order to expand on the data consolidated through the literature review a series of interviews were conducted with key informants involved at various nodes of the PHSSC. Initial informants were identified through pre-existing professional networks and additional interviewees were identified through these initial contacts. Interviews were conducted with multiple informants from the processing, distribution and retail nodes of the seafood supply chain to assure respondents remained anonymous. Semi-structured interviews were conducted by telephone between May 15th, 2013 and June 30th, 2013 with each industry informant willing to participate. Interviews lasted between 10 and 30 minutes and the interviewer recorded key points manually. Questions were general in nature so as to allow flexibility in conversation, but focused on the company's ability to track seafood loss, retrieve any data they may have on seafood loss rates, and identify typical practices around the handling of seafood losses. An example of the basic interview guide used is presented in Appendix A.

Estimates of seafood loss rates provided were recorded in a table identifying the type of product and node of the supply chain for which the estimate was made. In addition, the fates of seafood losses were recorded for each company and a list of existing formal programs established to reduce seafood loss was compiled.

2.3.4 Data Compilation

All estimates of seafood loss rates were consolidated into a single table with the data identified to the original source. Loss estimates were aggregated for each supply chain node and separated by type of seafood (finfish or shellfish) and product form (fresh, frozen or live). Where variation in estimated loss rates were found, the range was reported.

Data from the retail level were further broken down in a subsequent table because this node was able to provide much more refined data for loss rates and significant variation was found in the reported estimates. Estimates of loss rates were consolidated by product type. In some instances, multiple estimates were provided for the same product type either because multiple retailers reported loss rates for the same product type or because a single retailer reported seasonal fluctuations in loss rates for that product type. In both instances, the range was reported.

Finally, the potential cumulative loss of seafood along the entire PHSSC was calculated for each of the five seafood supply chains. This was calculated by determining the number of product units needing to be produced in order to yield one unit of consumed product given the loss estimates reported for each node of the supply chain (a sample calculation is provided in Appendix B). From this calculation, resultant values are not reported as percentages, but rather as whole numbers that are best interpreted as scalers. Both a high and a low potential cumulative loss were calculated for each supply chain due to the large range in estimates at some of the supply chain nodes. Note that these values are reported as *potential* cumulative losses in order to emphasize the provisional nature of the data presented.

2.4 WHY SEAFOOD LOSSES MATTER

The commonly cited definition of sustainable development is "development which meets the needs of current generations without compromising the ability of future generations to meet their own needs" (Brundtland, 1987, p.37). It is difficult to argue that seafood losses foster any of the objectives outlined in this definition. They do not help us meet present day needs and, in fact, do quite the opposite. Seafood losses amplify many of the environmental, social and economic challenges that current generations face, which in turn categorically compromise the ability of future generations to meet their own needs.

From an environmental perspective, the sustainability implications of seafood losses are three pronged. First, seafood losses are an unsustainable use of fisheries resources. Every unit of seafood that is lost represents a unit that was needlessly harvested or produced. Seafood production systems have placed immense pressure of global fisheries resources and their supporting ecosystems while aquaculture production poses a variety of challenges to local ecosystems that inevitably reflect the scale of production. Global fisheries resources are limited and hence must be managed and utilized judiciously. The practice of producing seafood for it to end up in the garbage uneaten is unjustifiable and certainly unsustainable. Seafood losses are in no way a *need* of current generations and the potential cumulative amounts of lost product suggest that seafood losses are putting undue pressure on vulnerable fisheries resources.

The second environmental impact of seafood losses is the misallocation of secondary resources. Seafood is not only the product of a harvested or cultured fisheries resource, but it also represents an investment of multiple additional resources. This is

most evident in the context of fed cultured production though it applies to all forms of fished and cultured seafood resources. Both fishing and aquaculture, for example, can be highly energy intensive (Pelletier et al., 2011; Troell et al., 2004; Tyedmers, 2004). In 2005 it was estimated that global fisheries burned almost 50 billion liters of fuel to land just over 80 million tonnes of marine fish and invertebrates, accounting of 1.2% of global oil consumption and resulting in the direct emission of 130 million tonnes of CO_2 (Tyedmers, Watson & Pauly). These numbers are substantial unto themselves and yet they do not account for further energy inputs incurred during the transportation, chilling and/or freezing, processing and packaging of seafood products, all of which are typically required to get seafood from the dock to the plate. Secondary resource inputs into seafood products are also not limited to energy inputs. Other notable inputs include *inter alia* biological resource inputs for bait and aquaculture feed, freshwater, additional food resources (in the case of value-added products), and packaging resources. Indeed, every step of the supply chain results in additional inputs of various resources ultimately increasing the overall material and energy investment into that product (Henriksson, Pelletier, Troell, & Tyedmers, 2012; Tlusty & Lagueux, 2009). The loss of seafood at any stage of the supply chain represents a misallocation of these secondary resources, however if loss is occurring further along the supply chain (*i.e.* at retail and consumer level) then this creates a compounding negative impact.

Lastly, the actual discarding and decomposition of lost seafood presents yet another environmental implication that result from losses through the PHSSC. A 2012 report on food waste in America found that only 3% of lost food is composted, while the remainder goes to landfills where the decomposition process accounts for 23 % of all

methane emission in the U.S. (Gunders). As methane is a harmful greenhouse gas that is 25 times more potent than CO_2, food loss in general holds important considerations for climate change. It is true that seafood-specific losses are likely to make up only a small percentage of overall food loss resulting in a proportionally smaller contribution to methane production from decomposition, however in the pursuit of sustainable seafood systems consideration of the end-of-life impacts is still warranted.

Together these three environmental implications of seafood losses through the PHSSC provide a clear rationalization of the sustainability implications of seafood losses. No matter how sustainable or eco-efficient the seafood production process may be, the loss of that product at any point during the post-harvest component of the seafood supply chain represents an unsustainable *use* of seafood, which ultimately undermines the sustainability of the entire seafood system.

2.5 Results and Discussion

2.5.1 Data Collection

Through the meta-analysis of existing literature only one article from the academic literature (Buzby, 2011) and four reports/data sets from the grey literature (Gustavsson et al, 2011; Buzby, Wells, Axtman, & Mickey, 2009; Muth, Karns, Nielsen, Buzby, & Wells, 2011; Statistics Canada (StatsCan), 2013) were found to fit the inclusion criteria for this study. Only the report by Gustavsson and colleagues (2011) presented loss estimates for all stages of the seafood supply chain, while the remaining four reports focused on loss rates at the retail and/or consumer level. None of these reports were specific to seafood, but rather included seafood as one category within a broader research scope that focused on food loss more generally. The 2009 report by the Buzby and

colleagues, which focused on food loss estimates from U.S. supermarkets, was the only one to differentiate between seafood types by providing separate estimates for finfish and shellfish.

Interviews were conducted with 17 informants from the PHSSC with representatives from processing (7), distribution/transportation (6), and retail (5). As some informants were able to speak to multiple stages of the PHSSC, the cumulative number of responses per node is greater than the total number of informants. Informants were from North American and European companies, all of which are considered to be large international players in the seafood system, typically handling a variety of seafood products in excess of 45.4 tonnes per week.

By nature of the data available, this study speaks primarily to North American seafood supply chains, although additional insights were gained from European-based processors and distributors. Industrialized seafood supply chains are global in nature, making it difficult to delineate specific geographic boundaries around any one seafood product. In addition, advances in technology that maximize efficiencies through the SSC have resulted in similar practices being adopted across developed countries involved in seafood processing. Note that seafood supply chains in developing countries, which are not addressed herein, can be significantly different than those of industrialized, developed nations and are believed to exhibit different patterns and scales of product loss (Gustavsson, 2011; IMECH, 2012; Smil, 2000).

In all, loss rates were collected for each node of the PHSSC for five broadly defined seafood supply chains: fresh finfish, frozen finfish, fresh shellfish, frozen shellfish and live shellfish.

2.5.2 Mapping Seafood Losses Along PHSSCs

The seafood loss rates derived from the literature review and the series of interviews with key informants appear in Table 2.1. The most apparent pattern to emerge from these data is that seafood losses increase along PHSSCs. Processing and distribution both reported seafood losses below 1%, while retailers report average loss rates between 1.8 – 12%. The greatest loss rate was found to be at the consumer level wherein the literature reports that between 25% (Buzby et al, 2011) and 40% (Buzby et al., 2009) of seafood is lost. All estimates of consumer loss include losses that result during cooking and preparation, discards due to over-preparation, spoilage, and plate waste. Literature on seafood loss rates at the consumer level was scant with only three papers reporting such values and in all instances the loss rates were derived mathematically from national food availability data and food consumption surveys. These data are therefore considered the most robust estimates available, however they should be interpreted with caution.

For the most part, the seafood loss rates identified through interviews are comparable to those cited in the literature, with the exception of estimated loss rates at the processing level. At this node, interviewees consistently report a loss rate below 1% while the Gustavsson et al. (2011) reports a loss rate of 6%. The variation in reported numbers for seafood loss at the processing level results from a differing interpretation of 'loss' whereby the Gustavsson et al. (2011) report defines loss to include both product that is thrown out and product that is down-graded to non-human food uses while this study only includes product that is thrown-out as a loss.

Table 2.1: Estimated loss rates of seafood products across different stages of the post-harvest seafood supply chain

	Finfish		**Shellfish**		
	Fresh	Frozen	Fresh	Frozen	Live
Processing	<1%	<1%	<1%	<1%	n/a
	---------- 6 % (Gustavsson et al, 2011) ----------				
Distribution	0.1-2%	0-1%	0.4%	0	0.4-1%
	---------- 0.5% (Gustavsson et al, 2011) ----------				
Retail	1.6-25%	0.6-0.8%	1.9-29%	0.6%	2.6-5.5%
	----------1.8 -12% ----------				
	8.7% (Buzby et al., 2009)		9.3% (Buzby et al., 2009)		|| || 38% (StatsCan)* ||
	---------- 8% (Buzby et al, 2011) ----------				
Consumption	----------33 (Gustavsson et al, 2011) ---------- ---------- 33-40% (Muth et al., 2011) ---------- ---------- 25% (Buzby et al, 2011) ----------				||

* Food loss estimates from StatsCan include both retail and consumer level losses

2.5.3 Variation In Seafood Losses Across PHSSCs

Through processing and distribution, little variability is observed in loss rates between product types (finfish/shellfish) or among product forms (fresh/frozen/live). This nominal variability results from having an overall low loss rate at these nodes (<2% in all cases), which may be attributed to the systems in place to re-direct product to other uses (as discussed in section 2.5.4).

At the retail level, greater variability is observed for loss rates between product types, with ranges of 1.7-25% and 1.9-29% for fresh finfish and fresh shellfish,

respectively. The broad range in loss rates for both fresh product types result from variability in loss rates for specific seafood products (Table 2.2). For fresh finfish products, the highest loss rates were recorded for whole fish (26%) and trout (11%), while halibut fillets were recorded to have a loss rates as low as 1.6%. Fresh shellfish loss rates were highest for mussels (7 – 29%) and crab cakes (11%) and the lowest loss rate was observed for soft shell crab (2.3%).

Table 2.2: Retail level loss estimates for specific seafood products. Note that data are reported over different time frames and may represent annual averages or weekly averages.

Fresh	**% Loss**
Halibut Filet	1.6-8%
Farmed Salmon	2.5-4.4%
Other Finfish	5.5-8%
Wild Salmon	8%
Trout	11%
Whole Fish	26%
Soft shell crab	2.31%
Live lobster	2.6-5.5%
Shellfish	4-6.8%
Scallops	1.9%
Clams	8.3%
Crab cake	11%
Mussels	7-29%
Frozen	
Fin Fish (Packaged)	0.8%
Fin Fish (Bulk)	0.6%
Shellfish	0.6%
Total seafood loss rate at retail level	**1.8-12%**

The variability observed in loss rates across product types at the retail level is due in part to the data collection methodology, which provides only a snapshot of day-to-day practices of seafood handling in the retail sector. Seafood managers of major retail

chains were only interviewed once and the time periods for which they were able to report loss rates varied considerably. Some reported data for losses from the previous year, while others reported an average from the week previous to the interview. Notably, seafood managers consistently reported that variability in loss rates are common and highly dependent on the season and market availability of fish types. For example, two different companies provided loss rates for halibut fillets, which ranged from 1.6 to 8%. The company that reported the lower loss rate reported an annual average for halibut fillet loss, while the company reporting the higher loss rate reported their loss for the week previous to the interview. The manager for the company reporting the 8% loss rate identified that this was an unusually high loss value, and attributed it to the fact that it coincided with the first week that fresh sockeye salmon had become available, which would have changed consumer purchasing patterns for halibut.

Unsurprisingly, the loss rates for frozen products (both finfish and shellfish) were found to be consistently below 1% through processing, distribution and retail (Table 1). In the literature, consumer level loss rates were not differentiated between product forms, likely due to the challenge of gathering such data at a household level, and hence specific conclusions cannot be drawn with respect to variability in loss rates across seafood supply chains at this level. It is not unrealistic, however, to assume that loss rates of fresh seafood are likely to be greater than those for frozen seafood at the consumer level due to the inherent perishability of fresh product and the limited shelf life that fresh product has once it has reached the home.

2.5.4 The Fate Of Seafood Losses

The processing node of PHSSCs exhibit very low levels of seafood loss because there are multiple mechanisms in place to recover or redirect the product before it goes to landfill or a similar fate. These mechanisms primarily include the production of secondary products (such as fishmeal, minced fish, or fish fertilizer) and were initially implemented in an effort to create additional revenue from fish components that are otherwise considered to be non-edible by humans. Some have justifiably argued that this practice, often referred to as downgrading, should in itself be considered a loss because the product is being removed from the human food supply (Gustavsson et al., 2011; Stuart, 2009). As previously discussed, for the purpose of this paper we did not consider downgrading as a form of loss because the product is still being used for some beneficial purpose (*e.g.* animal feed). However, some insight into the practice of downgrading was provided by two of the interviewed processing companies, both of which suggested it is relatively uncommon. Both companies processed a variety of white fish species into value-added products and reported that for all species handled in 2012 only 0.4-0.6% of edible product was downgraded to production of secondary products.

The distribution node of PHSSCs reported loss rates below 2% in all instances. Here, the relatively low loss rate was attributed to the versatility of seafood products and adaptability of seafood distributors. All distributors interviewed operated at relatively large scales, typically moving 45 to 110 tonnes of seafood per week. Three of the representatives interviewed spoke to how their diversity of buyers allowed them to move product effectively and reduce loss. Two companies noted that they are able to reduce loss of fresh product by processing it in-house, typically by freezing it, if it is not selling.

One company that handles live lobsters said that they collect “weak lobsters”, cook them in-house and will then sell the cooked meat. The small percentage of product that is lost at distribution was found to go to the garbage (three of five companies) and to compost (two of five companies).

At the retail level, seafood losses are primarily discarded to compost (four of five companies) and, to a lesser extent, the garbage. All companies interviewed were found to trace seafood losses using an electronic tracking system, which requires employees to scan the bar code for each discarded product and record the reason for discard. All companies identified this type of program as their primary way of reducing seafood loss in their operations. The efficacy of this system is variable as seen by the differences in reported loss rates for both the retail level overall (1.8-12%) and for various fresh products (1.6-29%).

Two of the five retail companies interviewed have also recently adopted a seafood recovery program whereby seafood products are pulled the day before the best-before date and cooked in-house. The pulled fresh product is either then processed into a value-added frozen product (such as fish cakes or fish burgers) or sent to the prepared foods department to be used that day. As these recovery programs were relatively new for both companies little data were available to assess the effectiveness of the programs, but one company estimated that only about 1.5-3% of their typical losses were being recovered by this program. The companies that did not have a seafood recovery program in place all stated that they had not adopted such a program due to health and/or product quality concerns around using soon-to-be-expired seafood products. For the most part, they identified that they would rather absorb the financial cost associated with seafood loss so

as to maintain their reputation of selling top-quality fresh seafood as opposed to selling discounted or processed product.

The fate of seafood losses at the consumer level is highly dependent on the waste management systems in place for a given region and hence cannot be speculated here. Though primary data were not collected at consumer level, the literature on consumer level food loss provides insight into some of the driving factors behind the high loss rates reported. As the consumer level loss rates included here are specific to North America (with the exception of the Gustavsson et al. (2011) estimate which combines North America and Oceania) the high loss rates are most attributable to the consumer attitude and marketing strategies of this geographic region. Both Gustavsson and colleagues (2011) and Buzby and colleagues (2011) attribute high loss rates at the consumer level to increasing food availability, changes in food merchandizing that promote increased portion sizes and consumption rates (*e.g.* buffet-style restaurants), and the economic status of average consumers whereby the majority can afford to waste food.

2.5.5 Potential Cumulative Losses Of Seafood Through PHSSCs

The potential cumulative losses of seafood through PHSSCs are reported herein as the amount of product units needing to be produced in order to yield one unit of eaten product (see Appendix B for sample calculation). Overall, it was determined that between 1.34-2.37 units of seafood need to be produced to result in one unit of eaten product (Table 2.3). The variability in the reported range results predominantly from the broad estimates of product loss at the consumer level (15 percentage points), while variability in loss rates for different seafood product types at the retail level accounts for much of the remaining deviation.

Table 2.3: Amount of product required at each node of the seafood supply chain to yield one unit of eaten product based on the high and low estimates of loss rate presented in table 2.1.

Seafood Type	Estimate	Units Produced	Units at Distribution	Units at Retail	Units Purchased by consumer	Units Eaten
Fresh Finfish	High	2.28	2.26	2.21	1.67	1
	Low	1.36	1.36	1.36	1.33	1
Frozen Finfish	High	1.68	1.68	1.68	1.67	1
	Low	1.34	1.34	1.34	1.33	1
Fresh Shellfish	High	2.37	2.35	2.34	1.67	1
	Low	1.37	1.36	1.36	1.33	1
Frozen Shellfish	High	1.69	1.68	1.68	1.67	1
	Low	1.34	1.34	1.34	1.33	1
Live Shellfish	High	1.77	1.77	1.76	1.67	1
	Low	1.37	1.37	1.37	1.33	1

Accordingly, frozen seafood products (both finfish and shellfish) were found to have the smallest range for potential cumulative loss due to the minimal variability in loss rates through most of the supply chain. Frozen finfish and frozen shellfish were estimated to require between 1.34-1.68 units and 1.34-1.69 units of produced product, respectively, to result in one unit of eaten product. Live shellfish also exhibits a relatively small range in the potential cumulative losses whereby 1.37-1.77 units need to be produced to result in one unit of eaten product.

Fresh shellfish and fresh finfish displayed the highest potential cumulative losses. Calculated estimates suggest that 1.36-2.28 units of fresh finfish must be produced to

result in one unit of eaten product, while for fresh shellfish this range is as high as 1.37-2.37 units.

Estimates of cumulative seafood loss available in the literature are relatively broad and do not differentiate between seafood types or product forms, making it difficult to compare the results presented herein with those in existing literature. In general, however, we find that the calculated estimates made here are of similar scale, if not greater than those presented in other reports on food loss. Gustavsson and colleagues (2011) present the only other report with seafood-specific estimates of loss along the entire supply chain. In this report, the authors found that total waste throughout fish and seafood supply chains in North America and Oceania was approximately 50%, of which 33% was estimated to occur at the consumption level. The cumulative seafood loss rates presented herein are also relatively high in comparison to loss estimates for other food products. Gustavsson and colleagues (2011) estimated that meat loss along the supply chain in North America and Oceania is approximately 25%, while dairy products experience a loss rate of 20%. The only commodity groups to experience loss rates similar to those of seafood were roots and tubers (~60%) and fresh fruits and vegetables (55%) (Gustavsson et al., 2011). Earlier estimates of fruit and vegetable loss were significantly lower with Kader (2005) reporting a loss rate of one-third and Garnette (2006) estimating fruit and vegetable waste in relation to the United Kingdom market to be approximately 25%.

2.5.6 Addressing And Accounting For Seafood Losses To Promote Seafood Sustainability

Estimates of seafood losses presented herein, although broad, imply that seafood is not being utilized in a sustainable fashion. In fact, it appears that significant amounts of seafood are not being utilized at all but rather left to go to waste and thrown away into the trash. Calculations of the potential cumulative losses through the supply chain suggest that, at a minimum, an additional 0.342 units of seafood must be produced for every unit of eaten product; in fresh seafood supply chains, this number may be as high as 1.374 units.

In the pursuit of seafood sustainability it is imperative that we begin to account for both sustainable production and sustainable consumption of seafood products. Although the data presented herein are admittedly preliminary, they suggest that seafood losses through PHSSCs are likely to play a key role in the overall sustainability of seafood systems. Broadening the conversation of seafood sustainability to include post-harvest seafood losses may not be simple because it fundamentally requires addressing topics such as consumer behaviour, shifting marketing strategies and realigning economic values to support reducing wasteful consumption. More approachable solutions exist, however, that can facilitate the initial steps towards reducing post-harvest seafood losses.

It is recommended that further research be carried out to identify the more nuanced differences in loss rates for various seafood products and provide greater detail to loss rates at the consumer level. In particular, focus should be paid to fresh seafood supply chains given the high variability in observed loss estimates. Elucidating more specific data at these two levels would be beneficial in developing more tailored solutions

to the issue of losses through the PHSSC, but as previously noted collecting this type of data – particularly at the consumer level – can be extremely challenging. Current programs such as the UK-based Waste and Resource Action Programme (WRAP), the 'Love Food Hate Waste' campaign throughout the UK and Australia, and the United Nations Environment Program's (UNEP) 'Think.Eat.Save' campaign, provide useful models for creating research-driven initiatives that work cooperatively with all stakeholders to address the issue of and solutions for waste reduction. A foundational component to each of these initiatives has been their ability to start a dialogue around the topic of food loss generally, emphasizing the importance of education and awareness as part of a broader strategy to address losses through the PHSSC.

The sustainable seafood movement provides a unique opportunity to begin this type of educational and awareness-oriented dialogue with respect to seafood losses given the many well-defined partnerships between non-governmental organizations (NGOs), retailers, producers and consumers that have cultivated a community of highly engaged and committed stakeholders. By leveraging some of the social media and communication techniques already employed by the sustainable seafood community much could be gained in the effort to promote a strong approach to sustainable seafood consumption. For example, working directly with retailers to adopt in-house waste diversion programs that recover seafood and make it into secondary product prior to it reaching its best before date provides a relatively accessible solution that can help minimize loss at the retail level. Consumer awareness campaigns around the issue of seafood loss could be coupled with educational tools, such as recipe cards, cooking classes, and mobile apps, that aim to inform consumers about the versatility of different seafood products, how they can

preserve seafood, and provide creative ways on how to use leftovers. Many of these approaches have been used by the "Love Food Hate Waste" campaign undertaken in Greater Manchester, UK. The success of this campaign, which engaged over 35,900 residents during a two-year campaign and resulted in a sharp increase in the number of residents taking action to reduce their food waste from 37% to 76.4% (Chartered Institution of Wastes Management, 2012), suggests that these types of approaches hold great potential.

Although these sorts of initiatives seem like small steps in relation to the potentially sizable implications of, and relating to, the issue of seafood loss through the PHSSC, they open the door to broader discussions and can, most importantly, bring the issue of seafood loss to the forefront of conversations that relate to seafood sustainability.

2.6 Conclusion

This study shows that seafood losses through the PHSSC may hold important implications for overall seafood system sustainability. Initial estimates from this research, although preliminary, suggest that in some instances, upwards of 2.3 units of seafood may have to be produced in order to result in one unit of seafood being consumed. This reality holds significant implications for the sustainability of seafood – from both wild capture fisheries and aquaculture – as it puts undue pressure on these systems to produce more than what is truly needed by today's seafood consumers. Given ongoing concerns about the long-term sustainability of many fisheries (both capture and aquaculture), it is imperative that we broaden the current conversation around seafood sustainability. To date, efforts to promote seafood sustainability have almost exclusively been focused on making seafood production systems more eco-efficient. Although, cleaner production

systems will unequivocally play an important role in supporting overall sustainability of seafood systems, it will not be until sustainable consumption practices are also adopted that the goal of seafood sustainability can be achieved. Addressing the issue of seafood loss through the PHSSC provides an accessible and easily understandable avenue through which the conversation of sustainable consumption, as it relates to seafood (and food more generally), can be addressed. We urge all individuals and organizations interested in improving the sustainability of seafood systems to include the issue of seafood loss, and more broadly the concept of sustainable consumption of seafood, into their current initiatives, goals and visions to support a future of seafood sustainability.

CHAPTER 3. DISCUSSION AND CONCLUSION

Seafood makes a significant contribution to our global prosperity: it supplies much of the growing global population with a source of nutritious food and animal protein, provides livelihoods and incomes to some 660–820 million people through primary and ancillary activities, and remains one of the most traded food commodities world wide (FAO, 2012). Unfortunately, the growth in fisheries production (both wild capture and aquaculture), as seen through the past half century, has placed environmental, social and economic stress on global seafood systems (Pauly et al., 2002; Pitcher & Cheung, 2013; Worm, 2006). Given the extensive contributions that seafood systems make to global food security and economic development, it is imperative that we address the constraints on the systems in order to support their sustainable development. At the Rio +20 United Nations Conference on Sustainable Development, the FAO's corporate mandate stated

> sustainable consumption and production systems are essential to eradicate hunger and protect ecosystems. Underpinning this message is the need to increase food security – in terms of availability, access, stability, and utilization – while using fewer resources through improved management and efficiencies through the food value chain. This requires policies that create incentives for producers and consumers to adopt sustainable practices and behaviors. (P.89, FAO, 2012)

Notable achievements have been made to date in advancing the sustainability of production systems of seafood by adopting eco-efficient fishing and farming techniques. The concept of sustainable consumption as it relates to seafood, however, has been negligibly addressed. It is clear that if we hope to promote seafood sustainability, it is essential that we further the concept of sustainable consumption in tandem to that of sustainable production.

This project was intended to serve as an exploratory study to shed light on the importance of addressing sustainable consumption in seafood systems by focusing on the issue of seafood loss through the PHSSC. By conducting a meta-analysis of the current literature and interviews with 17 key informants along the PHSSC it was possible to map out loss rates along and between different seafood supply chains. The potential cumulative losses for each of the seafood supply chains were also calculated. This allowed the author to identify priority management areas where efforts to promote sustainable consumption behaviour and practices are likely to be most effective.

Results of the study suggest that fresh seafood supply chains experience greater overall loss rates as well as greater variability between loss rates of different product types when compared to frozen seafood supply chains. Loss rates through PHSSCs were also found to be greatest in the latter part of the supply chain, namely at the retail and consumer levels. Overall, the study found that, when accounting for product loss at all levels of the PHSSC, between 1.34 and 2.37 units of seafood are produced for every one unit of seafood eaten. Full results can be found in section 2.5, along with a brief discussion of the importance of addressing the seafood losses in the pursuit of seafood sustainability and some initial management considerations. The following sections offer an expanded discussion on the sustainability implications of seafood losses, as well as a more detailed management plan for how the issue of seafood loss through the PHSSC may be addressed.

3.1 Seafood Losses and Sustainability

3.1.1 Environmental Considerations

The direct environmental implications of seafood losses on seafood sustainability are relatively self-evident; every unit of lost product represents a unit of seafood that was needlessly harvested. From the simplest perspective, seafood losses suggest that we are producing too much seafood. In light of the ongoing concerns about the over-exploitation of fish stocks and the environmental consequences of some types of aquaculture, the practice of harvesting seafood simply for it to end up in the garbage is inexcusable. Should the amount of lost seafood, or even a portion of it, not be harvested it would undoubtedly reduce the pressure that current seafood production systems are placing on dwindling stocks and supporting ecosystems.

The unsustainable use of fisheries resources is, unfortunately, only the tip of the iceberg when it comes to environmental implications of seafood losses. All seafood products represent an investment of numerous resources including *inter alia* fossil fuels used in harvesting and transportation, energy used in refrigeration, freezing and processing of products, water used in production and/or processing, natural resources used in product packaging, and, in the case of many value-added products, additional food resources (Henriksson, Pelletier, Troell, & Tyedmers, 2012; Tlusty & Lagueux, 2009). As such, every step along the supply chain that a seafood product 'survives' results in greater resource investment into that product. Resultantly, the further down the supply chain a seafood product is lost (*i.e.* at the retail or consumer level) the larger its environmental footprint and the greater the number of misallocated resources. Not only does this represent an unsustainable use of the secondary resources used in the processing, transportation, and distribution of seafood, but also exacerbate other

environmental concerns. Research conducted in the UK, for example, found that the production of avoidable food and drink waste – *i.e.* food that would not have been wasted had it been properly handled – generated by an average household was associated with roughly the equivalent of 0.8 tonnes of CO_2, or 2.4% of total consumption-associated greenhouse gas emissions (WRAP, 2008). The pattern observed in this study of greater loss rates near the end of the supply chain, particularly at the consumer level, suggests that seafood losses through the PHSSC are having a compounding negative effect on environmental sustainability.

The actual discarding and decomposition of lost seafood presents yet another environmental implication of losses through the PHSSC. A 2012 report on American food waste found that only 3% of lost food is composted, while the remainder goes to landfills where the decomposition process accounts for 23 % of all methane emission in the U.S. (Gunders). As methane is a harmful greenhouse gas that is 25 times more potent than CO_2 (Gunders, 2012), food loss in general holds important considerations for climate change. It is true that seafood-specific losses are likely to make up only a small percentage of overall food loss and, hence, create a proportionally smaller amount of methane through decomposition; however, that is no reason to disregard the environmental impacts that accrue through the discarding and decomposition of lost seafood when the goal is to achieve sustainability throughout seafood systems.

3.1.2 Social Considerations

It is expected that the global population will rise to some nine billion people by 2050 and that this will occur concurrent to an increase in per capita wealth (Charles et al., 2010). Resulting from this shift in population demographics, higher consumption rates

and greater demand for processed food, meat, dairy and fish are anticipated (Charles et al., 2010). Rosegrant and colleagues (2007) estimate that meat production will have to increase by 85% between 2000 and 2030 to meet the increase in demand. As fish and fisheries products represent a valuable source of protein – accounting for 16.6% of the world population's intake of animal protein (FAO, 2012) – it is anticipated that increased supplies of seafood products will play an important role in meeting this increasing demand for protein. As previously discussed, however, landings from wild capture fisheries have remained stable since the mid-1980s at approximately 90 million tonnes (FAO, 2012). Since, the growth of aquaculture has filled the gap between supply and demand and although it remains one of the fastest growing food-producing industries, its growth has begun to slow in recent years (FAO, 2012). Questions as to how current seafood production systems will grow to sustainably supply the increased demand are omnipresent (Bartley, Brugere, Soto, Gerber, & Harvey, 2007; Delgado, Wada, Rosegrant, Meijer, & Ahmed, 2003; McClanahan, Allison, & Cinner, 2013; Worm & Branch, 2012). Reducing post-harvest seafood losses can (and should) be at the forefront as part of the potential solution.

Notwithstanding the forecasted population growth, global food inequality and food insecurity is a stark reality of today's global society. The 2012 State of Food Insecurity in the World reported that almost 870 million people were chronically undernourished in 2010-12 (FAO, International Fund for Agricultureal Developmetn (IFD), & World Food Programme (WFP), 2012). Godfray and colleagues (2010) report that more than one in seven people suffer from malnutrition due to inadequate access to sufficient protein and energy in their diet. Although the issue of food insecurity is

concentrated in developing countries, it is not limited to these regions. In the United States where food appears plentiful and is readily wasted (total food loss estimates are in around 40%), one in six households do not have a secure supply of food (Coleman-Jensen, Nord, Andrews, & Calson, 2011). The issue of inequitable access to food is by no means novel; quite disappointingly, hunger, malnourishment and food justice have been longstanding points of discussion at all political levels and the persistent nature of the issue suggests that there is no easy solution. The issue is addressed here, however, because it too must be considered in the goal of seafood system sustainability. Most certainly, the weak approach to sustainable consumption of seafood taken to date through the simple promotion and marketing of more sustainably produced seafood products will not be sufficient to address the social dimensions of seafood sustainability such as inequitable access to complete, nutritious diets.

3.1.3 Economic Considerations

The economics of seafood losses through the PHSSC are an interesting point of consideration. In developed countries where seafood losses occur predominantly at the end of the seafood supply chain, individual consumers and retailers absorb the lion's share of the financial burden of seafood losses. Only one study was found that quantified the monetary value of seafood losses specifically. Buzby and Hyman (2012) reported that in 2008, retail and consumer loss of fish and seafood in the United States was valued at $8.135 billion, which represented a relatively small fraction of the overall value of food losses that was estimated to be over $165.6 billion. In the UK, the total cost of avoidable food waste was estimated at £12 billion per year, or £480 per household per year (WRAP, 2009), and in Canada an estimated $26.6 billion of food is lost annually (Gooch, Felfel &

Marenick, 2010). In all these cited cases, approximately 50% of these values are generated by product that is purchased by a consumer and subsequently lost at the household level. In the report that specified the monetary cost of U.S. fish and seafood losses, consumer level loss accounted for more than 75% of the $8.135 billion (Buzby and Hyman, 2012). The fact that gross expenditures on lost food products are so great, especially at the consumer level, highlights an important point: food loss is a net asset in the current economic system.

The willingness of retailers to absorb the financial cost of food losses speaks loudly to the current state of food marketing. The former president of Trader Joe's, a large American grocery chain, was quoted in Gunders (2012) stating, "the reality as a regional grocery manager is, if you see a store that has really low waste in its perishables, you are worried. If a store has low waste numbers it can be a sign that they aren't fully in stock and that the customer experience is suffering" (p. 10). Many of the retail representatives that were interviewed for this project reiterated similar points, whereby they would stock certain products (*e.g.* whole fish) primarily to make their seafood counter look complete, create extravagant display cases to appeal to customers, or simply discard product the day before the best-before date so as to ensure that quality (and, ultimately, customer experience) is not compromised. This reality brings forth much broader questions about societal and cultural values, consumerism, and our economic system that are, unfortunately, too complex to address herein. Recognizing that these larger topics play an important role in the broader concept of seafood sustainability is crucial, however, if we ever hope to achieve a sustainable seafood system.

3.2 LIMITATIONS OF STUDY

Despite a conscious effort to scope this project so that it would be manageable within the short time frame available, the greatest challenges faced while conducting this research related to temporal constraints and some typical realities that result from conducting exploratory-type research.

The dearth of relevant and applicable literature to the topic of post-harvest seafood losses meant that the success of this study was highly dependent on identifying and engaging key informants that would lend first hand accounts of their company's practices. Given that data on loss rates (or 'shrink' as it is referred to in the industry) are considered proprietary, it was unknown how informants were going to respond to the information request. For this reason, an introductory letter that described the nature and intent of the project was sent to all potential informants. In addition, a confidentiality agreement that guaranteed anonymity of all data and information was provided upon request. The selection of informants was, to a certain degree, dependent on pre-existing professional contacts of the author and academic supervisor, as these served as the initial points of contact for information requests. Subsequent contacts were identified through these initial contacts. Although this proved to be an effective way to engage industry informants, it does suggest that the scope of informants interviewed is limited geographically with greater emphasis on North American companies. Furthermore, some informants were unable to respond to the information request due to lack of human resource capacities, time of year or scheduling conflicts despite initial interest and enthusiasm about the project. Overall, 60% of the industry informants contacted were able and willing to provide information for this project all of which had a primary or

secondary degree connection to the researchers. Unsurprisingly, all of the cold-call attempts to contact industry informants went not responded to. This highlights the importance of and leverage that can be drawn from pre-existing professional relationships when working with the seafood industry.

The actual process of data collection through interviews was also challenged by the lack of consistency in how seafood loss is defined, reported and recorded by various industry players. As previously discussed there is no one definition for 'loss' as it pertains to seafood (and food more generally) and a number of different terms - such as 'waste', 'discard', and 'shrink' - are commonly used interchangeably. This proved particularly challenging for conducting interviews as a fine balance had to be struck between setting out a clear, well-articulated definition of loss (as it pertained to this project) all the while ensuring that the definition was not so restrictive that it excluded informants from participating. Using a semi-structured interview style and conducting interviews by phone were two techniques that were particularly helpful for addressing this point as it allowed the researcher to tailor the questions so as to reflect differences in industry practices and seek immediate clarification when needed.

Data collection and collation was further challenged as industry informants, particularly at the retail level, reported shrink rates for differing time frames; some would report average shrink rates for the previous year, while others reported shrink rates for the week prior to the interview. Evidently this adds a certain degree of inherent variability to the data, however in all circumstances where informants provided data from a shorter time frame they stated that the data being reported were representative of normative practices.

Lastly, the data collection period for this research was limited to a three-month time frame, which means that the study provides only a simple snapshot picture into the issue of seafood losses through the PHSSC. Consequently, the results presented lend well to drawing general conclusions but, should they be applied outside of this report, a cautionary note that speaks to the preliminary nature of the data should preface their use.

3.3 Priority Management Areas

Two predominant patterns emerged from this study. First, that fresh seafood products experience both greater variability and greater overall loss rates through the post-harvest component of the seafood supply chain than frozen seafood products. Second, this study found that a vast majority of post-harvest seafood losses occur at the later end of the supply chain; namely at the consumer level and, to a lesser degree, at the retail level. These two points highlight the priority management areas that should be addressed in relation to post-harvest seafood losses: reducing losses through fresh seafood supply chains, addressing consumer behaviour around seafood and food waste, and reviewing opportunities for reducing seafood losses at the retail level. These points will best be addressed by taking a multi-pronged approach that engages all stakeholders and is shaped by a range of short-term actions that will lead to broader, long-term change.

The issue of seafood loss, particularly at the consumer and retail level, is strongly rooted in cultural norms and societal values as they pertain to consumerism, health, wealth, and food habits. In North America, which is the focus of this study, high food loss rates at the consumer level have been attributed to increasing food availability, changes in food merchandizing that promote increased portion sizes and consumption rates (*e.g.* buffet-style restaurants), and the economic status of average consumers

whereby the majority can afford to waste food (Gustavsson et al, 2011; Buzby et al, 2011). As discussed in section 3.1.3 above, seafood loss at the retail level is in some ways considered part of a successful business model as it insinuates that the consumer experience is being prioritized – a critical factor to maintaining a competitive edge in today's markets. These realities suggest that the broader solution and end goal for addressing the issue of seafood loss rests in our ability to change consumer behaviour and, ultimately, shift societal values. Admittedly, this will be no simple task. Indeed, much work has already been done to research and analyze the development, adoption and efficacy of promoting sustainable behaviours (*e.g.* Kollmus & Agyeman; Seyfang, 2007; Tukker et al., 2008), but overall it remains inconclusive due to the inherent complexity of human and societal behaviours.

Ultimately, the management plan presented here aims to reconnect people with their food and remind each and every person that their choices matter. It is about empowering people and communities to encourage engaged and responsible citizenship. To many this will seem like a plan for societal and/or economic reform and most will question its pertinence to fisheries management. In 2007, Hilborn stated, "fisheries management is managing people" (p. 287). Although in this context Hilborn was referring to 'people' specifically as fisherman, the definition can – and should – be extended to encompass all parties and players that interact with fisheries resources, from fishers to consumers. The reality is that the commodification of seafood and the globalization of the industry have, to some degree or another, separated fisheries management regimes from those that are impacted by management decisions and too often ignore the link between consumer demand and market supply. This has undoubtedly

furthered some of the on-the-water management challenges experienced by fisheries management, but more evidently it has allowed consumers to become passive players in fisheries management, too often disconnected from the impact of their day-to-day choices. In order to address these acknowledged challenges and support this broader goal of responsible citizenship so as to ultimately reduce post-harvest seafood losses, a number of tangible initiatives and management practices can be implemented in the short- to medium-term.

3.3.1 Awareness

Despite the fact that food loss and waste has been acknowledged and studied to varying degrees for the past half-century, the issue remains relatively unaddressed by all stakeholders. As it pertains to seafood loss, the conversation has typically been restricted to production losses with little to no acknowledgement of post-harvest losses (Alverson, 1994; Harrington, Myers, Rosendberg, 2005; Stuart, 2009; Sharpless & Evans, 2013). The conversation of food waste has been reinvigorated as of late, however, thanks to a number of international initiatives and the growing body of research focused on the issue of food waste. The United Nations Environment Programme (UNEP), for example, made food waste the theme for World Environment Day 2013 (June 5th) and used this as a platform to highlight their "Think.Eat.Save" campaign. Other examples of anti-food waste programs include UK-based Waste and Resource Action Programme (WRAP) and the 'Love Food Hate Waste' campaign in the UK and Australia.

These programs, although focused on the general issue of food waste, can serve as useful models when looking to develop awareness campaigns around seafood loss. All of the previously mentioned food loss programs employ a multi-faceted approach by

conducting research into food loss rates at regional and national scales in addition to creating innovative engagement strategies for businesses, governments, and the public to make tangible change to reduce food waste. The programs are typically carried out by non-profit organizations or by government. The success of these types of programs is exemplified by the "Love Food Hate Waste" campaign undertaken in Greater Manchester, UK, which engaged over 35,900 residents during a two-year campaign and resulted in a sharp increase in the number of residents taking action to reduce their food waste from 37% to 76.4% (Chartered Institution of Wastes Management, 2012).

Given the growing international momentum around reducing food waste, the first step in this proposed management plan to address the issue of seafood loss through the supply chain is to initiate a series of awareness campaigns that aim to focus attention to the implications of seafood loss. This could be accomplished in one of two ways: 1) by creating a campaign specific to seafood loss, or 2) include the issue of seafood loss into a more general campaign around food waste. In the first instance, the motivating players are likely to be those already involved in the promotion of seafood sustainability. The seafood sustainability platform provides a unique opportunity to begin this type of awareness-creating dialogue with respect to seafood losses given the many well-defined partnerships between non-governmental organizations (NGOs), retailers, producers and consumers that have created a community of highly engaged and committed stakeholders. In the second instance, the motivating players are likely to be either non-profit organizations and/or governments (either at the municipal or provincial/state level), as seen with the other programs implemented internationally.

Although the end goal of an awareness campaign is to reduce seafood losses and ultimately minimize the unsustainable use of fisheries resources, the image of the awareness campaign need not take solely an environmental perspective on the issue. Seafood loss holds an implicit financial burden for the party responsible for discarding the product, which means that there is a direct financial incentive to reduce seafood loss. Although not the sole motivator for fostering sustainable consumption behaviours, economic considerations have always played a significant role in decision-making (Kollmuss & Agyeman, 2002; Jackson, 2005; UNEP & ESOMAR, n.d.). This point should thus be leveraged as one avenue for engagement because it shows that the responsibility for seafood loss, and ultimately the potential benefits for reducing losses, is shared amongst everyone. By breaking down the financial cost of food waste per household, the "Love Food Hate Waste" campaign in the UK was able to show that food wastes costs the average household £480 per year. This provides a clear and direct message to which most people can relate and immediately understand the opportunity for personal gain should they choose to reduce food losses. This is particularly important since it has been noted that effective public campaigns that promote sustainability require "translating the big vision into messages that are both personal to the audience and practical in terms of inspiring a response" (p.15, Futerra Sustainability Communications, 2005).

3.1.2 Educate and Engage

Concurrent to launching a series of awareness campaigns around the issue of seafood loss, various engagement strategies can be employed to educate various stakeholders on what they can do to reduce waste. The handbook *Communicating*

Sustainability: How to Produce Effective Campaigns highlights that "providing information is not enough" (p.13, Futerra Sustainability Communications, 2005) and that the most successful campaigns have tightly defined target audiences, well developed tailored messages, and practical solutions (Futerra Sustainability Communications, 2005). The results of this project show that seafood losses are greatest at the retail and consumer levels; hence, engagement strategies should be focused primarily on these sectors as they present the greatest opportunity for change. Again, the seafood sustainability platform and those involved with the issues to date have, over the past fifteen years, cultivated numerous partnerships between NGOs, retailers, producers and consumers that would lend well to engaging and educating a broader community about the issue of seafood loss and the opportunities that exist to address the issue. These efforts need not be limited to this community, however, and may also be lead by other NGOs (driven by social-justice and/or environmental mandates), governments or innovative industry members.

At the retail level, it is important to encourage businesses to adopt waste diversion programs that recover seafood prior to it reaching its 'use by' date. These programs may take a number of forms from in-house production of secondary products to food donation programs. Although increasingly common, all retailers should also have a compost system in place that can be used to divert any unavoidable food losses away from landfills.

At the consumer level, diverse educational and engagement tools can be employed to help encourage the reduction of household level waste. A few examples include attaching recipe cards, cooking tips and storage instructions to specific seafood products so that consumers are more aware of how to use and preserve the diverse range

of seafoods available in today's markets. These points could also be made available online or through a mobile application. The "Love Food Hate Waste" campaign has an online portion calculator that helps people cook properly proportioned meals so as to reduce leftovers that frequently go uneaten. This campaign has also created an interactive online recipe index for innovative ways to use leftovers wherein all recipes are crowd-sourced by the campaign's digital followers. Encouraging people to better plan their meals and shopping lists so as to reduce excessive or spontaneous purchasing of products that will ultimately be thrown out instead of eaten has also proven to be a common strategy amongst existing anti-food loss campaigns.

Perhaps of utmost importance for reducing seafood loss at all levels of the supply chain is to breakdown the myth that fresh seafood is better than frozen seafood. Evidently, the shelf life of fresh seafood is significantly less than that of frozen seafood and, as shown in this study, this often results in higher loss rates. Despite the common belief that 'fresh is best', seafood will often better maintain its quality and nutritional value if frozen immediately after catch (SeaFish, 2011; Cartwright-Taylor, 2003). Encouraging consumers to purchase more frozen seafood products can help reduce waste through transportation, distribution, retail and in the home.

3.1.3 Policy Implications

Policy makers should aim to implement legislation that set binding food waste reduction goals that ultimately lead to a zero food waste policy. This will reduce land use conflicts associated to landfills, decrease methane production that results from the decomposition of organics and increase the usability of food waste by creating a secondary product (*e.g.* compost). In Canada, waste management falls under municipal

authority and hence municipal governments will play a key role in implementing such policies. The City of Vancouver provides one illustration of such policy as it is currently working towards a complete ban on organics in the landfill, which will come into force in 2015 (City of Vancouver, 2013). Given the scale of this type of change, the associated costs and the widespread benefits, provincial and national governments would do well by creating supporting legislation that set cohesive provincial and national targets that aim to reduce food waste. Additionally, policy makers at all levels can help address seafood loss by providing funding for and/or creating awareness campaigns that promote the reduction of food waste. The state government of New South Wales, Australia took such an initiative through their Environmental Protection Authority and has successfully implemented a "Love Food Hate Waste" campaign with specific action plans for households, the hospitality industry, the retail industry and other businesses.

3.1.4 Research, Monitoring And Evaluation

In order to effectively monitor and evaluate any management strategy it is critical to clearly identify goals and outline a set of well-defined indicators that can be used to measure the degree of success (Futerra Sustainability Communications, 2005). These goals and indicators will vary depending on the scale at which awareness campaigns and engagement/educational strategies are undertaken. However, in all instances it will likely be necessary to first gain a more detailed understanding of the scope and scale of seafood losses through different seafood supply chains at the appropriate geographic scale. This study provides a useful initial survey as to where seafood losses may be of greatest concern, however it does not allow for refinement between specific seafood products or differentiation of loss rates geographically and it provides little resolution of seafood loss

rates at the consumer level. As such, it is recommended that further research be carried out to identify the more nuanced differences in loss rates for various seafood products and provide greater detail to loss rates at the consumer level. These data can then be used to build a baseline data set to monitor and evaluate the effectiveness of management strategies.

In addition to directly monitoring the rate of seafood losses, evaluation and monitoring of management programs can occur in a number of different ways including assessing stakeholder awareness to the issue of seafood loss, engagement rate (*i.e.* number of consumers/retailers/businesses that are engaged), and strength of engagement (*i.e.* what measures have stakeholders taken to reduce seafood loss). Each of these indicators are likely to be applicable across many initiatives, however, as previously mentioned, the scale, scope and methods of monitoring will be highly dependent on the initiative.

3.2 Conclusion

This study aimed to gain a better understanding of the scale and patterns of seafood loss through the post-harvest seafood supply chain (PHSSC). By conducting a meta-analysis of extant literature and 17 interviews with key informants along the PHSSC it was found that seafood losses occur primarily in fresh seafood supply chains (as opposed to frozen seafood supply chains) and that loss rates are highest for all seafood types at the consumer level and, to a lesser extent, the retail level. Furthermore, by calculating the potential cumulative loss rate it was found that between 1.36 and 2.37 units of seafood have to be produced in order to result in one unit of seafood being consumed. This latter point highlights that seafood loss through the PHSSC play a key

role in overall seafood system sustainability. In addition to being an undue pressure on seafood production systems, seafood losses result in the misuse of secondary resources used in the processing, packaging and transportation of seafood, contribute to climate change, and lend to the issues of food security, accessibility, and distribution. As such, addressing the issue of seafood loss through the PHSSC should be of utmost consideration for all individuals and organizations interested in improving the sustainability of seafood. The patterns that emerged from this study, although preliminary, suggest that efforts that aim to address the issue of seafood loss should be focused at the retail and consumer level as these present the areas of greatest opportunity for change.

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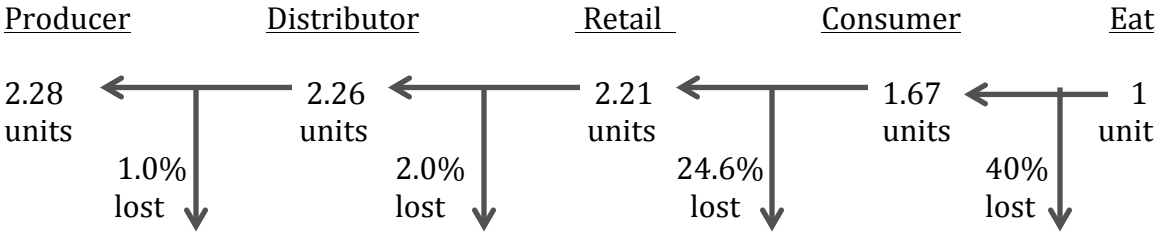
Appendix A: PHSSC Informant Interview Questions

The following five questions served as the basis of an interview guide and highlight the type of data that were collected from each interview.

- What type and what volume of seafood products does your company handle (species and product form)?
- Can you provide estimates on the volume of product discarded and/or redirected into non-human food uses (due to spoilage, cosmetic imperfection, etc.)?
- If your company handles more than one type of seafood, can you provide estimates for each seafood product type?
- What is the end fate of 'lost' product?
- Does your company have any formal programs in place that aim to reduce seafood loss?

Appendix B: Sample Calculation for determining the potential cumulative losses of seafood through PHSSCs

Calculation for high cumulative losses of fresh finfish:



P – (0.01P) = 2.26 P(1 -0.01) = 2.26 P = 2.26/0.99 D = 2.28	D – (0.02D) = 2.21 D(1 -0.02) = 2.21 D = 2.21/0.98 D = 2.26	R– (0.246R) = 1.67 R(1 -0.246) = 1.67 R = 1.67/0.75 R = 2.21	C – (0.40C) = 1 C (1 -0.40) = 1 C = 1/0.60 C = 1.67

Note that loss rates were sourced from Table 2.1.