BY-CATCH 22:
Regulatory pressures of selective fishing on commercial salmon fishers and impacts of handling on chum salmon (*Onchorhynchus keta)* released from purse seine fisheries in Northern British Columbia

By

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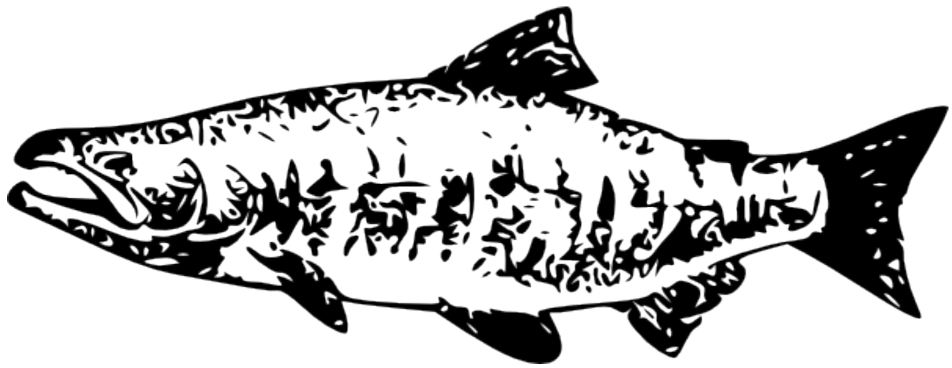

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ABSTRACT

In Canadian Pacific salmon fisheries, a policy of selective fishing practices was introduced to reduce impacts on salmon populations of conservation concern while allowing fisheries to continue on species that can withstand fishery exploitation. The outcomes of this policy have resulted in fundamental changes in the operation of commercial salmon fisheries in British Columbia. Recently, concerns have been raised that noncompliance with selective fishing policies and handling regulations are resulting in higher post-release mortality of chum salmon than is sustainable for populations on the north coast of British Columbia. Fishery- or species-specific recommendations do not exist for handling practices in salmon purse seine fisheries, and social factors, such as stakeholders' perceptions of regulations, can be determining factors in the success of conservation actions. In this project, I assess both biological and social factors of chum salmon bycatch handling and release in the commercial purse seine fishery on the north coast of British Columbia. Reflex action mortality predictors (RAMP) are used to assess the effects of air exposure and fishery handling on chum salmon and suggest that reducing air exposure time to below three minutes will maximize the condition of released fish. Interviews with fishermen, fishery managers, and members of non-governmental organizations on perspectives toward selective fishing regulations reveal that fishers attitudes towards these regulations are a primary determinant of compliance and that improved communication and feedback between management and resource users is needed to rebuild trust between stakeholders.

KEYWORDS: *Pacific salmon, commercial fishing, selective fishing, RAMP, human dimensions, stakeholders*

COLLABORATION

This research was undertaken as part of a collaborative effort. The results presented in Chapter 2 are part of a project conceived by K.V. Cook and S.G. Hinch, and fieldwork was completed by K.V. Cook, M.S. Watson, S. Jain-Schlaephfer, and J. Flemming. The results presented in Chapter 3 are part of a project conceived by K.V. Cook and M.S. Watson, fieldwork was completed by K.V. Cook and M.S. Watson. Funding and support for this work was provided by Marine Conservation Caucus, NSERC Engage, the Canadian Fishing Company, University of British Columbia, and NSERC Ocean Tracking Network Canada. The data analysis and interpretation presented in this project were conducted by M.S. Watson with input on data analysis for Chapter 2 from K.V. Cook.

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Chapter 1. Introduction to Pacific salmon fisheries and the management problem

1.1 Background to the management challenges in Pacific salmon fisheries

Mortality of fish discarded as bycatch is one of the most significant issues affecting marine fisheries management (Davis, 2002) and creates serious conservation problems when the level of bycatch mortality is unsustainable for the non-target species' populations. Bycatch issues are prevalent in mixed-stock fisheries, where fish species and stocks co-mingle, making it difficult to avoid populations of conservation concern while maintaining fisheries on populations able to withstand fishing pressure. This is true of wild salmon fisheries in British Columbia, where co-migrating species and stocks of Pacific salmon are captured together. In an effort to counteract this problem, Fisheries and Oceans Canada (DFO) first officially introduced selective fishing techniques and regulations into the commercial Pacific salmon fishery in 1998. Selective fishing is the ability to avoid bycatch (non-target fish or other organisms such as invertebrates, seabirds, marine mammals), or, if encountered, to release them alive and unharmed. In the commercial salmon fishery, selective fishing involves the sorting of catch and releasing non-target salmon species (DFO, 2001). The introduction of selective fishing methods came as part of a large transformation in the management of the Pacific salmon fishery and has had significant impacts on the operation of commercial fisheries.

There are concerns that in some fishery areas, such as the north coast of British Columbia, noncompliance with selective fishing techniques and regulations, including handling practices for releasing fish, in the commercial purse seine fishery is resulting in a high mortality rate of salmon populations of conservation concern. In this chapter, I provide a review of Pacific salmon fishery management in British Columbia, the purse seine fishery, the introduction of selective fishing regulations, and the specific management problem that is the primary focus for this project.

1.2 Pacific salmon fishing in British Columbia

In British Columbia, wild Pacific salmon (*Onchorhynchus* spp.) are a keystone resource to many stakeholders in the province. The commercial fisheries, including those for Pacific salmon (some of the last large fisheries of wild fish in Canada) is one of the largest sectors of the provincial economy, and generate additional economic activity through subsidiary industries (Cooke et al., 2012). Salmon are of considerable significance to First Nations for food, social, and ceremonial purposes, and to the culture of many communities on the BC coast. Ecologically, salmon are critical to the health of coastal ecosystems, making a unique link between marine and terrestrial environments. This key resource is under threat; an assessment by the Raincoast Conservation Society found that 74% of salmon runs in the north and central British Columbia coast were not meeting the spawning targets necessary to produce sufficient numbers to sustain the next generations of fish populations (Harvey & MacDuffee, 2002). Overfishing of adult populations, climate change, and habitat degradation have had cumulative negative effects (Bradford & Irvine, 2000), limiting the salmon resources available to marine and terrestrial ecosystems and reducing the number of spawning salmon able to contribute to future populations.

Seven salmonid species belong to this genus, all of which are native to British Columbia. These are sockeye salmon (*O. nerka*), chinook salmon (*O. tshawytscha)*, coho salmon (*O. kisutch*), pink salmon (*O. gorbuscha*) and chum salmon (*O. keta*) salmon, and steelhead (*O. mykiss*) and cutthroat trout (*O. clarki clarki*). Marine commercial fisheries target the five salmon species as they return from the ocean to freshwater streams to spawn. The distinct lifecycles of each species means that different species are returning and targeted by fisheries depending on the run abundance and fishing opportunity allocations.

Due to their anadromous life history, spawning in freshwater and migrating to marine environments to grow to adulthood, salmon are an ecologically important species which support foodwebs in marine, estuarine, freshwater and terrestrial ecosystems. The movement of salmon between marine and freshwater environments contributes a spatial subsidy of nutrients between habitats (Leroux & Loreau, 2008). Changes in salmon abundance have been found to have significant and far-reaching influence throughout marine, aquatic and terrestrial habitats. These include the productivity and nutrient cycling in aquatic and riparian systems (Cederholm et al., 1999; Naiman et al., 2002), structure and growth in terrestrial vegetation (Hocking et al., 2011; Reimchen & Fox, 2013), and the behaviour of terrestrial and marine carnivores (*e.g.* Bryan et al., 2013; Darimont et al., 2008; Sigler et al., 2009). This yearly pulse of salmon to the Pacific coast represents a critical contribution to the ecosystem. Therefore, conservation concerns are focused on ensuring that adequate numbers of returning salmon reach specific watersheds, from both a biological (*i.e.* population sustaining) and ecosystem perspective.

The Pacific salmon fishery is complex in its organization, involving several distinct user groups (aboriginal, recreational, and commercial), and gear types that target different salmon species, each comprised of hundreds of unique populations, many of which migrate upriver toward spawning grounds at the same time. Fisheries are managed to the level of the stock; a biologically discrete aggregate of populations of a single species that are grouped for management purposes and which generally have similar migration patterns and run timing (DFO, 2001). There is estimated to be over ten thousand different breeding stocks of salmon spawning in streams of British Columbia, and the relative health of these stocks is extremely varied (Allendorf et al., 1997). This variation poses a problem for the management of mixed-stock fisheries like the commercial Pacific salmon fishery. As part of their mandate of biodiversity protection, DFO manages to the level of the weakest stock. This means that fishers can see an abundance of fish, but fisheries may remain closed due to the management of particular stocks within an area.

Salmon fisheries are coordinated regionally within BC with many management decisions occurring in area and field offices. Allocations of Pacific salmon are divided amongst user groups in a hierarchy. Conservation is the highest management priority, and stream-specific escapement goals are set each year to maintain the critical number of mature salmon allowed to pass through (or escape) fisheries and return to fresh water to spawn. Allocation priorities are then given to First Nations fisheries for food, social, and ceremonial harvest, then to recreational fisheries, and then to commercial fisheries.

Within the commercial fishery, three gear types (seine, gillnet and troll) also receive shares of the allocation of fishing opportunities.

Purse seine fisheries receive about forty percent of the overall commercial salmon harvest allocation (Butler, 2006). Purse seining nets are over half a kilometer long and over fifty meters deep. Due to the sheer depth gradient near to the shoreline on the north coast, seine nets are set by tying one end to the shore – requiring a crew member (the "beach man") to sprint up steep rocky shores covered in algae and barnacles with the net's beach line. The vessel sails away from shore, unwinding the net which is then towed for up to twenty minutes before the beach line is released and the whole net is drawn up and 'pursed' closed using the net 'purse strings' (Fig. 1.1). Finally, the net is brought alongside the boat and fish are loaded onboard. During a fishery opening, a crew will repeat this process between 16 to 20 times in a day. As with other commercial Pacific salmon fisheries, purse seining is managed as a limited access, competitive fishery. Most commercially-caught salmon in BC are fished in a 'derby-style' fishery where any boat with a commercial fishing license races to catch as many fish as they can while the fishery remains open. Openings are typically 16 hours long and their frequency is determined by in-season assessments of salmon return abundances.

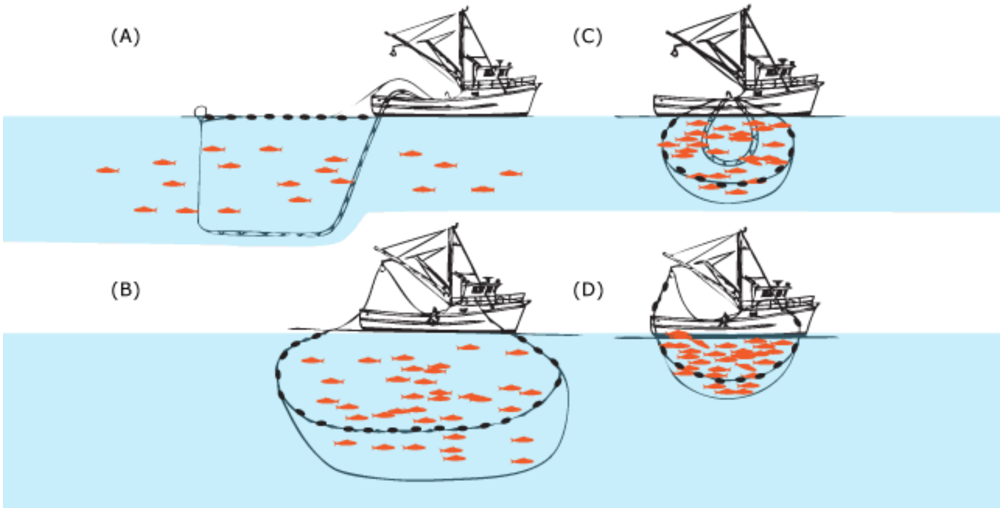

Figure 1.1. The purse seining process: (A) net is set, unwound and let sit for up to 20 minutes (B), the 'purse string' cable at the base of the net is drawn in to close the bottom of the net, (C) the net is drawn up to the boat, (D) smaller nets called brailers are used to move the fish out of the seine net and onto the boat. Image from http://www.montereyfish.com.

In the last 30 years, the commercial Pacific salmon fishery has seen a significant transformation in the way it is managed; including license conditions, fleet size, and species retention. In the seine fishery today, private investor fish processors based in southern British Columbia own the majority of boats and licenses (EcoTrust Canada, 2004). DFO allows boat and license owners to stack or combine their quotas onto a single boat, meaning that fewer boats can be sent out to catch the same amount of fish. This change and the increasing privatization of licenses has led to significant impacts on independent fishermen and fishing communities (Pinkerton et al., 2014).

1.3 Selective fishing: Regulations and Approaches

Many of the significant changes in commercial salmon licensing and species retention regulations originate from a period now referred to as the Coho Crisis. In 1997, DFO stock assessments indicated that coho salmon abundance had declined significantly, especially in the area of the upper Skeena River in Northern BC, and in the Thompson River in southern BC. Regulations were put in place in an effort to conserve coho stocks; in 1998 no fisheries were allowed to target coho and mandatory non-retention was introduced into all fisheries - coho had to be sorted from catches and returned to the water. Increased monitoring and enforcement was implemented in all fisheries. The Coho Plan committed 400 million dollars to conservation programs including salmon habitat enhancement, assisting communities and individuals to adjusting to changing fishing opportunities, to fleet restructuring, and to the development of selective fishing techniques (Fisheries and Oceans Canada, 1998).

The previously implemented 1996 Mifflin Plan had already set in motion a reduction of the commercial salmon fleet in BC through license retirement. Prior to the Mifflin Plan, licenses generally allowed the license holder to use more than one type of gear (*i.e.* could combine troll and gillnet gear) on a single vessel and to fish anywhere along the BC coast (Muse, 1999). Under the Mifflin Plan, the coast was divided into fishery management areas (Fig. 1.2) which were then grouped into larger management areas by gear type; 2 for seining, 3 for gillnet, and 3 for trolling. License holders also had to choose a single gear to fish and a management area they would fish with the license (Muse, 1999). Through the license retirement program, the Pacific salmon fleet was reduced by 50% between 1996 and 2000 (Government of Canada, 2000).

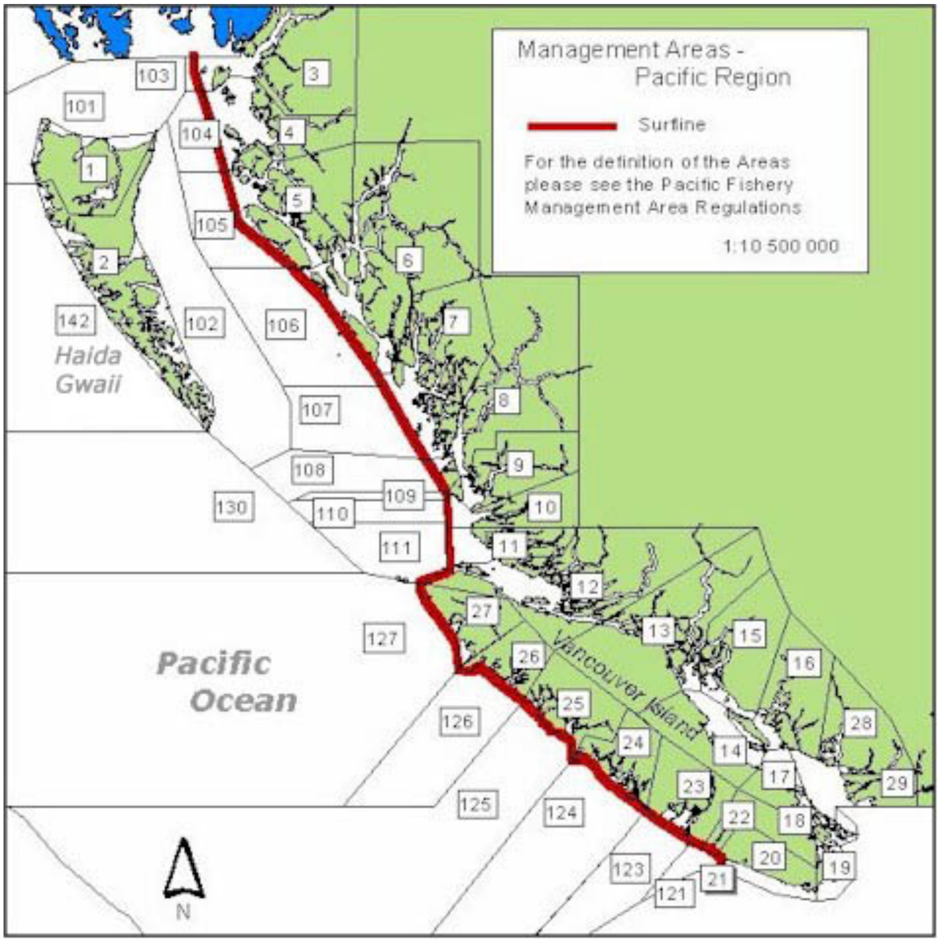

Figure 1.2. Fisheries and Oceans Canada fisheries management areas of British Columbia (from http://www.pac.dfo-mpo.gc.ca/). For the salmon purse seine fishery, Area A is comprised of Management Areas 1-10, and Area B is comprised of Management Areas 11-29 and 121).

Selective gear development was a major focus of the Coho Plan. The Selective Fisheries Program included support for experimental projects to test new technologies and release techniques to reduce coho salmon mortality, provide monitoring by fisheries observers, and increase enforcement and training (Government of Canada, 2000). Fishery regulations on selectivity were introduced and are still in place; purse seiners were restricted from bringing their catch in by hauling their nets over their stern (called ramping) and instead had to ‘brail’ their catch onboard using small nets to bring a few hundred fish onboard at a time, and to sort and release coho. All gear types were mandated to have a revival box on board; a large tub with flowing seawater in which unresponsive fish could be placed to revive before being released overboard. In combination with proper handling and fishing techniques, these boxes have been shown to improve the post-release survival rates of coho (Farrell et al., 2001a).

In 2001, the Policy for Selective Fishing in Canada's Pacific Fisheries (DFO, 2001) was introduced with a particular focus on Pacific salmon fisheries. The policy aims to encourage selective fishing through allocating commercial fishing opportunities in favour of those who can demonstrate their ability to fish selectively. Today, selective fishing measures in the Pacific salmon fishery have spread beyond the conservation of coho salmon. Sockeye, chinook, and chum salmon stocks are also now determined for non-retention in some areas based on their conservation status. Under the conditions of license for salmon purse seining, crews must brail fish onboard from their net, put fish to be sorted into a designated area onboard boats (many larger boats have a fabricated sorting box into which fish are brailed from the net, whereas smaller boats use a cordoned off area of the deck), crews must sort each brailer before taking a new one, and for non-retained species must "release fish with the least possible harm". Additionally, the implementation of 'short net, short set' regulations reduced net sizes and restricted the time that seine nets could be left in the water to 20 minutes, thus reducing the amount of time that fish spend within the net. The introduction of selective fishing to the commercial fishery has dramatically altered the fishing process in salmon purse seining.

1.4 Management Problem: Bycatch, release and mortality of non-retention salmon species

The complex nature of the Pacific salmon lifecycle means that there are many diverse pressures affecting salmon survival to spawning; including juvenile survival in freshwater, changing ocean conditions and climate change, fishing pressure, and land-based activities impacting spawning streams (*e.g.* logging and hydroelectric dams; Bradford & Irvine, 2000). Therefore, impacts to salmon populations from fishery capture is one component among many cumulative effects that need to be considered to improve survival, and to increase numbers of returning fish for populations of conservation concern. If there is significant mortality of non-target salmon released from commercial fisheries, bycatch mortality alone is an additional stressor that may inhibit recovery for populations that are already depressed or of lower abundance.

Estimated mortality rates of released fish in commercial and recreational fishing range between 0 to 75% depending on the fishing method, environmental conditions and fish species (Farrell et al., 2001a). Many interacting factors impact the stress level and mortality of fish caught in fishing gear (Davis & Ryer, 2003; Fig 1.3). In purse seine fisheries, variables during handling, sorting and release can impact the condition of a fish released after capture, including how net is handled and brought in to the boat, how fish are brailed onboard (such as the number of fish brailed at a time), sorting speed (Pacific salmon purse seine license conditions mandate fishers to sort fish one brailer at a time), and the infrastructure on vessels for sorting (*e.g.* are fish put into a sorting table, onto the boat deck, and is there a release chute built). The combination of these variables can result in crowding within the net, injury from time spent within net, air exposure during time in brailer and on deck, prolonged air exposure or injury during sorting and release overboard (*i.e.* are they thrown overboard or slide out in a chute). Improving the handling and condition of fish destined for release after capture by minimizing injury, stress and mortality requires information on fish physiology (*e.g.* injury and stress severity), fisher behaviour (*e.g.* fishing, handling, and release techniques), and acceptance and input to changes in handling practices from those exploiting and using the resource (commercial fishers and other stakeholders involved in the commercial fishery; *e.g.* Donaldson et al., 2013).

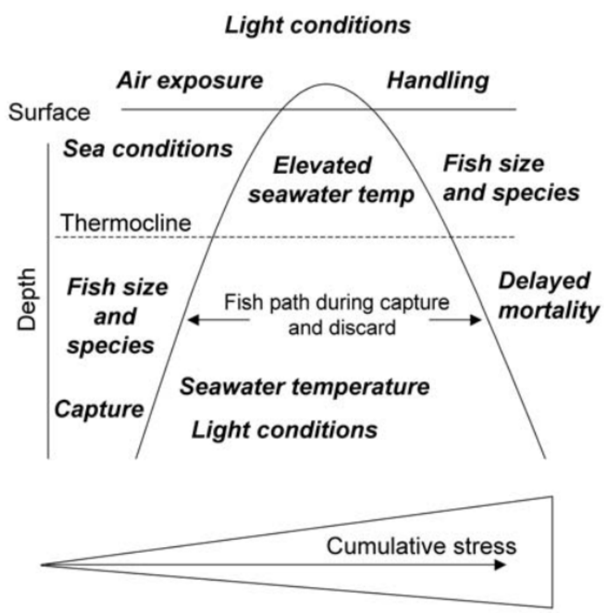

Figure 1.3. A conceptual diagram of influential factors in discarded fish stress and mortality, from Davis and Ryer (2003). The curved line indicates the path of a fish moving from depth to surface during capture and discard. Temperature and pressure changes associated with depth are not significant factors in purse seine fisheries.

In some commercial salmon fisheries, such as those on the remote northern coast of British Columbia, there are concerns that poor compliance with selective fishing regulations and handling of salmon to be released may be resulting in high post-release mortality of non-retention species. Many diverse and influential stakeholders with competing priorities are invested in the management of salmon fisheries, making management decisions and fishery issues highly politicized and often controversial (Lackey, 1999). Therefore, there is a need for an unbiased assessment of how different handling practices influence fish condition and post-release survival. It is also important to understand the perspectives of stakeholders engaged in this issue in order to facilitate communication on these critical management issues.

1.4.1 Literature Review – How biological and social sciences have been used to inform Pacific salmon bycatch management

As post-release mortality of fish bycatch results from adverse interactions between animals, fishing gear, and handling, reducing mortality rates will require a combination of biological and social solutions. The use of physiological indicators to produce a technological solution to increase bycatch survival is reviewed in a case study of the introduction of the revival box, or coho box, into the Pacific salmon fishery. Social factors influencing the uptake of these solutions are discussed.

Biological studies are crucial to developing, supporting, and improving management and conservation measures. Physiological tools have been used to inform management measures for Pacific salmon, including the effects of fisheries capture and the ability of fish to recover prior to release (Cooke et al., 2012). As part of DFO’s Selective Fishing Policy, all commercial salmon fishing vessels in BC are required to carry and use fish recovery boxes for use to revive coho salmon on board the vessels prior to release. Prior to 2000, however, the benefits of these boxes for aiding recovery of salmon post-capture had not been tested. Farrell et al. (2000) tested physiological recovery post-capture in all three commercial salmon gear types (gillnet, seine, and troll) and found that physiological condition of coho salmon was not improved after a 1-hour period within the recovery box. This led to a re-evaluation of the use of the boxes and several changes were made to the box, such as the use of laminar water flow over the fish and reduction of the box size to limit fish movement. These changes resulted in significant improvements in the physiological condition of coho salmon post-capture in gillnet fisheries (Farrell et al., 2001). The demonstrated improvement in the design of these boxes has led to their implementation in marine commercial fisheries for reviving and releasing coho salmon.

Although biological studies can provide support for the implementation of conservation measures into regulations and management policies, this does not ensure that these measures will be accepted and practiced by resource users. Social science has been used in conjunction with biological studies to assess fishers' reception to methods of reducing post-release mortality of Pacific salmon, such as the use of recovery bags to facilitate reduction of stress before release (Donaldson et al., 2013; Raby et al., 2014; Nguyen, 2012). Donaldson et al. (2013) used physiological assessments to assess the utility of a recovery bag for use in recovering pink salmon following capture and interviewed recreational salmon fishers to determine potential acceptance of the use of the recovery bag. They found that anglers were divided over the need for a fish to recover post-capture, and that both non-supporters and supporters of recovery showed more positive support when they were given scientific evidence of the bag's effectiveness.

Raby et al. (2014) used biotelemetry and reflex impairment to evaluate the impact of fishery capture on coho salmon survival and interviewed Aboriginal fishers to understand perspectives on factors influencing salmon bycatch post-release mortality and on ways to reduce mortality. Although the majority of their respondents were unconvinced that beach seine capture affected salmon survival, fishers were receptive to the use of a recovery box, and the number of positive responses was increased when respondents were provided with evidence of the effectiveness of the boxes. Nguyen's (2012) interviews with recreational salmon anglers highlighted the diversity of behaviour and motivation among fishers, and found that fishers reactions and acceptance of management measures depends on their perspectives of the legitimacy of the measure as well as their personal costs (financial and otherwise) incurred (Nguyen, 2012). Together, these studies demonstrate the need for combining biological and social science to evaluate the implementation of bycatch handling techniques, and that the provision of scientific evidence to support the use of handling techniques is important to their overall acceptance by fishers. Successful implementation of conservation or management strategies requires an understanding of the social dynamics, or human dimensions, of the group under management, and their perspectives on conservation or management measures.

Understanding the human dimensions of the fishery is critical for the implementation and acceptance of new information and techniques determined through biological studies. The human dimension of the management process includes an understanding of the impact that management decisions have on the people who are being managed (Kaplan & McKay, 2004). Goals of human dimensions work in fisheries research include understanding human thoughts and actions (such as behaviour and relationships) regarding fish, fishing, fisheries governance and management, and the connections between natural and human components of the fishery system (Hunt et al., 2013). Fishers are the most familiar with problems within their fishery, and changes involving their gear or practices. Human dimensions work can provide opportunities for fishers to contribute new and practical information, to refine existing strategies or explore alternative strategies (Nguyen, 2012). The social context in which new fishing technologies (*e.g.* bycatch reduction technologies and gear) are introduced is critical to their success or failure (Campbell & Cornwell, 2008). Understanding how the human and natural components of the fishery are connected through complex interactions can support understanding of the outcomes of management actions (Hunt et al., 2013).

Human dimensions within fisheries management are complex and can involve many diverse stakeholders. Policy and management decisions can have pervasive and long-lasting impacts for those under management. The rationalization of the commercial salmon fleet, and the resultant loss of fishing licenses, vessels, fishing opportunity, and of government support and infrastructure that supported fishing activities within communities has had documented negative social impacts on fishing communities (Pinkerton et al., 2014; Ecotrust, 2004). These also create negative feedback loops which drive further social losses; the decline of fishing opportunities diminish the influence of commercial fishermen within the management system, and reduced economic, social, and cultural benefits to communities from commercial fisheries reduces the overall support for the industry (Pinkerton et al., 2014).

When multiple stakeholders are involved in a fishery, communication and relationships between these groups impacts the overall success of fishery management. Failures in communication can lead to adversarial relationships and tensions between stakeholders, such as between the government and fishing community, which impede the overall management process (Kaplan & McCay, 2004). Acceptance of conservation management actions by fishermen must be understood within the context of larger issues of intersectoral competition and conflicts between stakeholders (Butler, 2006). The Pacific salmon fishery has had longstanding conflict between different sectors and stakeholders. Limited sharing of power and information regarding the structure of decision-making has degraded fishers' confidence that their concerns and investments are considered and incorporated into policy decisions (Pinkerton, 1994). The impacts of conservation policies, measures, or technologies designed to reduce ecological impacts will be limited if fishers have no incentive to implement them (Campbell & Cornwell, 2008). Understanding the social impact of management measures can inform the delivery, implementation, or modification of these policies to support their reception and use.

1.5 Research Objectives and Organization of Paper

The goal of this project was to explore biological and social approaches to reduce chum salmon bycatch mortality through 1) understanding which aspects of the sorting process which have the greatest impact on fish vitality and therefore their post-release survival, and 2) assessing the human dimensions of selective fishing practices and regulations (including fisher behaviour and attitudes to salmon bycatch handling). Recognizing the multiple stakeholder and interest groups within this fishery that are concerned with bycatch handling and release, the perceptions of fishery managers and members of non-governmental organizations of these issues were also assessed. Evaluation of the components of the fishing process with the greatest impact on the post-release survival of fish will focus efforts on improved handling practices. Understanding the human dimensions of selective fishing regulations may reveal reasons for noncompliance with selective fishing practices, and provide opportunity to explore solutions with input from multiple stakeholders.

In this project, I assess both biological and social factors of chum salmon bycatch handling and release in the commercial purse seine fishery in northern British Columbia. In Chapter 2, I use measures of vitality to determine aspects of handling and sorting that are most deleterious to fish survival and condition post-release from purse seine fisheries on the northern coast of British Columbia, using reflex impairment assessment to compare the relative condition of fish under different handling methods and scenarios. In Chapter 3, I assess fisher attitudes and perception of salmon bycatch impacts, regulations, and management decisions and reveal reasons for non-compliance with regulations and provide solutions for bycatch mortality reduction through semi-structured interviews conducted with commercial purse seine salmon fishermen. To compare the perceptions of fishers to that of other stakeholders, interviews were also conducted with fishery managers and members of non-governmental organizations concerned with issues relating to salmon bycatch handling and release mortality. In Chapter 4, taking both biological and social information collected into account, I present my conclusions and make recommendations for steps to improve the survival of salmon released from purse seine fisheries and including how management actions can influence the success of these initiatives.

Literature Cited

Allendorf, F.W., Bayles, D., Bottom, D. L., Currens, K. P., Frissell, C. A., Hankin, D., Lichatowich, J.A., Nehlsen W., Trotter P.C., Williams, T.H. (1997). Prioritizing Pacific Salmon Stocks for Conservation. *Conservation Biology*, *11*(1), 140–152.

Bradford, M.J., & Irvine, J.R. (2000). Land use, fishing, climate change, and the decline of Thompson River, British Columbia, coho salmon. *Canadian Journal of Fisheries and Aquatic Sciences*, *57*(1), 13–16. doi:10.1139/cjfas-57-1-13

Bryan, H.M., Darimont, C.T., Paquet, P.C., Wynne-Edwards, K.E., & Smits, J.E.G. (2013). Stress and reproductive hormones in grizzly bears reflect nutritional benefits and social consequences of a salmon foraging niche. *PloS One*, *8*(11), e80537. doi:10.1371/journal.pone.0080537

Butler, C. (2006). Understanding the Coho Crisis: Political Knowledge in a Fractured Salmon Fishery. *Maritime Studies*, *4*(2), 73–92.

Campbell, L., & Cornwell, M. (2008). Human dimensions of bycatch reduction technology: current assumptions and directions for future research. *Endangered Species Research*, *5*, 325–334. doi:10.3354/esr00172

Cederholm, C.J., Kunze, M.D., Murota, T., & Sibatani, A. (1999). Pacific Salmon Carcasses : Essential Contributions of Nutrients and Energy for Aquatic and Terrestrial Ecosystems. *Fisheries Management/ Habitat*, *24*(10), 37–41. doi:10.1577/1548-8446(1999)024

Cooke, S.J., Hinch, S.G., Donaldson, M.R., Clark, T.D., Eliason, E.J., Crossin, G.T., Raby, G.D., Jeffries, K.M., Lapointe, M., Miller, K., Patterson, D.A., Farrell, A.P. (2012). Conservation physiology in practice: how physiological knowledge has improved our ability to sustainably manage Pacific salmon during up-river migration. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *367*(1596), 1757–69. doi:10.1098/rstb.2012.0022

Darimont, C.T., Paquet, P.C., & Reimchen, T.E. (2008). Spawning salmon disrupt trophic coupling between wolves and ungulate prey in coastal British Columbia. *BMC Ecology*, *8*, 14. doi:10.1186/1472-6785-8-14

Davis, M.W. (2002). Key principles for understanding fish bycatch discard mortality. *Canadian Journal of Fisheries and Aquatic Sciences*, *59*(11), 1834–1843. doi:10.1139/f02-139

Davis, M.W., Ryer, C.H. (2003). Understanding Fish Bycatch Discard And Escapee Mortality. *AFSC Quarterly Report*, *Janary-Mar*, 1–9.

Department of Fisheries and Oceans Canada (DFO). (2001). A Policy for Selective Fishing in Canada's Pacific Fisheries, (January).

Donaldson, M.R., Raby, G.D., Nguyen, V.N., Hinch, S.G., Patterson, D.A., Farrell, A.P., Rudd, M.A., Thompson, L.A., O'Connor, C.M., Colotelo, A.H., McConnachie, S.H., Cook, K.V., Robichaud, D., English, K.K., Cooke, S.J. (2013). Evaluation of a simple technique for recovering fish from capture stress: integrating physiology , biotelemetry , and social science to solve a conservation problem. *Canadian Journal of Fisheries and Aquatic Sciences*, *70*, 90–100.

Ecotrust Canada. (2004). Catch 22: conservation, communities and the privatization of B.C. fisheries. An economic, social and ecological impact study. Vancouver, BC. Retrieved from http://ecotrust.ca/wp-content/uploads/2015/02/Catch-22-November2004_0.pdf

Farrell, A., Gallaugher, P., Clarke, C., DeLury, N., Kreiberg, H., Parkhouse, W., Routledge, R. (2000). Physiological status of coho salmon (*Oncorhynchus kisutch*) captured in commercial nonretention fisheries. *Canadian Journal of Fisheries and Aquatic Sciences*, *57*(8), 1668–1678. doi:10.1139/f00-116

Farrell, A., Gallaugher, P., Fraser, J., Pike, D., Bowering, P., Hadwin, A.K.M., Parkhouse, W., Routledge, R. (2001). Successful recovery of the physiological status of coho salmon on board a commercial gillnet vessel by means of a newly designed revival box. *Canadian Journal of Fisheries and Aquatic Sciences*, *58*(10), 1932–1946. doi:10.1139/cjfas-58-10-1932

Fisheries and Oceans Canada Pacific Region. (1998). *Final Report Coho Response Team*.

Government of Canada. (2000). *A Plan to Revitalize Canada's Pacific Fisheries: Progress Report for Year Two*.

Harvey, B., MacDuffee, M. (Eds.) (2002) Ghost Runs: The Future of Wild Salmon on the North and Central Coasts of British Columbia. Raincoast Conservation Society. Victoria, BC.

Hocking, M.D., Reynolds, J.D. (2011). Impacts of salmon on riparian plant diversity. *Science (New York, N.Y.)*, *331*(6024), 1609–12. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/21442794

Hunt, L.M., Sutton, S.G., Arlinghaus, R. (2013). Illustrating the critical role of human dimensions research for understanding and managing recreational fisheries within a social-ecological system framework. *Fisheries Management and Ecology*, *20*(2-3), 111–124. doi:10.1111/j.1365-2400.2012.00870.x

Kaplan, I. (2004). Cooperative research, co-management and the social dimension of fisheries science and management. *Marine Policy*, *28*(3), 257–258. doi:10.1016/j.marpol.2003.08.003

Lackey, R.T. (1999). Salmon Policy: Science, Society, Restoration, and Reality. *Renewable Resources Journal*, *17*(2), 6–16.

Leroux, S.J., Loreau, M. (2008). Subsidy hypothesis and strength of trophic cascades across ecosystems. *Ecology Letters*, *11*(11), 1147–56. doi:10.1111/j.1461-0248.2008.01235.x

Muse, B. (1999). *Fleet Reduction in British Columbia's Commercial Salmon Fisheries: 1996-1998* (pp. 1996–1998).

Naiman, R.J., Bilby, R.E., Schindler, D.E., Helfield, J.M. (2002). Pacific Salmon, Nutrients, and the Dynamics of Freshwater and Riparian Ecosystems. *Ecosystems*, *5*(4), 399–417. doi:10.1007/s10021-001-0083-3

Nguyen, V.M. (2012). *The biological and social sciences of improving post-release survival in sockeye salmon following fisheries interaction in the lower Fraser River, British Columbia*. Carleton University.

Pinkerton, E.W. (1994). Local Fisheries Co-management: A Review of International Experiences and Their Implications for Salmon Management in British Columbia. *Canadian Journal of Fisheries & Aquatic Science*. 51, 2363–2378.

Pinkerton, E., Angel, E., Ladell, N., Williams, P., Nicolson, M., Thorkelson, J., Clifton, H. (2014). Local and regional strategies for rebuilding fisheries management institutions in coastal British Columbia: what components of comanagement are most critical? *Ecology and Society*, 19(2) 72. http://dx.doi.org/10.5751/ES-06489-190272

Raby, G., Donaldson, M., Nguyen, V., Taylor, M., Sopinka, N., Cook, K., Patterson, D.A., Robichaud, D., Hinch, S.G., Cooke, S.J. (2014). Bycatch mortality of endangered coho salmon: impacts, solutions, and aboriginal perspectives. *Ecological Applications*, *24*(7), 1803–1819.

Reimchen, T.E., Fox, C.H. (2013). Fine-scale spatiotemporal influences of salmon on growth and nitrogen signatures of Sitka spruce tree rings. *BMC Ecology*, *13*(1), 38. doi:10.1186/1472-6785-13-38

Sigler, M., Tollit, D., Vollenweider, J., Thedinga, J., Csepp, D., Womble, J., Wong, M.A., Rehberg, M.J., Trites, A. (2009). Steller sea lion foraging response to seasonal changes in prey availability. *Marine Ecology Progress Series*, *388*, 243–261. doi:10.3354/meps0814

Chapter 2. Using vitality indicators to assess handling methods for chum salmon released from commercial purse seine fisheries

2.1 Introduction

The impacts of commercial fisheries on fish populations are managed using estimates of fishing mortality; this includes the mortality of targeted species and the unintended mortality of non-target species, or bycatch. Post-release mortality is a significant component of cryptic fishing mortality or mortality that is not directly observable or detectable during fishery operations (Gilman, 2013). The survival rate of fish discarded as bycatch is difficult to ascertain and is unknown for many fisheries. This therefore creates a large amount of uncertainty in estimates of fishing mortality (Hall et al., 2000). Physiological stress induced during capture is an important variable influencing the post-release recovery of fish (Donaldson et al., 2010; Wilson et al., 2014). Minimization of stress during capture and use of recovery techniques can facilitate post-release survival of discarded fish (*e.g.* Farrell et al., 2001).

Bycatch issues are especially prevalent in mixed-stock fisheries, such as wild salmon fisheries in British Columbia (BC) where the co-migration of species and stocks of Pacific salmon (*Onchorhynchus* spp.) make it difficult to avoid populations of conservation concern while maintaining fisheries on populations able to withstand fishing pressure. The Selective Fishing Policy mandates the release of certain species of Pacific salmon assessed to be of conservation concern, while allowing harvest on more abundant species or stocks (DFO, 2001). In some fisheries, such as those on the remote northern coast of BC, there have been concerns of poor compliance and handling of bycatch resulting in higher mortality rates of salmon released from these fisheries.

Little is known about the post-release mortality of salmon bycatch in these fisheries, and ascertaining the post-release survival of these fish is very difficult. Salmon caught and released in commercial fisheries within large channels may be heading to any of hundreds of river or stream systems to spawn, making it logistically challenging to track fish. Instead, focusing on pre-release predictors of survival and condition may provide insight into the best practices for handling fish that will maximize their survival. Reflex assessment mortality predictors (RAMP), also referred to as vitality assessments, is an approach based on scoring simple reflex action in a binomial scoring system (presence or absence) and a reflex impairment score is the sum of absent reflexes. There is often a direct relationship between losses in reflex actions and induced stress, and testing multiple reflexes on individual fish can be used to predict delayed mortality (Davis & Ottmar, 2006). RAMP has been used as a predictor of bycatch related mortality in field fishing experiments (Davis, 2007; Davis, 2010), and has been confirmed to predict mortality in coho salmon bycatch (Raby et al., 2012; Raby et al. 2014).

Several studies have established the negative impacts to fish from air exposure, and that different species can tolerate different amounts of air exposure (Cook et al., 2015). Most fisheries, including commercial salmon fisheries, lack specific regulations or recommendations for fishers on air exposure thresholds specific for released species. Induction of stress also differs between specific fisheries due to gear type and fishing techniques. Tolerance to stressors differs between fish species, life history stages, and can be influenced by environmental conditions (Cook et al., 2015). Thus, handling recommendations from one fishery or targeted species may not be applicable to another. Ascertaining the degree of reflex impairment of fish under different air exposure and handling can give a relative indication of their condition and can be used to predict their post-release survival (*e.g.* non-vigorous fish or those unable to orient themselves are less likely to be able to escape predation post-release). Reflex impairment assessments can be used to determine tolerable levels of air exposure and which parts of the fishing process have higher impact on fish stress, and may therefore be most influential in determining their fate post-release. These aspects of handling and sorting can then be concentrated on as areas to manage or regulate.

Here, assessment of reflex impairment using RAMP was conducted on chum salmon following capture in a simulated purse seine fishery to investigate the impacts of different handling methods on these fish before they are released. Through understanding which components of the fishery have greatest influence on reflex impairment, we can give recommendations on which fishing methods are least detrimental to incidentally captured fish, and support recommendations for handling and air exposure minimization in chum salmon.

2.2 Methods

Sampling was undertaken from chartered purse seine vessels in Fisheries management Area 6 (Fig. 1.2) in July and August 2015. Fishing was conducted with commercial purse seining boats and crews. Fishing and handling scenarios were conducted on sets and a sample of chum salmon were brought onboard, these fish were immediately RAMP-assessed and were then either released or held in revival tanks for transport for another component of the study. Handling scenarios included an air exposure time on deck, different lengths of time fish were held within the net, and loose and tight nets alongside the boat.

Fish removed from the net for scenarios were held in a recovery box until they were RAMP-assessed. We tested for the influence of this period of recovery by testing for a correlation between time spent in a recovery box before RAMP assessment and vitality scores.

For RAMP assessment (Fig. 2.1), each reflex is scored categorically (0=unimpaired, 1=impaired). We assessed each fish for the presence or absence of six reflexes: 1) spontaneous body flex, 2) restrained body flex, 3) operculum flare, 4) vestibular ocular response (VOR), 5) burst swim, and 6) orientation. The total score given to a fish was then divided by 6 to give a score of the proportion of impaired reflexes.

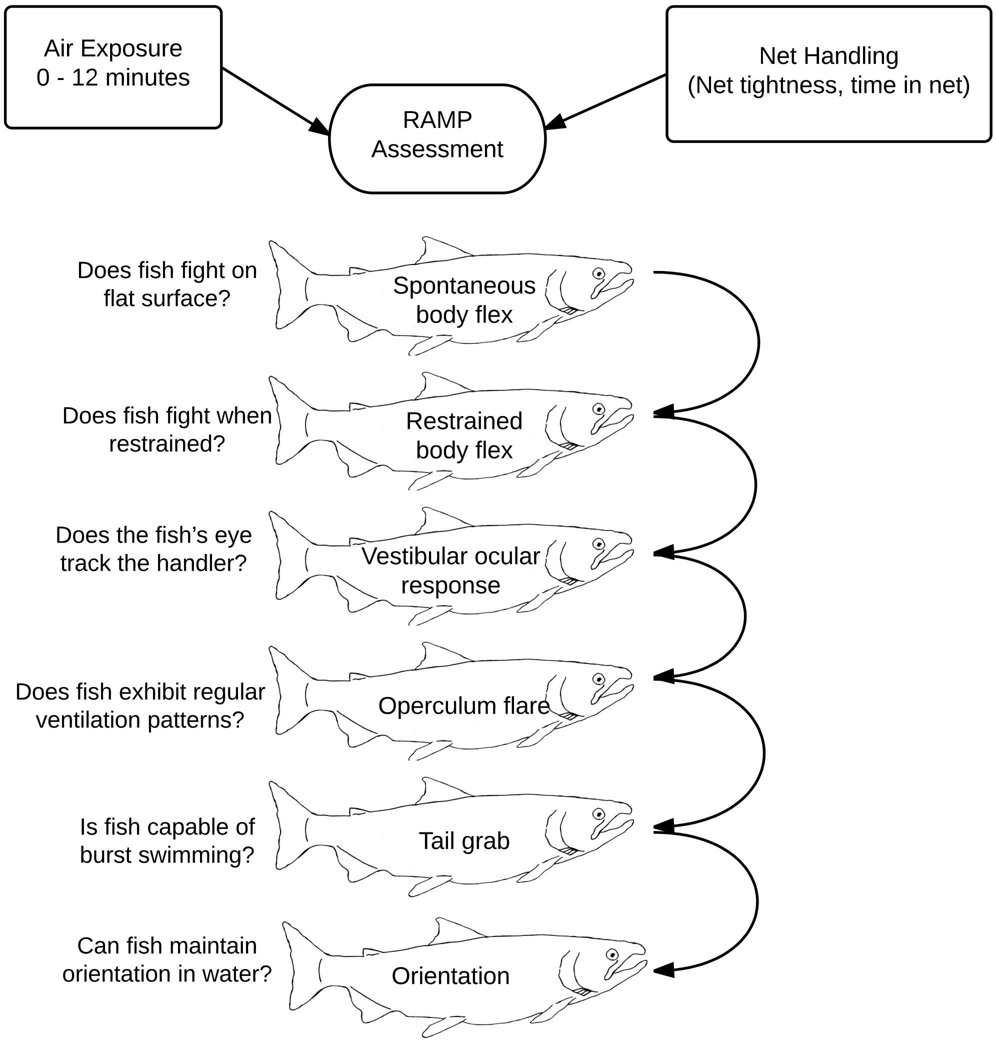

Figure 2.1 Reflexes assessed for impairment in Reflex Action Mortality Predictor (RAMP).

2.2.1 Ethics statement

Animal research ethics for this project was obtained from the University of British Columbia by the University of British Columbia's Pacific Salmon Ecology & Conservation Lab. Research permits for scientific fishing in Area 6 were obtained from Fisheries and Oceans Canada (DFO).

2.2.2 Air exposure

To assess the impacts of air exposure during the sorting process, chum salmon were brailed onboard from a loosely held net and placed in the sorting table on deck. Fish were removed from the box and RAMP-assessed at 1 minute intervals up to 12 minutes. Fish were sampled from 7 separate net sets.

Table 2.1. Sample sizes for RAMP-assessed chum salmon for air exposure treatments.

Time Interval (min)	Number fish sampled
1-3	11
3-5	16
5-7	20
7-10	12
10-12	6
Total	**65**

2.2.3 Net handling

For each of the net handling scenarios, fish were sampled after short (<20 minutes), medium (20-30 minutes) and long (30–40 minutes) times within the net as it was held alongside the boat for brailing. Nets were held either loosely or tightly against the side of the boat. In the loose and tight net scenarios, skippers were asked to use their discretion as to what a tight and loose net was, as this was dependent on the number of fish within the set.

Table 2.2. Sample size of RAMP-assessed chum salmon for fishery handling scenarios.

Net handling	Short Net time (<20min)	Medium Net time (20-30min)	Long Net time (30-40min)
Tight net	n=9	n=19	n=20
Loose net	n=12	n=19	n=3

2.2.4 Statistical analysis

All analyses were conducted in R (Version 2.15.0; R Development Core team, 2012). Using the assumption that fishery handling time would have a negative effect on fish vitality, the change in RAMP score with fishery handling time was evaluated using a non-parametric Spearman rank correlation test. Differences in RAMP scores between net handling treatments were tested with a non-parametric Kruskal-Wallis test, and two-way comparisons were conducted with a Mann Whitney U-test.

2.3 Results

RAMP scores were assigned to a total of 190 individual chum salmon, the sample sizes for different air exposure and handling treatments are summarized in Table 2.1 and Table 2.2. The influence on reflex impairment of time a fish spent within a recovery box prior to RAMP-assessment was found to be non-significant, and so was not included in subsequent analyses.

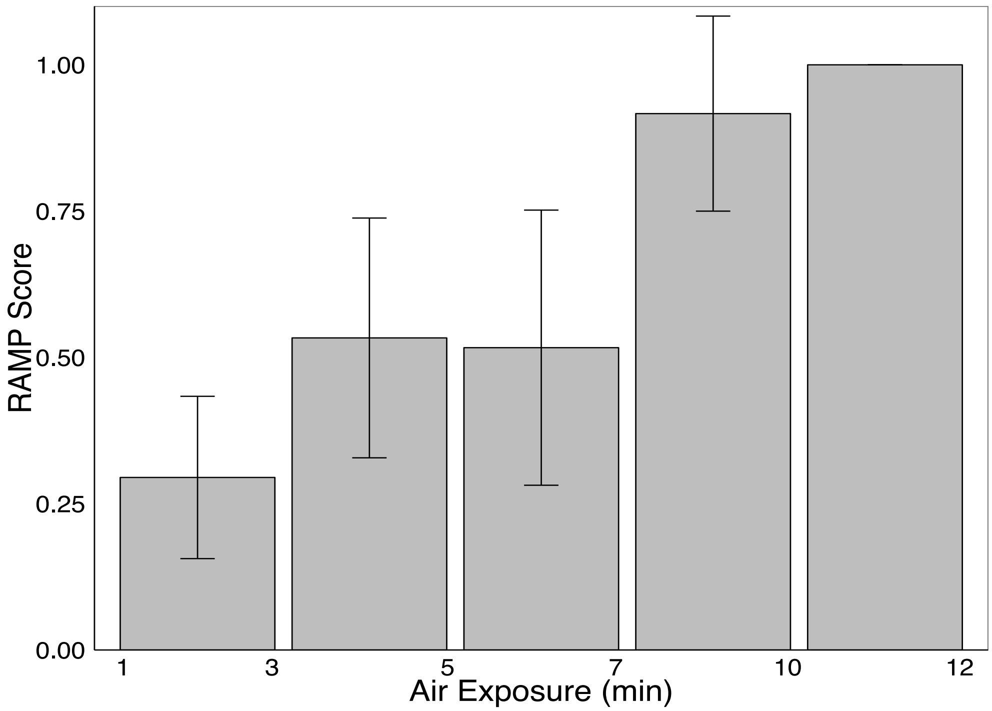

Figure 2.2. Mean RAMP scores for chum salmon with increasing levels of air exposure on board a fishing vessel following capture. Error bars indicate standard deviations of the mean.

There was a significant positive correlation between fishery handling time and reflex impairment (Fig 2.2; Spearman rank correlation, r_s=0.73 , p<0.001). At less than 3 minutes of air exposure, average reflex impairment was 0.31, this increased to 0.44, and then 0.52 at 5 minutes and then 7 minutes respectively. All fish assessed at greater than 10 minutes of air exposure were un-responsive to all assessments, and 60% of these fish died within 30 minutes of RAMP assessment.

Proportions of fish able to orient themselves following release decreased with air exposure time. At less than 3 minutes of air exposure 92% of fish were able to immediately regain normal orientation, at under 5 and 7 minutes of air exposure this number decreased by nearly half (40% and 65% respectively), and only 8% of fish were able to orient themselves after 10 minutes of air exposure.

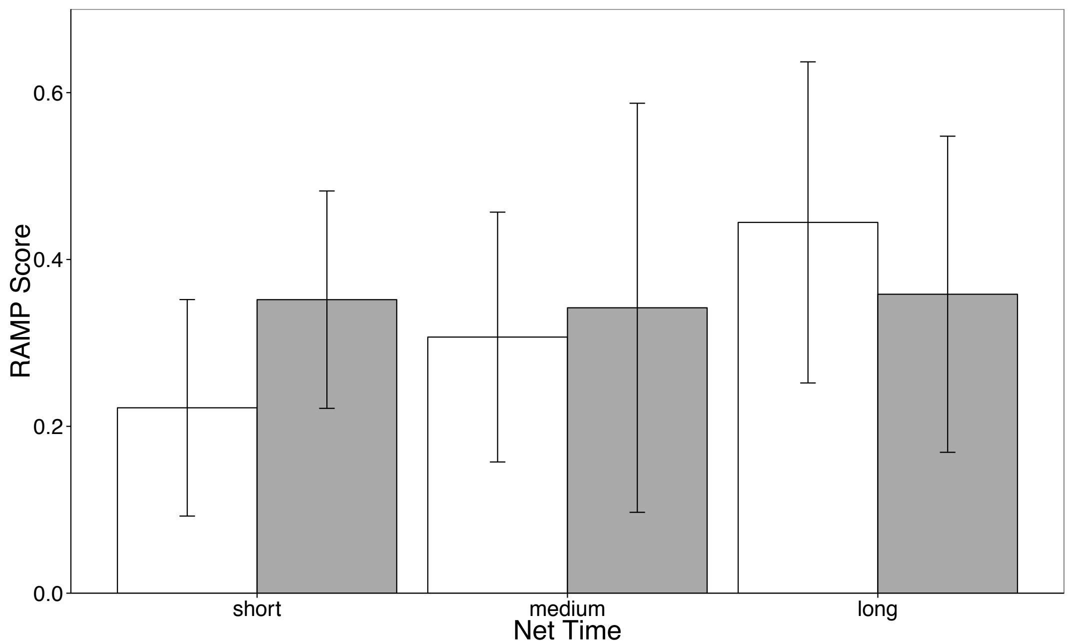

Figure 2.3. Average RAMP scores of chum salmon following different net handling scenarios by a commercial purse seine vessel. Nets were held alongside the boat while fish were brailed out for sorting, fish were removed from the net after short (<20 minutes), medium (20-30 minutes) and long (30-40 minutes) periods while the net was held loose (white bars) or tight (grey bars). Error bars indicate standard deviations of the mean.

There was no significant difference between vitality scores of fish held in the net for short, medium and long time periods (Fig 2.3; Kruskal Wallis test, p=0.25). Although the difference in vitality scores was greater between fish held in the net for short and long time periods, this difference was not significant (Mann Whitney U test; p=0.09).

RAMP scores were higher in those fish that spent longer in the net while the net was held loose, although this difference was not significant (Kruskal Wallis Test, p=0.065). Fish held in a tight set had consistent vitality scores regardless of time within the net.

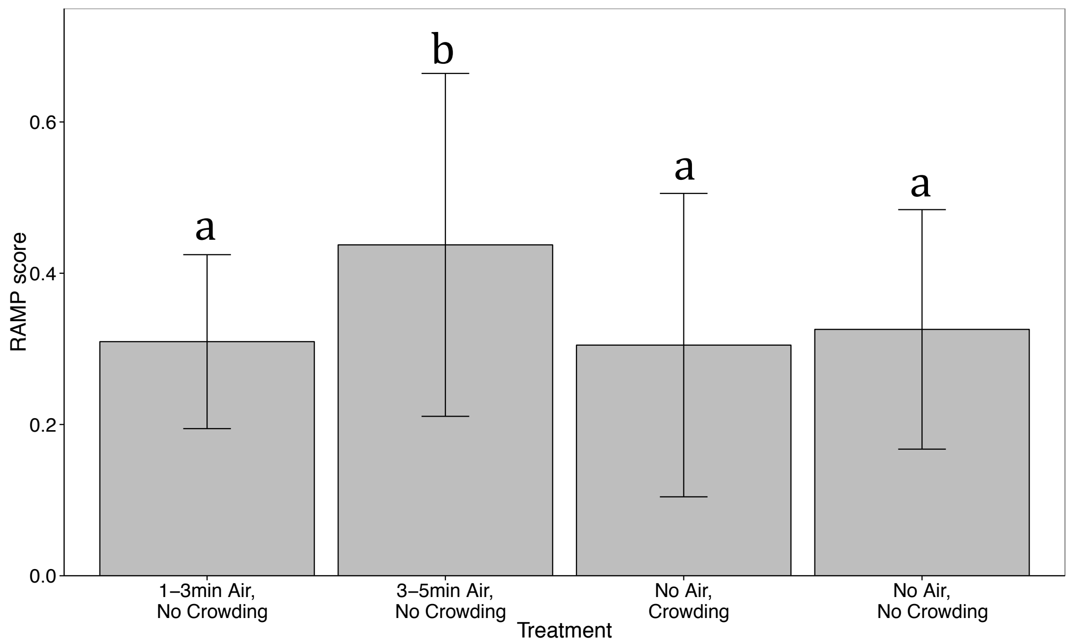

Figure 2.4. Average RAMP scores per treatment; (1) 1-3min Air, No Crowding, (2) 3-5min Air, No Crowding: (3) No Air, Crowding (4) No Air, No Crowding. To examine the difference in impacts of air exposure and net handling. Error bars indicate standard error of the mean. Letters indicate statistically significant differences.

To examine the difference between air exposure and crowding of fish within the net, the reflex impairment of air exposed fish and fish held within the net for over 20 minutes within a tight net or a loose net was compared. Reflex impairment was greater in salmon exposed to air for between 3 and 5 minutes than for those subjected to different net handling scenarios or those exposed to under 3 minutes of air (Fig. 2.4, Kruskal-Wallis test, p=0.01).

2.4 Discussion

The release of bycatch is often not a priority in commercial fisheries, where efficiency of obtaining the target catch is the primary goal. Mortality resulting from fishery release can negatively impact populations that are already vulnerable to exploitation. Few commercial fisheries have been assessed for specific handling practice targets such as air exposure limits, resulting in more general or subjective regulations for handling and releasing non-retained species. Delayed mortality of released fish can result from physical injury or physiological stress incurred during fishery capture (Davis, 2003). Therefore, providing fishery- or species-specific recommendations for bycatch can help to inform fishers and management regarding the most effective methods to handle and release non-target species to maximize post-release survival. Reflex impairment as an indicator of relative stress under different handling practices is a quick and easily performed assessment which causes little additional stress to the animal before it is released (Stoner, 2012).

Results from RAMP assessments of chum salmon captured in a simulated purse seine fishery show increasing reflex impairment with longer air exposure and time within the net. Our results suggest that for chum salmon, releasing fish within 3 minutes of bringing them onto deck is optimal for minimizing reflex impairment. Studies in recreational fisheries have suggested keeping air exposure to less than 10 seconds to minimize potential negative effects on released fish (Cook et al., 2015). Managing air exposure in commercial fisheries is further complicated by factors such as gear type, and methods for sorting fish.

Examining impairment of specific reflexes can give insight into the potential for fish to survive post-release. For example, normal orientation is necessary for swimming and therefore predator avoidance and escape from subsequent fishery capture. Raby et al. (2011) found that the body flex, tail grab, and orientation reflexes were most often impaired in RAMP-assessed coho salmon exposed to varying levels of fishery handling and that a lower proportion of fish with impaired orientation at release successfully migrated to their spawning rivers. In our assessment, nearly all fish were able to orient themselves when returned to the water within 3 minutes of initial air exposure. This suggests that most fish released within 3 minutes of being brought on deck will be able to regain normal swimming and escape behavior, but fish released after this could be in greater danger of predation or re-capture.

Air exposure is one of many factors that influence the condition of fish and their post-release survival, including injury, duration of stress, and environmental conditions all influence a fish’s condition (Cook et al., 2015). The duration of air exposure for fish captured in commercial fisheries is variable, ranging from a few minutes to over an hour (Davis, 2002). In purse seine fisheries, salmon experience a range of air exposure during the brailing and sorting process on deck. The duration of exposure is largely dependent on the number of fish in the set and the species make-up of the set, as these influence the speed of sorting and release. Management actions to reduce air exposure would require changes to gear or fish handling practices, such as reducing the number of fish sorted at a time, sorting within water-filled totes, and using chutes to quickly release fish overboard (Cook et al., 2015).

Net handling during the capture process can impact the post-release survival of captured fish. Long periods of time within the net and higher density of fish can result in high mortality of fish (Huse & Vold, 2010). Holding nets tight along the boat may elevate stress as crowding of fish within the net is increased. Crowding within nets can result in oxygen depletion (Raby et al., 2012) which would produce similar stress responses in fish to that of air exposure. For chum salmon captured in a purse seine fishery, the tightness of nets held alongside the boat during the sorting process appears to impact fish held in the net for long periods of time (30-40 minutes), as can occur for large sets as the sorting process is lengthened. Air exposure treatments longer than 3 minutes resulted in more reflex impairment than handling treatments. Air exposure has previously been found to have a greater influence on fish stress levels than other impacts such as injury (Nguyen et al., 2014). These results give support to recommending fishing practices of minimizing air exposure to chum salmon to less than three minutes, and holding nets relatively loose during the brailing and sorting process.

Salmon are able to recuperate following reflex impairment if given time to recover, such as within a recovery box, and this benefits the fish in escaping predation and recapture (Nguyen, 2012). However, in high volume fisheries where proportions of non-target species are high, the use of recovery boxes is not practical or efficient for reviving fish prior to release. Therefore, ensuring that released fish are in the best condition through net handling and sorting is necessary for maintaining low post-release mortality.

Our results cannot provide an absolute estimate for post-release mortality because we cannot account for indirect and delayed effects of discard and handling stress on survival, *e.g.* predation on discarded catch, injury, suppressed immune response mortality (Stoner, 2012). However, our data can be used to inform estimates of the relative condition of fish under different handling methods. Examining impairment of specific reflexes, such as orientation or burst swimming, can give an indication of potential post-release mortality in fish unable to escape predation. Wounding of fish may also impact RAMP scores (Nguyen, 2012), and we did not include injury information in the present assessment. The link between injury and reflex impairment is still unclear and further investigation into their relationship is needed if RAMP is to be used to predict mortality from injury (Nguyen et al., 2014). Data from a holding study will be used to assess relative condition in chum for 10 days following capture (Cook et al., unpublished data).

Identifying species-specific responses to air exposure and other capture stressors can be used to develop fisheries regulations, suggestions for best practices for fishers, and to clarify current regulations such as ‘release with least possible harm’ which are subject to individual interpretation. Fishing techniques, including net handling, fish handling and release methods are behavioral actions by fishermen and therefore fish condition may be different between boats and fishermen. Elucidation of which components of the commercial fishing process may be inducing the most stress within captured fish may provide insight into where efforts can be focused to improve the handling and release process within these fisheries. Species and fishery specific recommendations for handling and releasing non-retained catch can help to improve the survival and thus the conservation of vulnerable populations.

LITERATURE CITED

Cook, K.V., Lennox, R.J., Hinch, S.G., Cooke, S.J. (2015). Fish Out of Water: How Much Air is Too Much? *Fisheries*, *40*(9), 452–461. doi:10.1080/03632415.2015.1074570

Davis, M.W. (2002). Key principles for understanding fish bycatch discard mortality. *Canadian Journal of Fisheries and Aquatic Sciences*, *59*(11), 1834–1843. doi:10.1139/f02-139

Davis, M.W. (2007). Simulated fishing experiments for predicting delayed mortality rates using reflex impairment in restrained fish. *International Council for the Exploration of the Sea*. 64 (8): 1535-1542. doi: 10.1093/icesjms/fsm087

Davis, M.W. (2010). Fish stress and mortality can be predicted using reflex impairment. *Fish and Fisheries*, *11*(1), 1–11. doi:10.1111/j.1467-2979.2009.00331.x

Davis, M.W., Ottmar, M.L. (2006). Wounding and reflex impairment may be predictors for mortality in discarded or escaped fish. *Fisheries Research*, *82*(1-3), 1–6. doi:10.1016/j.fishres.2006.09.004

Davis, M.W., Ryer, C.H. (2003). Understanding Fish Bycatch Discard And Escapee Mortality. *AFSC Quarterly Report*, *Janary-Mar*, 1–9.

Department of Fisheries and Oceans Canada (DFO). (2001). A Policy for Selective Fishing in Canada's Pacific Fisheries, (January).

Donaldson, M.R., Clark, T.D., Hinch, S.G., Cooke, S.J., Patterson, D.A, Gale, M.K., Frappell, P.B. Farrell, A.P. (2010). Physiological responses of free-swimming adult coho salmon to simulated predator and fisheries encounters. *Physiological and Biochemical Zoology, 83*(6), 973–83. doi:10.1086/656336

Farrell, A., Gallaugher, P., Fraser, J., Pike, D., Bowering, P., Hadwin, A.K.M., Parkhouse, W., Routledge, R. (2001). Successful recovery of the physiological status of coho salmon on board a commercial gillnet vessel by means of a newly designed revival box. *Canadian Journal of Fisheries and Aquatic Sciences*, *58*(10), 1932–1946. doi:10.1139/cjfas-58-10-1932

Gilman, E., Suuronen, P., Hall, M., Kennelly, S. (2013). Causes and methods to estimate cryptic sources of fishing mortality. *Journal of Fish Biology*, *83*(4), 766–803. doi:10.1111/jfb.12148

Hall, M.A, Alverson, D.L., Metuzals, K.I. (2000). By-Catch: Problems and Solutions. *Marine Pollution Bulletin*, *41*(1-6), 204–219. doi:10.1016/S0025-326X(00)00111-9

Huse, I., Vold, A. (2010). Mortality of mackerel (*Scomber scombrus L.*) after pursing and slipping from a purse seine. *Fisheries Research*, *106*(1), 54–59. doi:10.1016/j.fishres.2010.07.001

Nguyen, V.M. (2012). *The biological and social sciences of improving post-release survival in sockeye salmon following fisheries interaction in the lower Fraser River, British Columbia*. [MSc. Thesis] Carleton University.

Nguyen, V.M., Martins, E.G., Robichaud, D., Raby, G.D., Donaldson, M.R., Lotto, A. G., Willmore, W.G., Patterson, D.A., Farrell, A.P., Hinch, S.G., Cooke, S.J. (2014). Disentangling the roles of air exposure, gill net injury, and facilitated recovery on the postcapture and release mortality and behavior of adult migratory sockeye salmon (Oncorhynchus nerka) in freshwater. *Physiological and Biochemical Zoology : PBZ*, *87*(1), 125–35. doi:10.1086/669530

R Development Core Team. (2012). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org

Raby, G.D., Donaldson, M.R., Hinch, S.G., Patterson, D.A., Lotto, A.G., Robichaud, D., English, K.K, Willmore, W.G., Farrell, A.P., Davis, M.W., Cooke, S.J. (2012). Validation of reflex indicators for measuring vitality and predicting the delayed mortality of wild coho salmon bycatch released from fishing gears. *Journal of Applied Ecology*, *49*(1), 90–98. doi:10.1111/j.1365-2664.2011.02073.x

Raby, G.D., Donaldson, M.R., Nguyen, V.M., Taylor, M.K., Sopinka, N.M., Cook, K.V., Patterson, D.A., Robichaud, D., Hinch, S.G., Cooke, S.J. (2014). Bycatch mortality of endangered coho salmon : impacts , solutions , and aboriginal perspectives. *Ecological Applications*, *24*(7), 1803–1819.

Stoner, A.W. (2012). Assessing Stress and Predicting Mortality in Economically Significant Crustaceans. *Reviews in Fisheries Science*, *20*(3), 111–135. doi:10.1080/10641262.2012.689025

Wilson, S.M., Raby, G.D., Burnett, N.J., Hinch, S.G., Cooke, S.J. (2014). Looking beyond the mortality of bycatch: sublethal effects of incidental capture on marine animals. *Biological Conservation*, *171*, 61–72. doi:10.1016/j.biocon.2014.01.020

Chapter 3. Human dimensions of the commercial Pacific salmon fishery: a multi-stakeholder assessment of perspectives on selective fishing

3.1 Introduction

A critical challenge facing fisheries management is to maintain fishing on species and stocks that are able to withstand exploitation while reducing pressure on populations of conservation concern. Declines of some stocks of salmon in northern and southern British Columbia in the 1990s stimulated efforts to develop of selective fishing techniques that would minimize impact on species and stocks of concern, either through avoidance or release. The DFO subsequently adopted the Policy for Selective Fishing in Canada's Pacific Fisheries in 2001, focusing on improving sustainability and selectivity of the Pacific salmon fishery. Under this conservation-based management approach, fishing opportunities and resource allocations are shaped by the ability of harvesters (First Nations, recreational, and commercial) to fish selectively (to avoid non-target species or populations, or reduce incidental mortality of those that are captured; DFO, 2001).

The Selective Fishing Policy is a conservation-based policy in that it aims to modify fishing activity through using ecological information on the status of salmon stocks and populations to determine whether certain species should be retained by fisheries or sorted from the catch and returned to the water. However, the success of conservation initiatives is not only based on ecological knowledge but must also consider social factors (including interactions between individuals, institutions, social organizations, and cultural norms) which influence the effective implementation of these initiatives (Ban et al., 2013). In understanding acceptance and compliance with fishery regulations, it is crucial to recognize the context within which these regulations are received by commercial fishers. These are the human dimensions of the management process; requiring an understanding of the impact that management decisions have on the people being managed. Including social considerations within conservation planning creates the opportunity to develop more realistic and clearer objectives.

For the commercial purse seine fishery, new techniques for sorting catch were introduced as part of the selective regulations, including brailing catches (using smaller nets to transfer fish from the seine net to the deck of the boat to be sorted) and holding unresponsive bycatch onboard vessels in revival tanks before release. As important as technological changes to fishing gear are for reducing bycatch and improving the post-release survival of fish, the way gear is used and how fish are handled and sorted is equally critical. The successful adoption of new techniques requires cooperation and support from fishers. DFO managers, Conservation and Protection Staff, independent observers, and fishermen themselves have recognized that compliance with selective fishing requirements can be low in Pacific salmon fisheries and is often inconsistent (SkeenaWild Conservation Trust et al., 2011), making it difficult to assess the effectiveness of these policies.

Under current management regulations in the commercial seine fishery, fishermen need to be as efficient as possible to obtain their maximum potential catch within the limited window of time of each fishery opening, and are in competition with their peers for greater portions of the set allowable catch. Every boat has to brail, sort, and release non-retained species from their catch, and sorting catches requires quick species identification and involves skill when handling of live fish. Estimates of mortality rates of salmon released from fisheries are incorporated into management decisions. Post-release mortality rates differ between gear types and salmon species captured and released. North coast commercial seine fisheries are managed on the basis of an estimated post-release mortality of 15% (Salmon IFMP Northern BC 2014/2015). However, DFO reports concede that data on salmon survival is lacking, and estimates of 50% for chum salmon are described to be ‘a placeholder’ given that there is no independent measure of chum survival (SkeenaWild Conservation Trust et al., 2011). Where large fisheries occur (*i.e.* high numbers of target catch returns) these fisheries have the potential to have a large impact on non-target species.

The Selective Fishing Policy was introduced with programs and funding to encourage development and uptake of selective practices. The policy was an outcome of the Canadian Fisheries Adjustment Program (CFAP) and its sub-program the Pacific Salmon Selective Fishing Program (PSSFP). The PSSFP encouraged commercial, First Nations, and recreational salmon harvesters to develop selective fishing gear and methods, to participate in education and training workshops, and to contribute to research projects that would increase the selectivity of salmon fisheries (DFO, 2005). A review of this program found that despite it being a conservation-based policy, the goal of achieving a sustainable fishery through selective fishing regulations had not been attained. This was believed to be due to a lack of effective implementation and indicators to measure progress as well as selective fishing compliance (DFO, 2005). While program participants encompassed by the review had been successfully engaged and had altered their vessels and modified gear where needed, it could not be established whether this applied to the broader community of harvesters (DFO, 2005). This review concluded that monitoring and enforcement of new selective regulations had not been maximally effective, and that greater incentives would need to be provided to harvesters in the future to encourage adherence to new regulations (DFO, 2005). Understanding the human dimensions of selective fishing in the salmon fishery can give insight into reasons for noncompliance with regulations. This knowledge can also guide decisions on what incentives will encourage selective practices and be acceptable to fishers.

Given the ecological, cultural, and economic importance of Pacific salmon, management decisions for wild salmon fisheries involve many diverse stakeholders, who often have conflicting objectives. Therefore, management decisions can have different impacts on these fishery stakeholders and these impacts can be perceived in different ways. Assumptions held about the attitudes, perceptions, and behavior of stakeholder groups can produce tension and mistrust between groups, which if left unrecognized can create barriers to cooperative management (Harms & Sylvia, 2001). Commercial fishers perceive their own activity, that of their peers, and that of the government in light of past and current experiences of allocation and conservation initiatives and within the power structure underpinning resource management (Butler, 2006). Fishery managers have the dual mandate of supporting conservation and economic growth in fisheries and face the task of balancing conservation goals with those of resource users and other interest groups when deciding on allocations of fishing quotas and species retention regulations. These decisions are influenced by both political and economic contexts on local and federal scales (Young et al., 2013). Environmental non-governmental organizations (eNGOs) aim to influence policy through independent review of management from an eco-centric viewpoint that often runs counter to the interests of commercial fishing (Andres, 2000). Several eNGOs interested in issues relating to commercial salmon harvest have been vocal about their concerns regarding compliance with selective fishing measures and the mortality of discarded salmon bycatch preventing the recovery of some salmon stocks (Skeena Wild Conservation Trust et al., 2011). Other influential stakeholders in the Pacific salmon fishery include First Nations and recreational fishers, who also have different perspectives on conservation and interests in allocation.

To assess the human dimensions surrounding selective fishing methods and regulations, we interviewed commercial purse seine fishers, fishery managers, and members of environmental non-governmental organizations (eNGOs). Our goals were to 1) understand potential reasons for noncompliance, 2) to obtain input and suggestions on ways to improve survival of released fish, and 3) to compare the perspectives of different stakeholders on these issues to identify areas within which to focus communication.

3.2 Methods

Semi-structured interviews were conducted with commercial purse seine fishers and those involved in the management of these fisheries. These interviews were conducted either in-person or over the phone. Directed questions were used along with sections providing the opportunity for participants to give their opinions on suggested handling practices, current management regulations, and to suggest their own thoughts on the best way to sort and release salmon. These interviews typically lasted about 30 minutes, and were all audio recorded with the participants' permission. These recordings were later transcribed for analysis.

Members of non-governmental organizations concerned with salmon handling and release from commercial fisheries were also sent questionnaires by email. These contained a core set of questions from the longer interviews, and responses were obtained either electronically or through conversations.

3.2.1 Ethics statement

Human research ethics approval for conducting interviews was obtained from both collaborators' institutions (Dalhousie University and the University of British Columbia). Identities of all participants were kept anonymous in the analysis and reported results.

3.2.2 Interviews with fishermen

Participants within the commercial purse seine fishery were identified and invited to participate either through DFO commercial advisory boards listings, or through conversations with other fishermen. We primarily interviewed the skippers (captains) of purse seine vessels, as these individuals are responsible for operations on the boat, training crew members in fishery practices (including fish handling and release methods), and have often been working on the vessel for the longest period of time. During interviews, fishermen were asked questions to determine their attitudes to several themes; conservation, management, and attitudes toward change. Key questions used to assess these themes are listed in Table 3.1.

Table 3.1. Themes and questions for semi-structured interviews with commercial fishermen in the salmon purse seine fishery to gain an understanding of perspectives and attitudes towards selective fishing methods and regulations.

Theme	Questions
General profession	a. How long have you been fishing? b. Can you describe some of the major changes you've seen in the salmon fishery since you've started?
Conservation	a. Do you think that bycatch is a significant problem in Pacific salmon fisheries? b. Do you think that released salmon survive to spawning following capture? i. What percentage? ii. Would it be better to keep the fish? c. Is it necessary to officially regulate procedures for handling bycatch? Enforce a set of standard handling rules/regulations/equipment or infrastructure?
Management	a. What do you think of DFO's current regulations for handling practices? Are these effectively communicated to fishermen? b. Do you think DFO makes regulations primarily with the best interest of industry, fishermen, fish conservation, or public opinion? c. Is enforcement of regulations sufficient to meet conservation goals? d. Do you witness poor handling of bycatch among fishermen?
Attitudes towards change	a. What is a single change that could be made to the fishery to improve bycatch survival that would be most effective (have the greatest impact at lowest costs to fishers)?

3.2.3 Interviews with managers

Participants involved in the management of these fisheries were identified through a DFO listing of north coast fishery managers on the Integrated Fishery Management Plan for the Salmon in Northern BC (DFO, 2014). The structure of interviews, including themes and questions, with those involved in fishery management followed that of conversations with fishermen. However questions were slightly modified to accommodate management perspectives.

3.2.4 Non-governmental organization questionnaires

Questionnaires were sent out to representatives of eNGOs that had been identified as having an interest in, or having projects focused on, the handling and release of salmon from commercial fisheries. Due to the typically smaller extent of direct involvement in fisheries amongst this group, questionnaires were shorter and focused on key questions to gain an overview of perspectives relating to each theme (Table 3.2).

Table 3.2. Themes and questions for members of environmental non-governmental organizations concerned with issues of selective fishing in commercial fisheries. The aim of this questionnaire was to gain an understanding of perspectives and attitudes towards selective fishing methods and regulations.

Theme	Questions
Conservation	a. Do you think the release of salmon by commercial fisheries negatively impacts their populations? b. Should there be an official set of regulations or a set of handling practices that is consistent among vessels enforced for sorting and releasing fish?
Management	a. What can fishermen do to reduce mortality in salmon released from purse seine fisheries? b. What is your position on regulations currently implemented by DFO and industry regarding handling and release of salmon? c. Are these regulations sufficiently enforced to meet conservation goals? d. Are these regulations communicated effectively to fishermen and industry?

Attitudes toward change	a.	What single change to the commercial purse seine fishery could be made that would be most effective at improving post-release survival of salmon (*i.e.* having the lowest cost with greatest impact)?

3.3 RESULTS

3.3.1 FISHERMEN

Interviews were conducted with fifteen commercial purse seine fishermen. Eight of these individuals identified themselves as belonging to a First Nation within British Columbia. Fishermen had been fishing on average for 50 years (ranging from 22 years to 60 years). The current commercial salmon purse seine fleet is about 40 vessels (fishermen interviews, personal communication) with 5 to 6 fishers per boat crew, so while 15 participants is not a large sample size, this represents 5-10% of the study target population.

Conservation

Ten out of the fifteen interviewed fishermen thought that a very high percentage of the fish they released survive to spawning (Table 3.3). Survival rates vary with factors such as the size and species composition of their set, as these influence the time that fish spend within the net and on deck during the sorting process. Bycatch of non-retained salmon and selective fishing was seen as a problem for the fishery because sorting is a difficult task for fishermen and significantly slows down operations in a fishery where efficiency is critical to obtaining more catch and money. Sorting catches and releasing fish is a problem when fishermen have to return fish to the water that are dying or dead because they are non-retained species.

Fishermen’s views on the survival of chum salmon were highly divergent, with fishermen either perceiving them to be the most vulnerable salmon species to handling or one of the hardiest. As one fisherman observed, the perception of the fish’s survival has a great impact on attitudes toward fish handling.

"The logic in the fleet is that they're not surviving…'I'm not doing it, they're not going to survive so I'm not going to do it'. That is without question the mentality - they're not surviving and nobody wants to change, everybody's used to doing things a certain way and they don't want to change their ways. Because at the end of the day there's a cost - either you're not catching as much fish or you've got to spend some money to do it and they’re not catching as much fish so they don't want to do it."
- Fisherman

When asked about the need for regulations regarding handling or sorting infrastructure, fishermen suggested infrastructural aids such as standardizing brailer size, and that boats

"If you have a standardized fleet you could have a standardized set of procedures, but you don't so it's whatever we find out, it's whatever works for you the best and I've

should use a chute to release fish. However, many voiced their concerns that infrastructure could not be regulated or standardized due to the variability of each fishing boat.

seen lots of different approaches. Some of them are fairly pathetic and some of them are pretty good." - Fisherman

The ambiguity of current license conditions regarding releasing non-retained fish 'with the least possible harm' was also pointed out by fishermen. Behavioural regulations, such as how the net is handled, are not enforceable because fish handling is subjective to each fisherman.

"You don't know what happens if you throw them over with their tail - nobody does because there's been no study done on it. Can't say I'm harming it [the fish], *can't say I'm not."* - Fisherman

Table 3.3 Summaries of responses from fishermen to questions within the theme of conservation.*

Conservation	Bycatch negatively impact populations?	Bycatch a significant problem in the fishery?	Survival to spawning?	Should keep all?
	YES (5/15) Conditional on factors such as species, specific fisheries or locations, *e.g.* when there is higher proportions of non-retained fish in sets	YES (9/15) • Problem in areas where there are high numbers of multiple species • Significantly slowed down fishery operations • Problem regarding allocation between stakeholders	HIGH (10/15) • Between 75%-95%, if released quickly through a chute. chum very susceptible LOW (2/15) • No, none survive OTHER (2/15) • Variation between different species in susceptibility to handling • Depends on size of set, more fish takes longer to process	YES (6/15) • Where bycatch incidence very low, or fish are too damaged by capture to survive • Unconvinced that managers know if releasing fish impacts their populations
	NO (10/15)	NO (3/15) • No, "Nature will always take care of itself"		

*Not all participants answered every question listed in Table 3.1 and so some totals presented in results tables do not sum to 15, but are meant to provide insight into the relative proportions on perspectives.

Management

When asked about the communication between fishermen and management, many described the disconnection between them and those making the regulations. Fishermen are aware of the regulations that DFO puts out, but feel that these regulations are made without consideration of how these will be put into practice and of how fishermen will be impacted. The main concern expressed by fishermen was that despite working on sorting and releasing fish, they receive no feedback on the results of their work. They were frustrated that the promises made by DFO regarding selective fishing were not fulfilled, but instead felt they were being increasingly regulated and opportunities being continually taken away. Several fishermen expressed concerns that DFO did not have the information to support the contention that selective fishing was

"20 years we've been throwing fish over, well we should benefit from that. And I don't think we have been benefitting from it, especially like the seine fleet they've been putting them over and putting them over and why? Why do we throw them over? Because they say it's low stocks in different areas, so for 20 years where's the information coming back to say - because you've done this for 20 years we're going to have a fishery, that's what really bothers me - well it pisses me off and I think it pisses a lot of fishermen off because you're doing something, what I can see is that you're doing something to protect the stocks and there is no information coming back about why you did it." - Fisherman

improving population status for released
fish.

Regulations developed by DFO were primarily perceived as being made to benefit the public perception of fishery management (Table 3.4). Many fishermen also believed that the goal of conservation was not successfully achieved by current management policies.

Several fishermen discussed their observations of 'poor handling' of fish during sorting and release; these included throwing fish over the side of the boat by the tail (a practice that has been observed anecdotally to dislocate fish's backbone), 'drying up a set' which refers to bringing the net up very tight next to the boat during the brailing and sorting, and observations of ramping sets of fish over the stern, though this practice has been banned in the purse seine fishery. Though these observations were discussed, fishermen all clarified that these types of handling were only observed in a small portion of the purse seine fleet and were not the standard.

Enforcement in the fishery was generally perceived as being sufficient (Table 3.4). A few fishermen spoke to disconnection between regulations being written and how they are put into action by fisheries enforcement may not be the way they were initially intended, or that current enforcement wasn't perceived to be effective, and that increasing enforcement presence would just worsen relationships between fishermen and DFO. Others felt that presence of fisheries enforcement officers during a fishery opening was key to ensuring good handling behaviour.

Table 3.4 Summaries of responses from fishermen to questions under the management theme.*

Management	**Effective communication between management and fishers?**	**DFO regulations made in the best interest of…?**	**Enforcement sufficient to meet conservation goals?**
	YES (5/15) • Fishermen are aware of regulations but just stubborn NO (9/15) • Need results of selective fishing to be communicated. • Disconnect between fishermen and managers on regulations.	PUBLIC PERCEPTION (8/15) • Mostly for appearance CONSERVATION (4/15) • Primary interest, but do acknowledge industry needs • Try to be on conservation side, deal with multiple stakeholders INDUSTRY (1/15) OTHER • Always reacting to crisis • Doesn't think they make them in the best interest of anybody or anything	YES (7/15) • But difficult to enforce behavioural practices • Yes, but enforcement is not effective or consistent NO (4/15) • Disconnect between regulations being written and how they are put into action by enforcement • Need more presence to ensure good handling behaviour • Inconsistent enforcement presence OTHER (2/15) • Handling practices are not enforceable, more enforcement just makes fisher-DFO relationship worse

*Not all participants answered every question listed in Table 3.1 and so some totals presented in results tables do not sum to 15, but are meant to provide insight into the relative proportions on perspectives.

Attitudes toward change

The perceived need for handling regulations was split between interviewed fishermen (Table 3.5). Those who thought that there was a need for handling regulation suggested regulations about infrastructure such as chute systems or brailer sizes. Others were opposed to the idea of handling regulations either because perceptions of what constitutes compliant handling behaviour varies among fishermen, it was not feasible to standardize handling across the fleet, or because they did not perceive regulations to be the solution as change required attitudinal changes to improve handling behaviour.

When asked for a single change to the fishery that would improve bycatch survival, the most common answer was for fishermen to use a chute system to release fish (Table 3.5). Overall 9 of the 15 fishermen interviewed already used chutes on their boats which had been custom built by the skippers to fit their boat and sorting tables. Even fishermen that did not currently have a chute on their boat agreed that a chute would be the best change to improve survival of released fish. Fishermen who had designed and built their own release chutes, customized to fit

"It's a very good system [chute system] *and it costs money to make and not all boats can have it because of the size of their decks. You can have similar but it's still the size of the deck that made it possible to build the one I have…I did a lot of changes to that* [the chute] *to make it just right, so it cost a lot of money to build that...there's so many things now that we have to pay for and we don't catch enough fish to meet that."* - Fisherman

their boat and sorting box said this increased their fish sorting efficiency and reduced stress on the crew. When asked about barriers to fishermen to building chutes, fishermen perceived that it was the cost and time to design and build chutes, some boats are not the right size to accommodate chutes. They also felt that reconfiguring the sorting process involves effort in retraining a crew.

Other, non-infrastructural changes suggested included improved communication and feedback between DFO and fishermen, because attitudes toward handling would improve if fishermen knew that their efforts were working and that they would be rewarded.

Table 3.5 Summaries of responses from fishermen to questions under the attitudes to change theme.*

Attitudes to change	**Single change to improve survival?**	**Need for handling regulation?**
	Chute system (9/15)	YES (7/15) Infrastructural regulations, *e.g* “some sort of chute system”
	Communication (2/15)	
	Management changes (3/15) • Remove corporate control on fleet to improve fishers attitude • Change fishery opening times • Keep all the fish	NO (7/15) • The regulations are already in place • No matter what you do it’s not going to work • Can’t standardize regulations on fleet
	Enforcement Presence (1/15)	

*Not all participants answered every question listed in Table 3.1 and so some totals presented in results tables do not sum to 15, but are meant to provide insight into the relative proportions on perspectives.

3.3.2 Comparison to manager and eNGO perspectives

Interviews were conducted with 5 individuals involved in the management of the commercial salmon fishery. These individuals had been working in various levels of management salmon management for an average of 29 years (ranging from 40 years to 15 years).

Responses to questions were given from three members each associated with separate eNGOs which have projects or focuses concerned with the management of salmon fisheries and the survival of released salmon.

Conservation

Managers saw selective fishing policies as more of a political issue than one of conservation (Table 3.6). Decisions regarding selective fishing regulations were driving political issues both internally and between stakeholders.

"I think it's a bigger problem of perception and interaction than it is an impact [to salmon populations]" – Fishery manager

Managers were also divided on whether released fish survived to spawning following capture in commercial fisheries. They also brought up factors of species and set size and composition as influential to the survival rate of released fish. Members of non-governmental organizations discussed several factors including fish species, and environmental factors as contributing to the survival of released fish (Table 3.6). The uncertainty surrounding actual mortality rates was discussed; requiring balancing precaution in setting regulations such as setting total catch allowances, and monitoring to manage for this uncertainty.

Table 3.3. Summary of responses from fishery managers and members of environmental non-governmental organizations (eNGOs) under major themes of interviews; (1) Conservation, (2) Management and (3) Attitudes to Change.

	Fishery Managers	eNGOs
Conservation		
	- Selective fishing more a problem of politics and perceptions than conservation impact - Most fish survive capture and release - More problems with handling and fish survival in bigger fisheries and sets	- Impact to salmon populations depends on many factors influencing mortality rates; *e.g.* fishery, location, species, handling practices, environmental conditions
Management		
	- Regulations are communicated to fishermen, also pressure from other stakeholders on fishermen to adhere to regulations - Fishermen do not trust DFO, communication between fishermen and managers is an area to be improved on. - Industry considered as one of the many stakeholders when regulations are made	- Current DFO regulations for handling are too vague and this leads to issues of compliance - Need improved knowledge of bycatch mortality and improvements to best practices - Ineffective communication between fishermen and managers due to lack of clear and simple regulations
	- Enforcement sufficient with the available resources - Regulations need to be induced through communication and agreement between management and fishermen, not enforcement	- Structure of fishery openings does not encourage good handling practices - Not enough enforcement, observer coverage, and monitoring on fisheries to ensure compliance and meet conservation goals
Attitudes to change		
	- Some gear improvements could help sorting efficiency, such as smaller brailers - Need to improve fishermen's attitude toward releasing fish - Need to be able to tell the fishermen that selective fishing is working to rebuild populations, but do not have the information	- Need a clear and simple set of handling regulations - Increase observer coverage, enforcement, monitoring - Change fishery structuring, *e.g.* incentive-based quotas, transferable shares, to remove 'race' mentality from fishery.

Management

Managers believed that regulations were communicated to fishermen effectively, that they understood what was expected of them by the regulations, and that external pressure from other stakeholders was also an important factor in making fishermen aware of these regulations and standards of practice.

Managers all acknowledged that poor handling of fish being released was occurring in the commercial fishery, but that this was happening in only a small portion of the fleet, and was mainly a problem during big fisheries where sets are large and fishermen are trying to be as efficient as possible to get more fish.

"He's got to make money, he wants to catch every bloody pink you can catch because that's all you're allowed to keep. He's not going to be screwing around with nursing every fish back to health and throwing them over the side." – Fishery manager

Mistrust between management and fishermen was acknowledged as a factor in that it molds in the attitude toward releasing fish, and the absence of feedback and direct benefits to fishermen for following sorting and release was also recognized.

“Educate the fishermen, tell them what they're doing is working, they can't do that right now, that's the problem, we can't do that. And I can't disagree with the fishermen at all, we've been throwing these chums back and we did start with a lot of effort to do it properly and as the years went on it got worse and worse and that’s

No managers expressed the need for more enforcement to increase compliance to regulations or sorting. The need for an attitudinal change toward regulations was stated, since the release of fish 'with the least possible harm' is ultimately determined by the fisherman and this would best be achieved through conversations between management and fishers on what makes sense to fishermen.

the result. And the department just goes and says 'nonretention, nonretention'."
– Fishery manager

Members of eNGOs all thought that enforcement of regulations was insufficient to meet conservation goals (Table 3.6). They believed that noncompliance issues were a result of DFOs current regulations being too vague, expectations not being communicated effectively to fishermen, and insufficient enforcement, monitoring and observer coverage to meet conservation goals of policies.

Attitudes to change

While managers did suggest that changes such as tighter regulation on brailer size or introduction of regulation on chutes would be beneficial to improve survival of released fish, they mainly felt that an attitudinal change by fishermen would be

"If the skipper and boat crew want the fish to be released alive they will be, they don't need a tool, they don't need a number of the things - it's all there - the good boats do it already under almost all circumstances"
– Fishery manager

most effective, and that this would require efforts from both management and fishermen.

To improve handling practices and fish survival, eNGOs suggested education, gear changes, increased enforcement and monitoring. Infrastructural and handling changes suggested included smaller brailers, looser nets, and quick transfer and sorting on sorting tables with release via a watered chute. However, eNGO members felt that changes to the overall structure of the fishery management may be more effective than these infrastructural changes for improving survival of released fish. These included restructuring the fishery to be managed using Individual Transferable Quotas (ITQs), or implementing incentive-based quotas on all species, including bycatch, as this would remove the race to fish from the fishery and fishers could be more concerned with handling practices than with getting as many fish as possible within the fishery opening.

3.4 Discussion

Social factors are the primary determinants of the success of conservation policies; requiring changes to human decision-making and behaviour (Mascia et al., 2003). The success of the conservation-based Selective Fishing Policy to improve the sustainability of the commercial salmon fishery requires acceptance of new regulations by harvesters and suitable monitoring of the implementation of these regulations to ensure that they are meeting their intended goal: rebuilding or protecting fish populations. To understand the full impact of a management policy on those being managed, it is necessary to examine the perceptions and attitudes of stakeholders. The goal of this human dimensions project was to identify potential reasons for noncompliance with selective fishing and handling practices, to explore strategies for improving the survival of released salmon from purse seine fisheries, and to compare perspectives of stakeholders concerned with issues surrounding selective fishing.

Regulation acceptance must be understood within the broader context perceived by fishermen. Understanding regulatory change within the fishers' context, such as social and political environments, impacts to livelihoods, and how this contributes to uncertainty regarding their livelihoods is critical to uptake of and compliance with new regulations (Carawan, 2010; Eayrs et al., 2014). Interviewed fishermen had been fishing for an average of nearly 50 years. Many fishermen viewed the restructuring of the fishery (including license buyback and reduction of fishing opportunities) that occurred along with the introduction of the Selective Fishing policy as the single major change in the fishery that had occurred during their careers. This change in regulation required fishermen to adapt to new ways of carrying out their fishing operations and practices, which they had learned as young fishermen and had been practicing in some cases for up to 60 years. Also important to note is that observations from our interviews aligned with those of Plate et al. (2009), that some of the older fishermen are also the most progressive in their practices, and their knowledge of fishery changes is important to developing new strategies toward regulation. Additionally, experienced fishers' knowledge can contribute new and practical information to improve existing strategies or explore alternative solutions to fishery management problems.

There were two general opinions regarding selective fishing among interviewed fishermen. First, that the survival of released fish can be very high if appropriate handling practices are used. The majority of fishermen interviewed had designed and built their own chutes to fit their vessels and sorting boxes, and reported that these improved their ability to sort fish and believed this to increase survival of the fish they released by reducing handling and time on deck. Fishermen believed that other boats within their fleet may not have implemented their own chutes or other solutions due to the cost and time required to build them, and due to inertia involved in changing their fishing practices. Others have also noted that costs to changes in fishing practices can be a barrier to modifying fishing practices or gear for conservation strategies, especially where fishers perceive multiple restrictions and regulations to be disrupting their livelihoods (Nguyen et al., 2013a). Perspectives on regulations are influenced by a fishers' understanding of the legitimacy of that measure, as well as the personal costs (financial and otherwise) incurred as a result of the measure (Nguyen, 2012). In undertaking the use of techniques to facilitate the release of salmon, such as chutes, commercial fishermen must be convinced that these measures are effective (*i.e.* that releasing salmon is beneficial to their populations, and that rebuilding populations will result in benefits to fishers in the future).

"We don't get paid for the stuff we keep, so it may sound a little bit callous but when you've got a 12 hour opening or a 16 hour opening based on a 7 day week, that isn't a lot of time to be overly nice for something that we believe we should be keeping anyways. It's the hardest thing you're going to do is change attitudes and we've been doing this for god knows how many years now and we don't see any real benefit to us, because we're never allowed to catch the fish we throw away...if they're extinct that just makes our lives easier because there's nothing to release." – Fisherman

A second opinion among fishermen was that they were unconvinced of the need for a selective fishery and so did not support the resultant changes in fishing practices. This opinion was linked to some prevalent views that all salmon species should be retained, that DFO interferes too much with their regulations, that *"nature takes care of itself"*, or that fish don't survive anyway so why throw them away. Management strategies may be unsuccessful if those under regulation do not understand the need for the regulation, or do not believe that a conservation problem exists (Nguyen et al., 2013a). Fishermen also expressed the view that communication from managers was poor, that they felt disconnect between managers and fishermen, and that although they were made aware of regulations, there was no communication on the reasoning for regulations. Incentives and understanding of the conservation motive behind regulations are important factors influencing the uptake of regulatory or gear changes by commercial fishermen (*e.g.* Jenkins & Garrison, 2013; Nguyen et al., 2013a). Presenting information on the effectiveness of gear was also an important factor in fishers' receptivity to the use of a fish recovery bag by recreational and Aboriginal salmon fishers in southern British Columbia (Donaldson et al., 2013; Raby et al., 2014; Nguyen, 2012).

> *"I think the fishermen need to be understood if they're going to be making all these concessions over the years, we can't be clawing back constantly, and dangling a carrot in front of the fishermen's face saying if you conserve, if you throw back fish you'll be able to fish down the line here or whatever. You need a mechanism so that when the fish do return and there is an abundance the fishermen can be rewarded with that because if you don't have some sort of reward at the end for all your hard work, 'cause it's not easy as you guys know to handle these fish, and when you're talking about literally thousands…You're absolutely wiped out and then in the end, when there is an abundance, there is an opportunity, and you're not rewarded you're going 'What am I doing this for?'"* - Fisherman

Fishermen's acceptance of selective fishing regulations is also influenced by their perceptions of the effectiveness of these practices. Although many were unconvinced that fishery managers know if releasing fish impacts their populations, a greater proportion of interviewed fishermen perceived that bycatch of salmon species does not negatively impact populations of those fish. Fishermen considered the bycatch of salmon to be a problem for multiple other reasons, including that the sorting and releasing of salmon is a difficult task for fishermen. Views on susceptibility of different fish species to handling, especially chum salmon, were very divergent among fishermen, who either thought chum were one of the most hardy salmon species or that they were the most vulnerable to stress-related mortality during the capture and sorting process. Bycatch mortality rates estimated by DFO also vary by the fishing area, depending on the size of the fishery and potential for bycatch handling. For chum, these are generally low; for example north coast fisheries DFO have reported a 15% mortality rate of chum in a prior years' fishery (personal communication, DFO fishery manager). Perceptions on bycatch survival can influence handling and release by fishermen, and understanding these perceptions can inform strategies for developing best practices and for engaging fishers more effectively (Nguyen et al., 2013b).

Differences in perspectives among fishers, managers and members of eNGOs existed in regards to the influence of education and enforcement to improve compliance. Fishermen generally felt that current levels of enforcement were sufficient to meet goals of selective fishing, and that regulations regarding handling practices were mostly subjective between fishermen (*e.g*. net handling, sorting). Managers expressed views that enforcement was sufficient among fisheries given available resources, and that compliance and agreement was not best achieved through enforcement but instead through *"having conversations on what makes sense to fishermen and hopefully getting their agreement…and be really really careful that we don't make stupid or unenforceable regulations or guidelines because that kills it"*. Members of eNGOs all suggested that more monitoring and enforcement was necessary to improve handling practices and compliance with regulations. This group also suggested the need for more education on regulations and handling, in contrast to the opinion of fishermen that this was not an effective method for improving handling. Education as a means to improve handling practices assumes that improving understanding of conservation problems and handling practices will improve compliance. Education must be used carefully as a tool to facilitate uptake of new practices; fishermen may not hold the same values with respect to conservation as public, environmental groups, or management agencies (reviewed by Campbell & Cornwell, 2008). Additionally, the form in which education is delivered is critical; gear or handling practice demonstrations are not necessarily sufficient education to promote new practices, and the presentation of scientific knowledge as separate from fishers knowledge can produce negative reactions from fishers (Campbell & Cornwell, 2008). Delivery of scientific information and educational sessions should be approached carefully, incorporate fishers participation, and consider the broader social and political context of the fishery in which change is occurring.

"You can educate and educate and educate, but if you still don't have somebody there to keep an eye on them bottom line is they'll do what they want. You know, you're not going to have some 30 year old university student telling me what you know, if I do this and I do that the fish are going to survive so much better and the whole slideshow, and show me how to gently put them back in the water, and I sit there and go yah yah, and I'll give you all the right answers if you give me a little quiz...Yes, it's all educational but when it comes down to the practical end of it and I'm out there and the guy beside me is ramping and he's catching more than me it turns into I've got to get as much fish as him basically." - Fisherman

Both fishermen and members of eNGOs expressed concerns about the regulations made by fishery managers. Members of eNGOs felt that regulations regarding selective fishing were too vague and that this led to issues with compliance. Improvements would need to come from increased understanding of bycatch mortality and best practices for handling. Fishermen were generally convinced that fishery managers made their decisions primarily in response to public opinion, and not for conservation reasons. Managers emphasized that conservation was the top priority in decision making and that fishing industry considerations were balanced among other stakeholders when making regulations. These differences in perspectives on regulations suggest the need for clarification and communication of the basis for regulations between stakeholders.

Suggestions for changes to improve the survival of released fish also varied among interviewed stakeholder groups. Managers suggested that some gear improvements, such as regulating brailer size, could help sorting efficiency and therefore reduce impacts on non-retained fish. Managers mainly felt that any changes in fish handling would need to come from attitudinal changes of fishers. Members of eNGOs emphasized the need for monitoring and enforcing a simple and clear set of handling regulations, and also suggested changes in fishery structure, such as the use of individual transferrable quotas, which would remove the ‘race to fish’ from the fishery and would therefore allow more time to sort and release fish without fishermen losing money. Most fishermen suggested the implementation of regulations surrounding chutes that would remain flexible to accommodate differences in vessels in the fishery. Other suggestions of improved communication between fishermen and managers, and of management changes (such as removing corporate control on fishery licenses) were focused on improving fishers attitude toward selective fishing practices.

Consideration of these results should take into account the limitations of the range of participants, selection bias, and sample size. The perspectives of purse seine fishers regarding selective fishing policies may not be extrapolated to all commercial fishermen, as regulations from the selective fishing policy and decisions regarding species retention examined here were focused on the purse seine fishery and other gear types have been impacted differently. The fishermen who were willing to participate in our study may already have an interest in these issues and so may have more favourable opinions of the handling and release of salmon. Most fishermen discussed examples of noncompliance on other vessels, and therefore their insights into reasons for noncompliance largely involved inference. Sample sizes for interviews and surveys were limited, especially with respect to fishery managers and members of eNGOs, so these results must be interpreted cautiously; although these still likely provide good insight into where the differences in perspectives lie between these stakeholders. Further discussions with these groups will be needed to clearly establish the best approaches to facilitating communication between these groups on the issues discussed here.

"We now have a chance to develop fishing plans that save chums or any stock of concern and provide more fishing, and that's the holy grail for all of us. And in fairness to fishermen all we've done for my 34 years is cut them back. First we cut them back and say 'oh well it will get better', now we don't, now we say 'you're screwed because it's climate change' or for steelhead we're managing this small stock...So it just notches down for them constantly. 'Oh and by the way you're going to have to pay for your own catch monitoring'. So it's not good, but I no longer pretend that it's going to level off or get any better." - Fishery manager

Fishermen had strong opinions regarding the handling and release of salmon, as this is a major influence on the operation of their fishery and how they make their living. Fishermen suggested that the survival of salmon released from purse seine fisheries can be high if appropriate measures are used such as chutes, and perceived that cost and time to design and construct these systems were the major barriers to their implantation on other vessels. Additionally, many fishers were unconvinced of the need to selective fishing; highlighting the need for improved communication between management and fishermen. Although communication of basic regulations and fishery openings is clear to fishermen, the communication of the basis behind these regulations was perceived to be missing. Better communication from managers could improve fishers' attitude toward regulation and therefore the compliance with selective fishing regulations and handling practices used to release fish. While managers supported the need for improvement of attitudes toward releasing fish, strategies or approaches for improving communications were not suggested. Ultimately, improved relations between fishery stakeholders will require new approaches to how regulations are developed, communicated, and implemented.

Literature Cited

Andres, V. (2000). *Influence of Non-Governmental Organizations on the 1999 Canada/U.S. Pacific Salmon Treaty: A Canadian Perspective*. Royal Roads University.

Ban, N.C., Mills, M., Tam, J., Hicks, C.C., Klain, S., Stoeckl, N., Bottrill, M.C., Levine, J., Pressey, R.L., Satterfield, T., Chan, K.M. (2013). A social–ecological approach to conservation planning: embedding social considerations. *Frontiers in Ecology and the Environment*. 11, 194–202. doi:10.1890/110205

Butler, C. (2006). Understanding the Coho Crisis: Political Knowledge in a Fractured Salmon Fishery. *Maritime Studies, 4*(2), 73–92.

Campbell, L., Cornwell, M. (2008). Human dimensions of bycatch reduction technology: current assumptions and directions for future research. *Endangered Species Research*, *5*, 325–334. doi:10.3354/esr00172

Carawan, L.W. (2004). Added Layers of Stress in the Commercial Fisheries. *Stress, Trauma, and Crisis*, *7*(3), 187–207. doi:10.1080/15434610490500080

Department of Fisheries and Oceans Canada (DFO). (2001). A Policy for Selective Fishing in Canada's Pacific Fisheries, (January).

Department of Fisheries and Oceans Canada (DFO). (2005). Pacific Salmon Selective Fishing Program Evaluation - Audit and Evaluation Directorate.

Department of Fisheries and Oceans Canada (DFO). (2014). Pacific Region Integrated Fisheries Management Plan. Salmon Northern B.C. June 1, 2014 - May 31, 2015.

Donaldson, M.R., Raby, G.D., Nguyen, V.N., Hinch, S.G., Patterson, D.A., Farrell, A.P., Rudd, M.A., Thompson, L.A., O'Connor, C.M., Colotelo, A.H., McConnachie, S.H., Cook, K.V., Robichaud, D., English, K.K., Cooke, S. J. (2013). Evaluation of a simple technique for recovering fish from capture stress : integrating physiology , biotelemetry , and social science to solve a conservation problem. *Canadian Journal of Fisheries and Aquatic Sciences*, *70*, 90–100.

Eayrs, S., Cadrin, S.X., Glass, C. (2014). Managing change in fisheries: a missing key to fishery-dependent data collection? *ICES Journal of Marine Science*. doi: 10.1093/icesjms/fsu184

Harms, J., Sylvia, G. (2001). A Comparison of Conservation Perspectives Between Scientists , Managers , and Industry in the West Coast Groundfish Fishery. *Fisheries*, *26*(10), 37–41.

Jenkins, L.D., Garrison, K. (2013). Fishing gear substitution to reduce bycatch and habitat impacts: An example of social–ecological research to inform policy. *Marine Policy*, *38*(October 2015), 293–303. doi:10.1016/j.marpol.2012.06.005

Mascia, M.B., Brosius, J.P., Dobson, T.A., Forbes, B.C., Horowitz, L., McKean, M.A., Turner, N.J. (2003). Conservation and the Social Sciences. *Conservation Biology*, *17*(3), 649–650. doi:10.1046/j.1523-1739.2003.01738.x

Nguyen, V.M. (2012). *The biological and social sciences of improving post-release survival in sockeye salmon following fisheries interaction in the lower Fraser River, British Columbia*. Carleton University.

Nguyen, V.M, Larocque, S., Stoot, L., Cairns, N., Blouin-Demers, G., Cooke, S. (2013a). Perspectives of fishers on turtle bycatch and conservation strategies in a small-scale inland commercial fyke net fishery. *Endangered Species Research*, *22*(1), 11–22. doi:10.3354/esr00530

Nguyen, V.M., Rudd, M.A., Hinch, S.G., Cooke, S.J. (2013b). Recreational anglers' attitudes, beliefs, and behaviors related to catch-and-release practices of Pacific salmon in British Columbia. *Journal of Environmental Management*, *128*, 852–65. doi:10.1016/j.jenvman.2013.06.010

Plate, E., Bocking, R.C., English, K.K. (2009). Responsible Fishing in Canada's Pacific Region Salmon Fisheries. Pacific Fisheries Resource Conservation Council (PFRCC), Vancouver, BC.

Raby, G., Donaldson, M., Nguyen, V., Taylor, M., Sopinka, N., Cook, K., Patterson, D.A., Robichaud, D., Hinch, S.G., Cooke, S.J. (2014). Bycatch mortality of endangered coho salmon: impacts, solutions, and aboriginal perspectives. *Ecological Applications*, *24*(7), 1803–1819.

Salmon IFMP Northern BC 2014/2015. Department of Fisheries and Oceans Canada. http://publications.gc.ca/collections/collection_2015/mpo-dfo/Fs144-30-2014-eng.pdf

SkeenaWild Conservation Trust, Raincoast Conservation Foundation, David Suzuki Foundation, & Watershed Watch Salmon Society. (2011). *A review of the December 7 , 2010 draft MSC assessment of B .C . pink salmon fisheries*

Young, N., Gingras, I., Nguyen, V.M., Cooke, S.J., Hinch, S.G. (2013). Mobilizing New Science into Management Practice: The Challenge of Biotelemetry for Fisheries Management, a Case Study of Canada's Fraser River. *Journal of International Wildlife Law & Policy*, *16*(4), 331–351. doi:10.1080/13880292.2013.805074

CHAPTER 4. RECOMMENDATIONS & CONCLUSION: INTEGRATING BIOLOGICAL AND SOCIAL INFORMATION

The introduction of the Selective Fishing Policy, and the resulting changes in regulation of fishing and fish handling practices has been a significant influence on the commercial salmon fishery, especially for purse seining where the fishing process has been radically changed. The goal of this policy, and the related changes to the fishery, the fishing process, and monitoring goals, are to move toward a more sustainable fishery through better management of fishery impacts on non-target species. Stakeholder perspectives regarding these regulations, including decisions on species retention and the survival of released fish, have been highly contentious. Understanding the influence of sorting practices on salmon, and the perspectives of stakeholders towards these practices can inform positive modification of management decisions and improved communication strategies between stakeholders. This information on handling practices is critical to ensure that practices are effective and that releasing fish belonging to vulnerable populations is aiding conservation goals. These issues require data from multiple disciplines; input from biological sciences are necessary to be able to assess the condition of fish under handling scenarios and to support regulation implementation, and input from social sciences are needed to be able to understand stakeholder attitudes and perspectives on handling and to gain input on positive changes to regulations. This research sought to explore methods to increase chum salmon post-release survival through examining how the fishing and sorting process impacts the condition of the fish before they are released, and through assessment of the human dimensions to salmon handling regulations from perspectives of fishermen, managers, and members of eNGOs.

Data from vitality assessments in chum salmon caught by commercial purse seine boats shows that both net handling and air exposure significantly impact a fish's stress level and reflex impairment. This suggests that post-release mortality may be reduced for fish that spend less time within the net and have minimal air exposure during sorting. This data should inform the development of fishery regulations and recommendations of best handling practices so that fishers can be given species-specific information on air exposure tolerance and stress responses to crowding. These recommendations can reduce the subjectivity regarding what it means to minimize harm to fish during the sorting and release process.

Interviews with fishery stakeholders on selective fishing practices revealed communication barriers between groups which have led to development of mistrust, especially between fishermen and fishery managers. Fishermen and managers saw noncompliance with fishery regulations as primarily a problem of attitude toward releasing fish, while members of eNGOs perceived the structure of the fishery management, a lack of fishery enforcement and monitoring, and a need for further fisher education as contributing to non-compliance.

Fishermen, managers, and members of non-governmental organizations all discussed the use of chutes onboard purse seine vessels to increase sorting efficiency and minimize handling time for fish, thus decreasing both the effort of fishermen to move fish overboard and the time that fish spend exposed to air prior to release. The implementation of chutes as a standard piece of equipment in the purse seine fleet has potential to improve the post-release survival of chum salmon. Further studies to support the use of chutes could include assessments of changes to sorting efficiency with implementation of chutes onboard vessels, or holding studies to estimate post-release condition of fish released via a chute. If regulations regarding the use of chutes are to be implemented in the purse seine fishery, it will be necessary to develop these in discussion with fishers and have some degree of flexibility as the exact design and use of chutes will not be standard across the fleet. Furthermore, fishers must have an understanding of the effectiveness of the use of a chute, or other selective gear aids, to support their use onboard vessels (*i.e.* that releasing salmon is beneficial to their populations, and that rebuilding populations will result in benefits to fishers in the future). This must be facilitated through communication between management and fishers on the reasoning driving regulations such as those on species non-retention and fishery openings.

4.1 Recommendations

Although a technological solution such as chutes would appear to be relatively easily implemented, there is a larger scale issue of communication and trust between fishermen and managers influencing policy reception, compliance with regulations, and the implementation of new regulations. Fishermen's attitudes towards selective regulations were generally poor because they saw selective fishing policies within the policy context of fleet reduction and decline in fishing opportunities for individual boats. Additionally, the reasoning behind regulations is not effectively communicated to them, and there is no evidence given to show that their actions are effective or that they will benefit from compliance. Many fishermen expressed disbelief that releasing fish actually had an impact on population or species conservation. While fishers may have concerns about populations and stock conservation, the management system currently does not provide incentives for behaviour that will support conservation goals. Behavioural compliance is key; handling practices, such as net tightness, are subjective between fishermen and are therefore unenforceable through regulation. However, if incentives were provided for good handling behaviour then fishermen may be more likely to adopt recommended behaviours or infrastructure to improve the survival of released fish. The following recommendations will support steps toward fulfilling fishermen's proposals for improving the survival of released fish, and for improving communication between fishers and management, ultimately improving the reception and implementation of conservation regulations.

4.1.1 Further research

Reflex impairment data for chum salmon presented in this project supports the value of minimizing handling and air exposure that fish experience during capture and sorting processes. To achieve this, fishers recommended the use of a chute system on board vessels to quickly and efficiently release fish with the least possible harm. Reflex impairment studies in other species of Pacific salmon will help to inform species-specific recommendations for handling and air exposure tolerance.

The use of chutes for the handling and release of salmon within the purse seine fleet can be formalized with test fishery studies to provide data to support their use.

Studies assessing the utility of chutes will need to be conducted in collaboration with fishermen in order to support the implementation of chutes within some form of fishery regulation. Facilitation of fishers' participation in the development of gear or handling adaptation in way that is meaningful to fishers and managers will help to encourage uptake of these changes and compliance, and ensure that any development of regulation or suggested best practices is done so in a way that is practical for use by fishers.

To remove barriers to implementing chutes onboard vessels, some formal support or funding should be directed into a program to encourage the construction of chutes on purse seine vessels. This will need to be implemented in coordination with skippers and crews so as to achieve the best configuration for each boat. Skippers who have successfully built chutes could be supported so that they can provide feedback or information to others on how they built theirs and the benefits of using these chutes.

4.1.2 COMMUNICATION & TRUST

Improved communication between fishermen and managers is critical to improving compliance to selective fishing regulations and handling practices. Trust and successful movement of knowledge between groups with different priorities and interests can best be facilitated through interpersonal connections and communications (Young et al., 2013). Communication is a fundamental component of fishers' participation in the management process. To produce effective fishery regulations or practices fishers must be engaged to utilize their knowledge of the fishing process, obtain practical solutions to problems such as those of bycatch reduction, and because any changes in fishers behavior must involve their commitment to the process (Hall et al., 2007).

4.1.3 Incentives

Incentives are an important way to stimulate the use of gear modifications for achieving conservation goals such as bycatch impact mitigation (Jenkins & Garrison, 2013). Fishery managers often apply selective fishing practices which impose costs on fishers (*e.g* reduced catch) without incentives to counter these lost profits which can result in noncompliance with, or modification of these practices by fishers (Pascoe et al., 2010). The current management process for selective fishing practices in the Pacific salmon fishery uses disincentives of enforcement and observer monitoring to encourage compliance. Incentives for good handling and compliance with regulations may be created if benefits accrued to fishermen through fishing opportunities are clarified. Incentive based regulations could be further implemented through strategies which create incentives for fishers to adjust their operations to maximize profits through quality of catch rather than volume (Pascoe et al., 2010), or other mechanisms which could allow fisheries to open on populations when they have reached a defined recovery point.

The Selective Fishing Policy enables DFO to encourage compliance with selective fishing through allocation of fishing opportunities to more selective sectors of the fishery, providing an incentive to adopt these practices. Industry has indicated that increased flexibility in selective fishing regulations would increase the incentive to comply when practices are required (Plate et al., 2009).

4.1.4 Transparency & Evaluation

Management decisions for the fishery should be based on scientific information and predictable criteria that is openly communicated. Information on stock and population status used to make decisions regarding non-retention should be made available to fishermen in a form that is logical to those external to the management process. Transparency around regulation development and decision-making is also important to ensure understanding among stakeholders when many diverse groups are involved in fishery management. Environmental non-governmental organizations (eNGOs) will continue to play an important role in the management process for British Columbia's Pacific salmon fishery by bringing an external perspective to fisheries management, by critiquing and evaluating decisions, and by informing the public of management decisions and their outcomes.

A transparent management process must also include monitoring and evaluation of management decisions and policy outcomes, and effective communication of these results. Evaluation of the outcomes of the Selective Fishing Policy is necessary to understand and monitor the outcomes and impacts of these regulations both on the resource and resource users and to inform fishermen and the public as to how regulations and management decisions are made.

4.1.5 Co-Management Arrangements

Co-management arrangements in which some management decision-making power is divulged to localized groups which represent local interests and stakeholders have been found to contribute to the effectiveness of recommendations discussed herein; including increased trust between fishermen's organizations and government, increased communication and sharing of information between fishermen and government, increased willingness of fishermen and government to explore solutions for regulatory problems, improved ability to develop and enforce regulations that are accepted by fishermen, and increased compliance (reviewed by Pinkerton et al., 2014). Potential barriers to implementing co-management strategies in British Columbia include the unwillingness of government to distribute powers of decision-making, and the heavy influence of private corporations within fisheries policy (Pinkerton, 1999). Creation of local management organizations or institutions could provide the basis for co-management arrangements between regions and the central management of DFO, where DFO, independent researchers, and nongovernmental organizations would play a key role in providing external support, including facilitating policy discussion, providing scientific expertise, and coordination of management to ensure that conservation goals are met (Pinkerton et al., 2014). Co-management can also help to ensure that diverse interests of multiple stakeholders involved and invested within the fishery are represented in decisions (*e.g.* processors, coastal communities, First Nations, environmental organizations, and citizen groups; EcoTrust Canada, 2004).

4.2 Conclusion

Concerns for threatened or vulnerable species come from an ecological foundation; however, conservation success can only be produced with knowledge of both ecological and social factors that influence this outcome (Fox et al., 2006). Understanding human dimensions of management can inform responses to varied social interests in resource use and conservation (Jacobson & McDuff, 1998). Ultimately, the concern for salmon conservation is one of both biological and ecosystem conservation, and of social concern for the preservation of fishers' livelihoods. As one of multiple cumulative pressures on salmon populations, post-release mortality of non-target salmon is one factor that may inhibit recovery of populations of conservation concern. Ensuring that fisheries maintain low impacts on populations vulnerable to exploitation is critical to the overall health of wild Pacific salmon, where population and species diversity is the foundation of their survival (Schindler et al., 2010). Sustaining abundances of returning salmon is crucial to maintaining their keystone ecological and social roles.

Literature Cited

Ecotrust Canada. (2004). Catch 22: conservation, communities and the privatization of B.C. fisheries. An economic, social and ecological impact study. Vancouver, BC. Retrieved from http://ecotrust.ca/wp-content/uploads/2015/02/Catch-22-November2004_0.pdf

Fox, H.E., Christian, C., Nordby, J.C., Pergams, O.R.W., Peterson, G.D., Pyke, C.R. (2006). Perceived barriers to integrating social science and conservation. *Conservation Biology : The Journal of the Society for Conservation Biology*, *20*(6), 1817–20. doi:10.1111/j.1523-1739.2006.00598.x

Hall, M.A., Nakano, H., Clarke, S., Thomas, S., Molloy, J., Peckham, S.H., Laudino-Santillan, J., Nichols, W.J., Gilman, E., Cook, J., Martin, S., Croxall, J.P., Rivera, K., Moreno, C.A., Hall, S.J. (2007). Working with Fishers to Reduce By-catches. In *By-catch Reduction in the World's Fisheries* (pp. 235–288).

Jacobson, S., McDuff, M. (1998). Training Idiot Savants: The Lack of Human Dimensions in Conservation Biology. *Conservation Biology*, *12*(2), 263–267.

Jenkins, L.D., & Garrison, K. (2013). Fishing gear substitution to reduce bycatch and habitat impacts: An example of social–ecological research to inform policy. *Marine Policy*, *38*, 293–303. doi:10.1016/j.marpol.2012.06.005

Pascoe S., Innes J., Holland, D., Fina, M., Thebaud, O., Townsend, R., Sanchirico, J., Arnason, R., Wilcox, C., Hutton, T. (2010). Use of Incentive-Based Management Systems to Limit Bycatch and Discarding. *International Review of Environmental and Resource Economics. 4*(2): 123:161. http://dx.doi.org/10.1561/101.00000032

Pinkerton, E.W. (1994). Local Fisheries Co-management: A Review of International Experiences and Their Implications for Salmon Management in British Columbia. *Canadian Journal of Fisheries & Aquatic Science*. 51, 2363–2378.

Pinkerton, E. (1999). Factors in overcoming barriers to implementing co-management in British Columbia salmon fisheries. *Conservation Ecology* 3(2): 2. [online] URL: http://www.consecol.org/vol3/iss2/art2/

Pinkerton, E., Angel, E., Ladell, N., Williams, P., Nicolson, M., Thorkelson, J., Clifton, H. (2014). Local and regional strategies for rebuilding fisheries management institutions in coastal British Columbia : what components of comanagement are most critical ? *Ecology and Society*, 19(2) 72. http://dx.doi.org/10.5751/ES-06489-190272

Plate, E., Bocking, R.C., English, K.K., (2009). Responsible Fishing in Canada's Pacific Region Salmon Fisheries. Pacific Fisheries Resource Conservation Council (PFRCC), Vancouver, BC.

Schindler, D.E., Hilborn, R., Chasco, B., Boatright, C.P., Quinn, T.P., Rogers, L.A., Webster, M.S. (2010). Population diversity and the portfolio effect in an exploited species. *Nature*. 465, 609–12. doi:10.1038/nature09060

Young, N., Gingras, I., Nguyen, V. M., Cooke, S.J., Hinch, S. G. (2013). Mobilizing New Science into Management Practice: The Challenge of Biotelemetry for Fisheries Management, a Case Study of Canada's Fraser River. *Journal of International Wildlife Law & Policy*, *16*(4), 331–351. doi:10.1080/13880292.2013.805074