RISK PERCEPTIONS AND MARINE SPATIAL PLANNING SURROUNDING TIDAL ENERGY IN BRITISH COLUMBIA

by

MATTHEW RYAN TACCOGNA

B.A., Royal Military College of Canada, 2004

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Abstract

This thesis examines in-stream tidal energy (ISTE) generation technology and its potential for development, underwater within Discovery Passage, a narrow channel ocean environment near Campbell River, British Columbia, Canada. The study took place in the summer of 2014 and measured levels of support and opposition towards two separate investigative license (IL) ocean energy sites held by a BC developer. The primary approach was to interview expert marine stakeholders and First Nations persons based on their commercial, recreational and cultural usage of the Discovery Passage waterway and its foreshores near the ILs. The study measured subjects' risk and benefit perceptions of the technology and the projects, levels of support for its development, willingness to pay for it, and any specific conflicts with the developments, both on and under the water. Interactive marine spatial planning (IMSP) and geographic information systems (GIS) were used to elicit respondents' principle areas of marine usage within the study area, levels of value associated with these areas and seasons of usage. In addition, at the end of the interview, subjects were shown the IL sites on a map and were given the opportunity to indicate areas of perceived conflict between their organizations' operations and the sites.

Results found respondents to be initially strongly in favour of developing tidal energy in BC, with 88% indicating a high levels of support for its development and willingness to pay small amounts for it as part of BC Hydro's rate increases. However, once the IL sites were shown to the interviewees specifically on a map, levels of support declined and specific opposition to the sites was identified amongst 72% of respondents, indicating highly localized risk perceptions towards the projects. Perceived risks identified by stakeholders included marine traffic interference stemming from installation operations, high costs, cumulative impacts of many turbine installations and tugboat towlines and fishing gear potentially snagging underwater turbines. Identified benefits of tidal energy included local reservoir water conservation from tidal energy generation displacing hydropower water use, local economic development, displacing regional area off-grid diesel generation and achieving more localized electrical generation on Vancouver Island.

Preface

The identification and design of the research program was primarily conducted by Matthew Taccogna (MT) with guidance and reviews from Dr. Hisham Zerriffi (HZ), Mr. Joe Truscott (JT), MREM, RP Bio. and Dr. Vladan Prodanovic (VP). MT conducted all of the field research and analysis with guidance and assistance on the GIS data processing and map making from Mr. Nicolas Kourepinis (NK), Hemmera Geospatial Analyst. For Chapter 3, MT gathered and analysed all of the research data and wrote the report with reviews by HZ and JT. Chapter 3 is intended to be submitted for publishing with MT as primary author and HZ and JT as additional authors. For Chapter 4 MT gathered and analysed all of the research data with some assistance on GIS data processing from NK. Chapter 4 is intended to be submitted for publication with MT as primary author and HZ and JT as additional authors. Chapter 2 is intended as an extended literature and technical review and did not involve field research but may be considered for publication; HZ, VP and JT contributed reviews and comments on this chapter and would be listed as additional authors.

UBC Behavioral Research Ethics Board (BREB) reviews and approvals were sought for both the stakeholder and First Nations peoples, submitted as two separate applications. The first application H14-00880, was entitled "A Marine Multi-Resource Usage Study for Possible Tidal Energy Installations in Campbell River, BC, First Nations portion." The second application, H14-01016, was entitled "A Marine Multi-Resource Usage Study for Possible Tidal Energy Installations in Campbell River, BC."

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Dedication

To my professors, colleagues, family and friends, who all helped me, pushed me and supported me through completing this endeavour.

Chapter 1: Introduction

British Columbia and Canada have long been touted as having an environmentally friendly and reliable electricity grid, an example for the world to follow. However, with BC possessing up to 70 MW of diesel-fueled electricity generation (both as primary and backup generation) in some 80 remote communities alone, and becoming almost entirely reliant on increasingly expensive and environmentally damaging large hydropower, this claim clearly has its flaws (Aboriginal Affairs and Northern Development Canada; Natural Resources Canada, 2011). While dams provide clean, reliable and economical baseload power, they are also known to have large scale ecosystem impacts on various fish species, as well as flooding important agricultural or traditional First Nations lands. The ongoing debate, and First Nations' court challenges against BC Hydro's controversial Site C dam construction project, highlight these and other concerns. Meanwhile, BC is neglecting various more renewable energy sources, including ocean renewable energy which offers a considerable resource much closer to BC's main population centres.

Controversy over the viability of large storage hydroelectric in the face of rising costs of construction, long distance transmission lines and reliability in the face of increasing competition over water flows due to global warming, all contribute to the ongoing debate over where BC should get its energy from. Over 80% of BC Hydro's total generation capacity of 12,048.9 MW lies in the Peace River and Columbia Kootenay watersheds, 400-800 km away from the 3.6 million people living in the lower mainland and Vancouver Island (BC Hydro, 2015; BC Stats, 2011). Localized generation assets in the lower mainland and Vancouver Island region make up only about 14% of BC's average annual energy generation, yet the region is home to 78% of BC's population (BC Hydro, 2015; BC Stats, 2011). Increasing presence of forest fires, extreme precipitation events and possible subsequent landslides, as well as the ongoing risk of earthquakes, could possibly place electrical transmission infrastructure in BC at risk due to the requirement for long supply lines and limited power generation on Vancouver Island, making the notion of achieving more coastal based generation appealing. One alternative is Independent Power Producers (IPPs). In British Columbia, IPPs have been small-scale renewable energy generating facilities with contracts to sell power to BC Hydro. However, IPPs accounted for roughly 20% of BC Hydro's generation supply in 2014 with roughly 60% of these providers being run-of-river (RoR) hydroelectric (BC Hydro, 2014). Cumulative impacts of multiple RoR projects within a region, high water diversion rates and semi-impoundment practices present at some project sites (smaller scale dams, weirs or head ponds), have resulted in some controversy over the technology's widespread use and associated ecological impacts (Anderson, Moggridge, Warren, & Shucksmith, 2015; Jager & Bevelhimer, 2007; Kumar & Katoch, 2016). Further, levels of ecological impacts stemming from RoR projects, per unit of energy generated, have been found on large scales to be equivalent to large hydropower or other conventional energy projects, raising speculation over their widespread development (Abbasi & Abbasi, 2011). In addition, all hydropower projects in the Pacific Northwest region are becoming increasingly vulnerable to low summer season flows due to declining snow packs and earlier freshets (Jost & Weber, 2013; Merritt et al., 2006; Payne et al., 2004). Often, BC will have ample surplus hydroelectric supply from all the RoR facilities at the same time as it main heritage hydroelectric assets causing a glut of electricity supply and the need to sell power on inter-provincial or international markets at reduced rates, or simply pay IPP facilities to not generate, as was recently reported by the media (Lavoie, 2016). Meanwhile, other RE technologies such as geothermal or land based wind, have encountered problems of high exploratory costs or limited levels of available grid penetration on constrained grids, such as experienced on Vancouver Island or Haida Gwaii (BC Hydro, 2013a; Boronowski, 2009).

An alternative to both large hydro and existing land-based or river based renewable energy sources can be found in the extensive coastline of British Columbia. On the Southern BC coast, there exists considerable potential for wave and tidal energy generation, especially on Vancouver Island. In-stream tidal energy in particular is estimated to have a theoretical potential of about 3,500 MW on the south coast alone (Tarbotton & Larson, 2006), nearly one-quarter of BC's current installed generating capacity, however, this number must be tempered for various reasons. Ecological concerns around allowable channel tidal turbine blockage ratios by installed turbines, as well as interference with other marine uses such as shipping and fishing, limit the percentage of sustainably extractable in–stream tidal energy (ISTE) to roughly 15% of this number, if not less (Hagerman & Polagye, 2006). However, more recent work from Nova Scotia, discussed in Chapter 2 of this Thesis, suggests that actual energy levels present may be substantially higher than initially, thus possibly raising the amount of safely extractable energy in British Columbia (Karsten, Greenberg, & Tarbotton, 2011).

BC's largest ISTE resource lies on the shores of Discovery Passage, near the City of Campbell River, BC. Between Seymour Narrows and South Discovery Passage alone, there exists an estimated 1113 MW of energy based on kinetic energy flux methods (Tarbotton & Larson, 2006a). Vancouver Island’s grid is reliant on limited local hydroelectric generation, a 200 MW gas fired plant in Campbell River and a 99 MW wind farm at Cape Scott with the remainder of its energy being transmitted from the mainland via two large undersea cables. Thus, the tidal energy resource at Campbell River (as well as other resources on the Island), represent a considerable potential generation asset, and is identified as such in BC Hydro’s last future generation prospectus conducted in 2009 (BC Hydro, 2009). However, Campbell River's tidal power must also compete against other local resource users within a very busy waterway.

This Thesis examines potential in-stream tidal energy (ISTE) installations within a narrow channel and the perceived and actual barriers to its development. Research findings are based on a case study of tidal energy investigative license (IL) sites in Discovery Passage at Campbell River British Columbia, Canada. The study hypothesized that certain marine resource use conflicts, both perceived and actual, would exist in relation to these proposed tidal energy investigative license (IL) sites, given the busy nature of the coastal passage and the variety of First Nations and stakeholders present there. It was also hypothesized that there would be a level of support for tidal energy development given its apparent low impacts and potential economic benefits to the local community if it were to be developed. Therefore methodologies were derived to measure overall concerns around tidal energy, potential benefits stemming from it, as well as spatially elicit areas where there were high levels of use or high levels of perceived conflict with the proposed ISTE sites.

The study involved an interactive marine spatial planning (IMSP) and a semi-structured interview process which aimed to measure risk, benefit and general perceptions surrounding tidal energy amongst key stakeholders and First Nations peoples within the local City of Campbell River. The IMSP methods used were based on studies designed to map and quantify ecosystem services for coastal marine environments (Klain & Chan, 2012). Interactive GIS mapping techniques were used to identify different stakeholders’ and First Nations peoples’ areas, as well as seasonality of marine usage and self-perceived levels of value associated with those areas. These GIS techniques also sought to identify stakeholders’ and First Nations peoples’ potential areas of conflict given the proposed tidal energy site locations which were depicted on a map along with some information on their design characteristics.

Chapter 2 of this Thesis begins with stating the need for renewable energy generation worldwide as a means of lowering greenhouse gas emissions from fossil fuel energy sources, and some of the challenges to its implementation. Concepts of regional advantages of different renewable energy technologies, distributed and centralized electrical grid networks, and the challenges which other renewables face in BC are all discussed. Ocean renewable energy technologies (ORE, includes wave, tidal and offshore wind) are then introduced with a brief state of the sector analysis and a subsequent focus on ISTE in particular, including some technical theory around tidal energy resource assessment and some of the oceanographic theory around tides in BC. Incentive for tidal energy generation in BC is also introduced including the potential vulnerabilities of large scale hydroelectric energy to climate change and the many off-grid communities in BC reliant on fossil fuel based generation. Some marine spatial planning (MSP) guidelines around ISTE implementation are subsequently introduced based on existing literature which largely stems from European ocean renewable energy projects. Finally, some broader potential MSP related concerns surrounding BC are discussed based on its geographic and socio-ecological makeup. Chapter 2 concludes with a discussion of the slow development rates of tidal energy worldwide and a particular focus is placed on the recent integrated resource plan document from BC Hydro in 2013 which placed little emphasis on small scale renewables, and ocean energy in particular, as a possible indicator why the sector is so slow to develop in BC.

Chapter 3 provides in-depth analysis of a case study of Campbell River looking specifically at risk perceptions surrounding the proposed tidal energy facilities. Thirty-nine subjects were interviewed in total, the majority from the shipping or boating sectors, with others comprised of eco-tourism operators, marina and harbor authorities, the Canadian Coast Guard, Department of Fisheries and Oceans, First Nations, sport fishers, aquaculture companies and City managers. Interviewees were selected based on their commercial, recreational or cultural usage of, or jurisdiction over, the Discovery Passage waterway. The five part interview script included an information briefing on energy in BC and tidal energy specifically. Parts 1 and 5 of the interview incorporated the IMSP questions, with part 1 analyzing subjects' usage characteristics and part 5 introducing the IL sites and measuring levels of perceived spatial conflict. The remainder of the interview protocol measured general perceptions around energy systems and tidal energy in particular. In part 2, concepts of reliability of local power systems were surveyed, along with choice prioritization questions on what subjects found most valuable when considering where their energy came from in BC. Following the information briefing (part 3), subjects were again given choice prioritization questions on the possible risks and benefits of tidal energy in part 4. Subsequently, they were asked to rank tidal energy in relation to 10 other energy generation technologies in accordance with 5 different criteria. Then, subjects were asked to state their levels of support for tidal energy development, willingness to pay for it, perceptions of its impact on marine life, its affordability and the possibility of it acting as a tourism draw for the region. Responses, particularly the risks and benefits questions, were classed by stakeholder group, producing a wide variety of differing responses. In addition, some of the dominant perceived risks and benefits were quite significant and real in their applicability to the proposed tidal energy projects and the surrounding area and were therefore analyzed in more detail. These risks and benefits predominantly pertained to shipping, sport fishing and hydropower in the area.

Chapter 4 reports on the IMSP methodology used and some of the spatial and temporal results. The general premise of the methodology was to elicit valued usage areas (or route lines in the case of shippers) and perceived areas of conflict with the tidal energy sites amongst classes of stakeholders and First Nations. At the beginning of the interview respondents were asked to define their usage areas. Then, information on tidal energy was introduced to the subject, and finally, the IL sites where the tidal energy was proposed were shown to respondents at the end of the interview and they were asked to delineate any particular conflict areas they had with those sites and give their reasons why. General analysis of the nature and location of the usage and conflict areas is discussed as well as how the geography of the sites and nature of the interviewed stakeholders present may have contributed to these perceptions. Some comparison is also drawn to other ISTE sites in Europe for contextual purposes. Temporal data showing seasonality of shipping use in the area are also presented along with some trends noticed on the specificity of conflict perceptions and some analysis of the methods used.

Finally, this thesis concludes by proposing a general stakeholder engagement framework for assessing the viability and possible conflicts deriving from ISTE and other ORE sites. A brief case study looking at BC's own Ministry of Forests Lands and Natural Resource Operations (FLNRO) Crown Land Use Operational Policy for Ocean Energy is used to contrast with this study. As well, further analysis of regional MSP and shipping routing density maps is undertaken. Some mitigation measures highlighting some of the issues uncovered in this study are also introduced. Finally, a prescriptive model for ORE and ISTE site assessment and stakeholder engagement is presented and the Thesis is summarized.

Chapter 2: Types of Renewable Energy Generation and an Introduction to Tidal Energy

2.1: Introduction, Incentive for Renewable Energy Generation

Global climate change is now driving the development of renewable energy technologies, and the challenges humanity faces in terms of reducing carbon emissions from energy sources are immense. The world's primary energy production, which drives our economies for a broad range of activities from electricity and heating to industrial processes, is about 82% derived from the combustion of fossil fuels. This energy use is in turn responsible for approximately 56.6% of all the world's GHG emissions (Yamba et al., 2011). The proportion of the world's primary and electricity energy supplies are shown below in figures 2-1 and 2-2. In figure 2-2, it can be seen that renewable energies (RE), only account for 22% of global electricity generation, including hydropower. However, there is growing opposition to large hydropower projects and how "renewable" they actually are, due to their destruction of river ecosystems and flooding of valuable agricultural, community and aboriginal lands, as well as producing significant amounts of methane from decomposition processes in reservoirs (Booth, 1989; Kemenes, Forsberg, & Melack, 2007; Wilson, 2012; Yang, Xu, Milliman, Yang, & Wu, 2015). Without hydropower, RE (incorporating wind, solar, geothermal, etc.) accounts for only 4.5% of global electricity generation in 2011; however this number has increased to 5.7% in 2013, an increase of some 279.8 TWh of energy generated per year globally (IEA, 2011, 2013). RE is generally defined as any energy supply that is produced from solar, geophysical, or biological sources which are naturally replenished at a rate which meets or exceeds their rate of use (Yamba et al., 2011). As well, most forms of RE produce little or no GHGs, unlike burning of fossil fuels, and thus represent key policy targets for governments around the world in the fight to reduce carbon emissions and combat global warming.

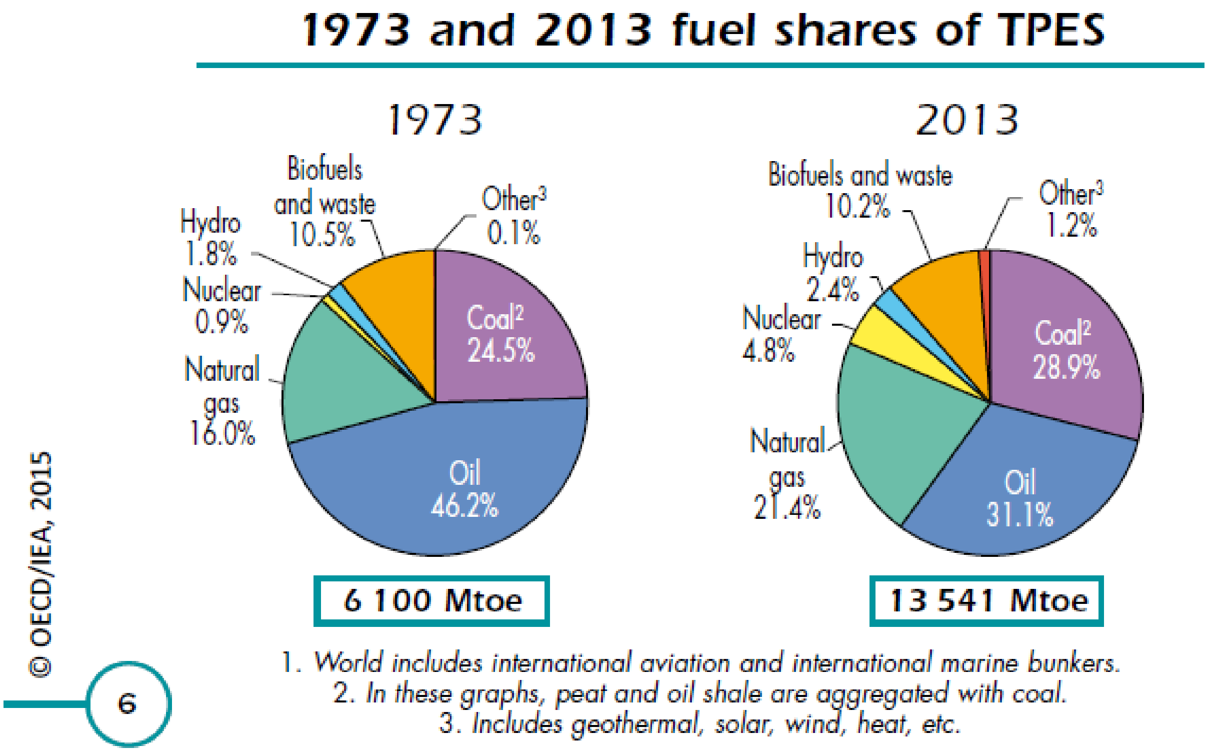

Fig. 2-1: The World's total primary energy supply in 1973 and 2013; total energy used is expressed in Mtoe or megatons of oil equivalent. Reprinted with permission of © OECD/IEA 2015 World Energy Outlook, IEA Publishing. Licence: www.iea.org/t&c

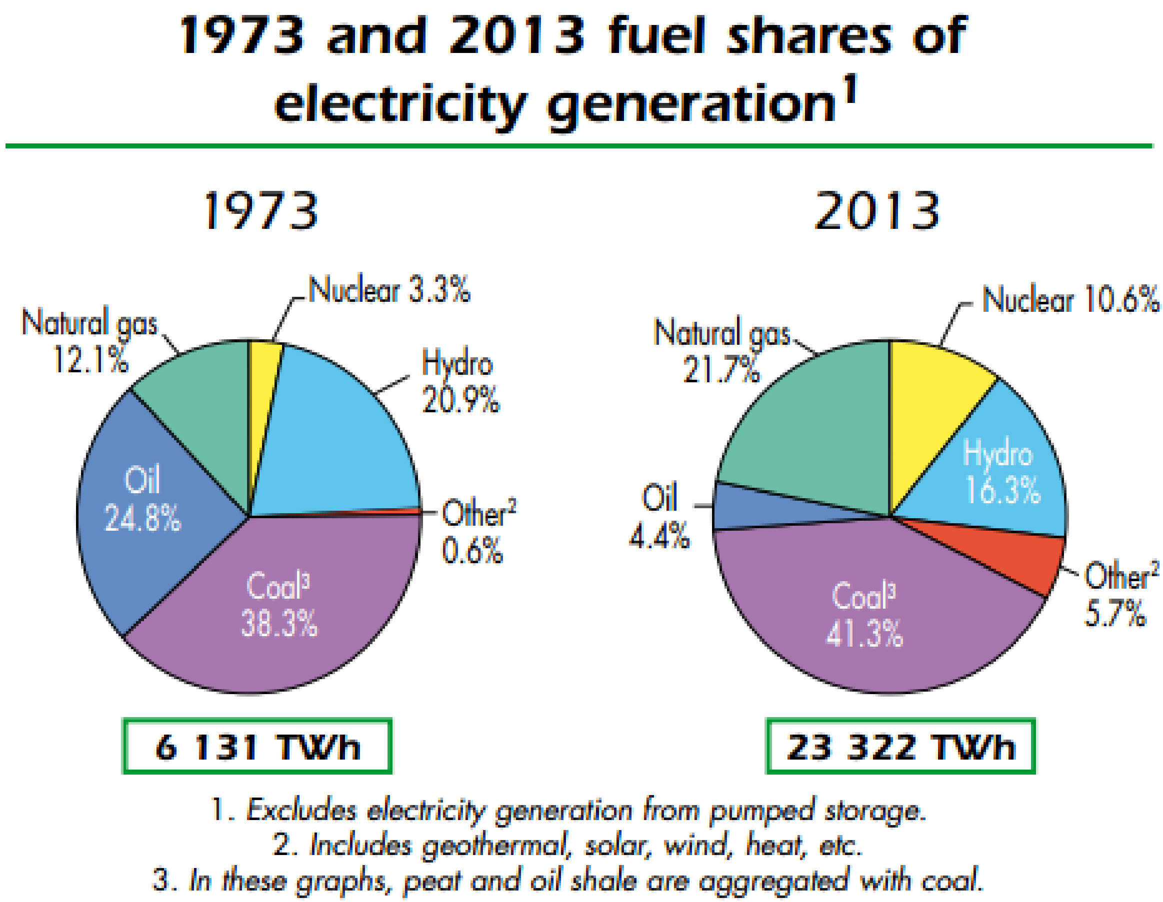

Fig. 2-2: Shares of electricity generation capacity in the world in 1973 and 2013 (TWh is terawatt hours, 1 TWh = 10^{12} watt hours). Reprinted with permission of © OECD/IEA 2015 World Energy Outlook, IEA Publishing. Licence: www.iea.org/t&c

2.1.1: Energy Access and Energy Distribution Systems

On top of reducing GHG emissions, access to energy is another significant problem for human development, and incentive for distributed RE generation, particularly in the developing parts of the world. Nearly 1.2 billion people in the world have no access to electricity, while another 1 billion has intermittent or unreliable access; on top of this, some 3 billion people still combust some type of solid fuel (mostly wood, coal, charcoal or dung) in order to provide heat for comfort or cooking (Zerriffi, 2011). Numerous environmental and health implications stem from this problem including GHG emissions, deforestation, erosion and loss of habitats due to fuel wood gathering, as well as indoor air pollution from burning solid fuels indoors in open fires. Human development indicators have linked energy access, particularly in rural developing areas, to fostering income generation, health benefits, preservation of biodiversity, education, gender equality (women often spend much of their day gathering fuel wood, for example), and food production (Yamba et al., 2011). Yet, the question remains: how best to electrify 1.2 billion people? In many developing areas of the world (and also some developed areas of the world), electricity grid infrastructure is very poor. As one example, an estimated 35% of India doesn't have reliable access to energy (Chaurey, Ranganathan, & Mohanty, 2004; Zerriffi, 2011). Even in Canada, a recent government of Canada study quantified some 200,000 people living in 292 remote communities across the country. An energy survey of these communities showed that some 71% of them used fossil fuel generation (predominantly diesel fuel as well as various other fossil fuels for heat and cooking) for their electricity needs (Aboriginal Affairs and Northern Development Canada; Natural Resources Canada, 2011).

When considering how best to electrify a population one important factor to consider is electrical grids. An electrical grid is an interconnected network for delivering electricity from suppliers to consumers. It consists of generating stations that produce electrical power, high-voltage transmission lines that carry power from distant sources to demand centers, and smaller, lower voltage distribution lines that connect the power source to individual customers. Electrical generation systems are generally lumped into two broad categories: centralized and distributed generation (CG and DG respectively) and typically today centralized systems are featuring more elements of distributed generation with much of this DG also being from renewable sources (Pepermans, Driesen, Haeseldonckx, Belmans, & D'haeseleer, 2005). This model is of course overly simplistic, given that many countries such as China, India and even Canada also possess what are known as remote grids, essentially a smaller, often remote electricity networks which serve several communities, complete with their own generation, transmission and distribution assets (Boronowski, 2009; Li, Li, & Zheng, 2014). At an even smaller scale are off-grid communities which will be discussed in section 2.1.3.

Classic models of centralized generation features large, megawatt (MW) - scale power plants, such as large hydro dams nuclear plants or coal plants, often far away from population centers, which transmit their energy at high voltages over long distances to the consumer. Electrical grid systems evolved into these centralized structures over decades as economies of scale dictated the efficiency of large scale plants and transmission lines. Conversely, however, distributed power systems bring the generation capability closer to the consumer, with smaller generation plants generally being situated on distribution lines at lower voltages[1], or even behind the meter, providing power closer to the point of use in the form of residential roof top solar plants or other

[1] There are varying definitions as to the voltage of a distribution versus a transmission line, but some areas of Canada use 50kv, being that any line operating below 50kv is a distribution line.

municipal scale green generation assets. There are various advantages and disadvantages of DG versus CG and numerous technical, economic, environmental and even social issues surrounding its reasons for integration into existing CG networks.

In a technical sense, DG provides voltage support to a grid, reducing the risk of low voltage or zero voltage events commonly known as brownouts or blackouts. “Islanding” is a term which refers to a DG system offering power to an isolated area or community while the remainder of the main grid may be blacked out. However, challenges arise in reconciling DG and CG systems, particularly in a blackout event such as this, as the grids and associated generators will have to be synchronized before being reconnected. Power grids typically operate at around 50Hz frequency but imbalances occur with differences between supply and demand within the system. Thus, power quality can be a significant concern. As an example, some large industrial consumers require high quality and reliable power (such as 3 phase versus single phase) for large, electrically driven equipment such as municipal water or sewage pumps (Pepermans et al., 2005). Interruption, re-routing or disturbance of a CG system via any number of natural or man-made disasters such as forest fires, landslides or avalanches, while not entirely blacking out a CG grid, may have other unintended consequences on power quality, frequency and phasing, which for certain applications as mentioned above could be considered a failure of power reliability. In addition, while most large generation assets are synchronous, reactive and able to adjust their generation characteristics in response to alterations in demand, some DG assets are not sufficiently equipped with power conditioning equipment or are asynchronous to the grid, thereby possibly placing heavier synchronizing loads onto the larger CG plants. Finally, an increased share of DG units on low voltage distribution lines could cause power to flow bi-directionally back into medium voltage grids, thereby necessitating power protection systems be installed between the grids presenting additional technical challenges to the integration of DG (Dondi et al., 2002).

Economically, DG has been argued to be 30% more economical than building additional transmission and distribution lines by the IEA (2002). In addition, Dondi et al. (2002) reported average large grid transmission efficiency losses of 6.8% within OECD countries and that well positioned DG assets can introduce economic savings of 10-15% in this regard. These statements should be tempered, however, with the fact that renewable energy generation assets can often be more expensive than large CG assets, thus casting notions of cost savings from DG RE assets into doubt. Yet, DG is also argued to be more environmentally friendly in that it allows penetration of more new renewable (not including large storage hydroelectric) generation technologies in areas which are well suited to them (Pepermans et al., 2005). For example, methane capture and combustion at a landfill, woody biomass combustion in active forestry zones, or-in particular relevance to this Thesis-ocean energy plants near high wave or tidal energy areas, all represent examples of potential DG plants which would allow for the harnessing of various environmentally friendly, low GHG energy technologies pertinent to their geographic areas. Economic challenges of environmentally friendly, renewable DG generation are that the technologies are often new and consequently expensive, sometimes technically unreliable and unpredictable in their generation parameters (such as wind and solar which rely on variable environmental conditions), even simply unsightly (described further in section 2.1.2). Of course, for DG, grid-connected renewables generation to be facilitated, particularly for newer, more expensive RE such as ocean energy, the utility provider must often subsidize its implementation, often through use of feed-in tariffs (FITs), or elevated prices paid for power from renewable sources as seen in Nova Scotia's Marine Renewable Energy Strategy (Dalton et al., 2015; Nova Scotia Department of Energy, 2012). In cases where a utility provider holds a monopoly over the market, such as in British Columbia with BC Hydro, decisions to develop large CG assets such as the Site C dam, while not providing FITs or subsidies for smaller scale renewables, arguably favours a CG type system and generally prohibits development of many new DG renewable assets. While BC Hydro's net-metering DG program allows for up to 100kw of household scale clean energy generation projects, their prescribed remuneration rate of $0.10/KWh yields very marginal profits for a household developer and longer return on investment time frames, making private investment in such projects arguably less appealing, particularly for rooftop PV solar for which a case study example is provided in section 2.1.3.

2.1.2: Off-Grid and Remote Grid Electrification

In an off-grid context, idealized conceptions of power systems seldom meet reality. The cost of electrifying rural areas is often a major inhibitor from a from a power utility's perspective, as running and maintaining transmission and distribution lines into remote communities can often cost more than it is worth in terms of number of paying customers in the community versus the cost of building the power connection (Chaurey et al., 2004; Zerriffi, 2011). Even in developed countries this can be the case. As an example, in British Columbia, rugged, mountainous terrain creates high construction and power transmission costs. BC Hydro recently cut 11 of its rural community electrification program (RCEPs) in early 2014 citing cost saving measures due to the difficulty of bringing transmission lines to some of these very remote, rugged regions (Mast, 2015). Not only must the lines be installed, but they also must be maintained and repaired, a likely occurrence given BC's high slope terrain with frequent risks of avalanches, landslides and possible seismic events, and also the need for routine vegetation clearing within rights-of-way.

The converse option of using distributed generation or off-grid generation to electrify remote communities also presents challenges. Often, affected communities are small in population and lack sufficient financial, social, and technical resources to buy, operate and maintain an off-grid energy system (Chaurey et al., 2004; Wilson, 2012). Further, the remoteness of the location can lead to significant logistical challenges in installation, maintenance and spare part acquisition. The notion of training local residents to conduct first line maintenance on an energy system is also ideal but not always guaranteed success. A well-known technology theorist, Arnulf Gruebler (2011) cites broad trends around the hardware and software sides of technology (in this case energy) adoption. "Hardware" refers to the physical infrastructure side of an energy system in this case, the generator, transmission lines and connections which all need to be maintained, but "software" deals with the social and economic aspects of new technologies. How will people feel about the new energy systems: will they support them, take the financial risk in buying them, and do they possess the adequate social and technical capacity to operate and maintain the technology?

Yet, the current incumbent off-grid energy system of choice, diesel power, presents many challenges which make the case for renewables more appealing. Diesel fuel must be transported often long distances via land, water or even air into remote communities at very high cost. Typical off-grid communities will pay from $0.25-1.00/KWh for diesel energy, dependent on fuel costs and transportation (International Energy Agency, 2008; Wilson, 2012). Wilson (2012) in particular conducted research in a remote aboriginal community on Williston reservoir in British Columbia. The community relies on diesel power generation and experiences problems with spilled fuel with subsequent soil contamination, poor air quality and associated health effects, in addition to high energy costs and total reliance on BC Hydro for their power supply and maintenance problems. Wilson (2012) also outlines the regulatory difficulty in dealing with utility providers and financial risk faced by communities trying to buy and transition to renewable energy systems as was seen in the community' struggle to adopt a combined heat and power woody biomass plant. Boronowski (2009) also examines the potential for wave and tidal energy to penetrate into the Queen Charlotte Islands' (also known as Haida Gwaii) grid, which is isolated from the mainland and heavily reliant on diesel generation with some storage hydroelectric. Energy costs for the islands were consequently calculated to be $0.26/KWh in

2006, with the islands' grid being separated between the north and south islands and completely isolated from the mainland. Fuel for several MWs of diesel generation must be routinely shipped to the islands simply in order to ensure the supply of reliable electricity. The results of Boronoski's (2009) study of the integration of ocean energy into Haida Gwaii's local grids are discussed further in section 2.2.1.

2.1.3: Barriers to Renewable Energy Diffusion

Typically, issues such as cost, generation intermittency, technical reliability, high land use, and lack of viable energy storage systems can inhibit development of renewable energy technologies (Yamba et al., 2011). Furthermore, opposition by some members of society to resource development projects and non-acceptance of "unsightly" technologies such as wind farms indicate that some populations are opposed to having to see their energy devices in operation (Wüstenhagen, Wolsink, & Bürer, 2007). Inhibitors to renewable energy development can often be largely policy influenced with issues such as carbon pricing and subsidies of oil and gas industries, while subsidies of renewables receive far less in most parts of the world (Yamba et al., 2011). In addition, studies have shown that many utility regulatory regimes around micro-grid and community power schemes where a grid-connected community can generate, sell and buy from the larger grid, are restrictive of any such developments (Granger Morgan & Zerriffi, 2002).

From a technical standpoint, intermittency (inability to provide a sustained power supply) affects almost all renewable energy technologies with the potential exception of biomass and geothermal. Wind and solar output are dependent on the wind blowing and sun shining, respectively, representing short time scale intermittency on a daily basis. Meanwhile, run-of-river, or small scale hydrokinetic generation facilities, which normally depend on limited water storage capacity in head ponds (or no head ponds at all) are subject to seasonal and annual fluctuations in hydrological conditions with resulting variable river flows, particularly in drought conditions as seen in BC in the summer of 2015, demonstrating longer time scale intermittency (Jost & Weber, 2012; Yamba et al., 2011). Consequently, hydroelectric RE projects that are not able to make use of large reservoirs may not be able to guarantee the ability to meet base load, which is the minimum level of demand on an electrical supply system over 24 hours (Jager & Bevelhimer, 2007). Thus, renewable energy systems currently need to be operated in concert with reliable generation systems that are able to run nearly constantly or can be dispatched (brought on or off load according to demand), such as coal, nuclear, oil, natural gas, large hydroelectric and geothermal (Yamba et al., 2011).

Another viable set of options being explored is energy storage. Renewable energy systems can incorporate various forms of storage such as batteries, pumped hydro storage, compressed air storage, and synthetic fuel or hydrogen fuel conversion, all in an effort to store their energy if the established grid cannot immediately accommodate it, or there is an excess of energy being generated and it is more economical for the utility provider to store the energy rather than sell it. For example, this trend is often the case when high levels of wind power are being generated, and there is not enough demand for the energy and therefore it must be sold at a negative price simply to dispose of it. Energy storage options all currently face challenges of scale, cost and technical feasibility. New and novel technologies such as the high-efficiency hydrogen electrolization (utilizing electricity to run current through water and produce hydrogen), are potentially groundbreaking, yet are only being achieved at a laboratory scale and likely face a variety of challenges before ever achieving commercialization. While not the focus of this paper, energy storage systems provide very viable means of incorporating more renewable energy into our world's energy systems, storing it when it is not needed, and then using it when it is. The pace of innovation in this sector is rapid as Tesla's home battery system, enabling household level energy generation and storage, and the coupling of a hydrogen production facility with experimental tidal energy arrays at the European Marine Energy Centre (EMEC) have recently been announced (EMEC, 2015; Tesla, 2016). Household level energy storage may be more feasible than large scale energy storage projects as it would avoid massive scale grid batteries or pumped storage facilities.

2.2: Types of Renewable Power Systems

As a general rule, different parts of the world are also better suited to different renewable energy sources due to energy availability and predictability. The equatorial regions for example are known as "sunbelts" holding high levels of normal direct solar radiation and being excellent regions for solar thermal or photovoltaic (PV) installations, especially given that many desert land areas are not used for any other purpose and thus would be ideal for solar energy emplacements. Fault lines in the Earth's crust, or areas of known close proximity of high temperature rock to the Earth's surface are strong potential areas for geothermal power, while temperate regions with mountains and higher levels of precipitation are ideal for hydropower. However, challenges face all of these technologies, particularly in a BC context.

Solar PV, while quickly dropping in price, requires relatively south facing land in BC with unobstructed sunlight in order to generate significant amounts of power. Finding large amounts of this kind of land is difficult in BC's very mountainous geography. In addition, cloudy coastal regions and dark winters can offer little solar power during these times. While rooftop solar developments help a home achieve some degree of self-sufficient generation, substantial amounts of panels and excellent sun exposure and predominantly clear weather conditions are required to power a house in BC year round and make financial sense. As a case study GabEnergy, a community based not-for profit energy company based on Gabriola Island, helped install 9.75 KW (39 x 250W panels) of solar PV panels on a large south facing roof of a community recycling building on Pender Island, located in the southern Gulf Islands of BC. Based on an online solar power prediction system, SolaRating.ca, the system was estimated to generate only 9300 KWh per year, enough to likely power the building say the proprietors ("Pender Island Recycling Depot," n.d.).[2] However based on this amount of energy generated, the system would only be running at a mere 10.8% capacity factor, or full power potential. [3]

In addition, the system cost $20,000 in materials to construct plus an estimated $5,000-10,000 worth of labour, which was provided on a volunteer basis for this project. On a typical commercial or residential solar PV system additional installation, site preparation and labour costs constitute 1.65 to 1.80 times the capital cost of the panels, representing a significant cost increase (IRENA, 2012). With a project lifespan estimated at 25 years, and an assumed total installation cost of $25,000 (only $5,000 for labour on the Pender Island project), an annual operating and maintenance cost of 2.5% of the capital cost of the panels ($500 per year) and a discount rate of 10%, assuming private capital is used, a simple levelized cost of energy calculation yields a unit cost of $0.20/KWh.[4] Included in the cost of capital is the cost of borrowing the capital. Assuming the $25,000 capital cost is acquired by the developer at an annual interest rate of 10% from a commercial bank, and is paid back over a 7 year term, the total cost of borrowing is $9871.76.[5] However, the capital funding for the Pender Island project was largely acquired through grants, thus improving the economic viability of the project somewhat and decreasing the LCOE to $0.161/KWh. [6] Nevertheless, based on BC Hydro's net metering payment rate of $0.10/KWh, this project would very likely lose money. The only

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[2] Recent data on the system's website indicate that generation levels are higher than predicted; this will likely improve the economics of the project.

[3] Solar project capacity 9.75 KW $\times$ 8760 $\frac{hours}{year}$ = 85,410 KWh per year. Expected generation = 9300 KWh per year. Capcacity factor = $\frac{9300\ \text{KWh}}{85410\ KWh}$ = 10.8%

[4] LCOE (with cost of borrowing)= $\frac{capex*opex}{total\ energy\ generated} = \frac{(\$25{,}000+\$9{,}781.76)+(25*\$500)}{9300\ KWh/year\ \times 25\ years}$ = $0.203/KWh

[5] Based on TD bank's online personal loan calculator. Source: https://www.tdcanadatrust.com/loanpaymentcalc.form

[6] LCOE (no cost of borrowing)= $\frac{capex*opex}{total\ energy\ generated} = \frac{(\$25{,}000)+(25*\$500)}{9300\ KWh/year\ \times 25\ years}$ = $0.161/KWh

exception perhaps is if the project generated more energy than planned or if maintenance costs were much lower than expected.

Geothermal power has the advantage of generating heat and therefore power consistently with no interruptions or "dark periods" (except for equipment maintenance windows) because the Earth's core is constantly radiating heat energy, right through to very near the Earth's surface in some cases. The challenge with geothermal, however, is finding these places with sufficient heat, rock porosity and proximity to the surface. Therefore, geothermal can have very high upfront exploratory drilling costs with no guarantee of finding a suitable site. For example, a recent project at Meagre Creek, BC was abandoned after spending $30 million to drill several wells, only to determine that the sites were not commercially viable (Bennett, 2014). Geothermal developers are based in BC but conduct their business internationally as the technology is generally deemed unable compete with heavy hydroelectric on an economic basis as BC Hydro's planned Site C dam is reported to have a 100 year lifespan and a levelized cost of only $0.08/KWh (BC Hydro, 2013b; Bennett, 2014). However, aside from the very high exploratory costs, if a suitable geothermal site is found, its very high capacity factor and low operation and maintenance costs dictate that a project would likely have low levelized costs and be able to provide consistent, perhaps even baseload power.

Hydropower in BC now also faces its own challenges. Aging existing dams and infrastructure are facing expensive upgrade costs, while increasing demand for electricity is necessitating numerous new generation and transmission projects. These costs are not small, as evidenced by BC Hydro's ongoing $17 billion, 10 year capital infrastructure upgrade program (BC Hydro, 2015). Ongoing rate increase programs to finance these upgrades in BC are not small either amounting to a 28% rate hike over 5 years from 2014-2019, with further, smaller rate increase options thereafter (BC Hydro, 2013a). By the end of the 5 year rate increase in 2019, a consumer will be expected to pay on average $0.114/KWh in BC, a comparable rate to most major North American cities (Hydro-Québec, 2014).[7] Hydro dams also accumulate large amounts of silt from erosion causing reduced reservoir storage capacity, and are experiencing reduced summer water inflows due to loss of snow and glacial melt stemming from global warming (discussed further in section 1.2).

[7] Based on a 1,000 KWh monthly energy consumption rate.

2.2.1: Non-Tidal Ocean Energy Potential

The ocean covers 71% of the Earth's surface and has a tremendous energy potential. As well, most of the world's population lives close to the ocean. Some 41% of the global population is located within 100km of the coast; more than 50% of coastal countries have 80-100% of their population within 100km of the ocean and 21 of the world's 33 megacities living are located within the same area (Martínez et al., 2007). Ocean energy technologies encompass a wide variety of systems from waves, ocean thermal energy conversion (OTEC), salinity gradients, deep ocean currents, coastal currents and in-stream tidal energy (ISTE). Tidal energy in itself can take several forms from impounding water through use of barrages such as are seen in Annapolis, Nova Scotia, Canada and La Rance, France, or lagoons such as are being constructed now in the UK. Total global ocean energy potential far exceeds total current and future human energy consumption; estimates range from 7 to 7400 exajoules (EJ, $1x10^{18}$ J) per year for all sources of ocean energy combined and clearly represent a large resource (A. Lewis et al., 2011).

Accessibility of this energy, however, presents a substantial barrier to its use. For example, while the heat capacity of sea water is large and thus the theoretical heat energy available in the ocean, accessible by OTEC, should be immense, it is of low quality due to the heat and energy exchange parameters defined by the laws of thermodynamics. These laws, particularly the Carnot theorem, render most OTEC plants' efficiencies in the order of roughly 3-4%, at most, rendering most plants inefficient and therefore uneconomical (Tester, Jefferson W., Drake, Elisabeth M., and Driscoll, 2012). Salinity gradient technology, harnessing the energy potential of different salinity levels (generally at locations where fresh water and salt water mix, such as at river deltas) has but a few prototype designs with capacities of less than 50kw. The most recent project, a 50 KW plant, began construction in 2013 and utilizes the technology of reverse electro-dialysis (RED). Salinity technologies are typically constrained by expensive membrane materials and high levelized costs as well as unknown environmental impacts (Kempener, R. and Neumann, F., 2013). Deep-ocean and coastal current technologies, including massive schemes at harnessing such continuous currents such as the Gulf Stream are similarly merely conceptual at present, but offer tremendous energy sources. Project Coriolis, designed to the capture the continual flow of the Gulf Stream current off of the Florida coastline envisioned very large scale, neutrally buoyant, deep water turbines producing up to 4,000 MW of power (Charlier & Justus, 1993). While many of these style of projects were conceptualized, up until present they were shelved due to high costs and more economical energy alternatives onshore.

However, with the appeal of renewable energy increasing, it may only be a matter of time until these project files are reconsidered. Already, research at Florida Atlantic University and the Southeast National Marine Renewable Energy Center is exploring the large amounts of energy in the Gulf Stream current, with energy flux estimates for Florida alone being 10 GW (Driscoll, Skemp, Alsenas, Coley, & Leland, 2008). Greater understanding of deep water oceanographic trends such as the Gulf Stream as well as internal gravity waves are also adding to our understanding of ocean energy possibilities. Internal gravity waves are very long period (in the order of hours rather than seconds), high amplitude (hundreds rather than several metres) waves which travel deep beneath the ocean surface and are now beginning to be understood as significant drivers in ocean processes and energy transfer (Alford et al., 2015). However, when considering ocean energy technologies, really only tidal and wave are achieving significant levels of development.

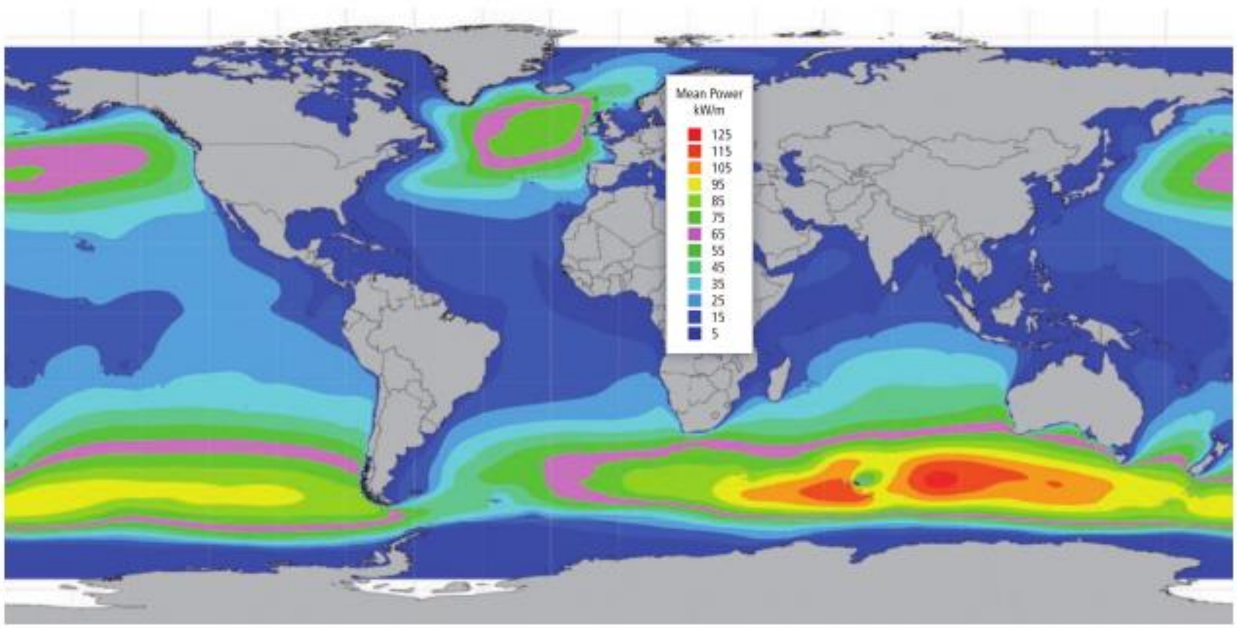

Figure 6.1 | Global offshore annual wave power level distribution (Cornett, 2008).

Figure 2-3: Global mean wave energy density in KW/m. Reprinted with permission from the Intergovernmental Panel on Climate Change (IPCC) source: (A. Lewis et al., 2011)

In general, wave power has a theoretical annual energy output of 29,500 TWh with the bulk of the energy in the high northern and low southern latitudes where wave energy density is higher, on the order of 30 kilowatts per metre section of wave (KW/m) on average (Lewis et al., 2011; see fig. 2-3). To date, wave energy development has lagged behind tidal energy; while its theoretical potential is massive, technical reliability and low survivability of physical infrastructure have been major issues with wave energy levels reaching upwards of 200 KW/m during storms (Tester, Jefferson W., Drake, Elisabeth M., and Driscoll, 2012). Extreme wave heights can damage wave energy devices; coupled with this, periods of low wave height offer little energy conversion, meaning the technology is currently both unpredictable and potentially unreliable, posing challenges to its diffusion. Innovation continues to forge ahead, however, with recent project successes being achieved through research on deeper water wave energy capture. That research is being conducted off the shores of Perth, Australia by Carnegie Wave Energy (Carnegie) in collaboration with a Royal Australian Navy (RAN) desalinization plant (see fig. 2-4). The design concept of Carnegie is to locate the floats, which move vertically with wave action, at depths or 1-2m below the surface (Carnegie Wave Energy, 2015). Circular wave particle motion decreases with depth from the surface, hence reducing the available energy. However, large enough submerged floats, as used in the Carnegie project, can still harness the vertical component of the wave particle motion to produce economical amounts of energy, while remaining clear of the largest breaking waves at the surface. As the float travels up and down with the wave motion, they pull on their tether to a pump on the sea floor (or on the tether in the later design), whereby they either produce high pressure seawater which travels ashore to a generator station or reverse osmosis freshwater plant, or drive a generator on the seafloor itself and transmit electrical power ashore (Carnegie Wave Energy, 2015). The adaptability of these systems to either pump high pressure seawater ashore to make fresh water, or to generate electricity makes them ideal for tropical regions throughout the world.

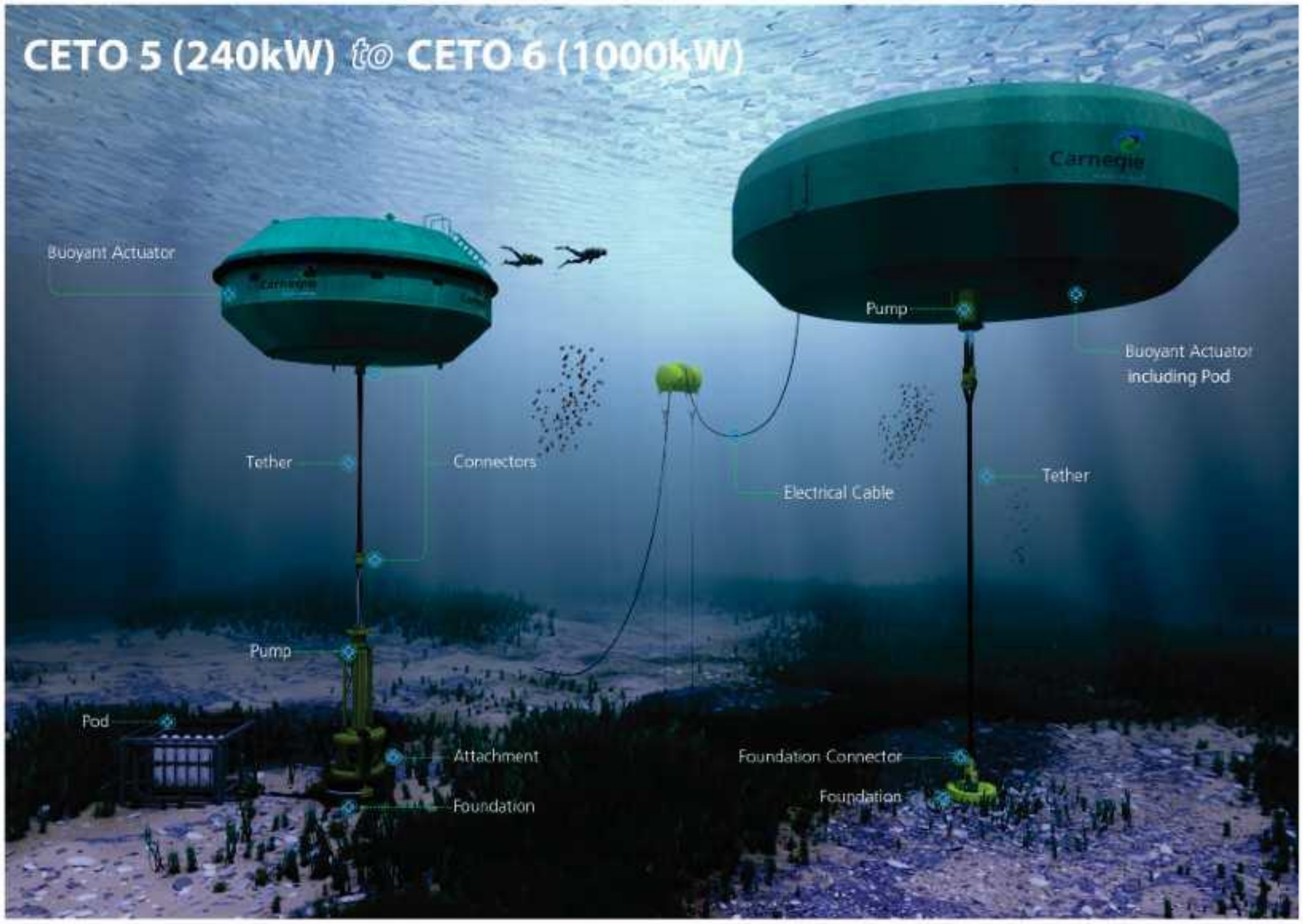

Figure 2-4: Designs for Carnegie Wave Energy deep water wave energy converters. Reprinted with permission from "Renew economy" source: http://reneweconomy.com.au/2014/carnegie-signs-wave-energy-research-deal-european-firms-96391

2.2.2: Tidal Energy Technologies

Tidal energy is leading the development of ocean energy systems. Amongst the technologies, tidal barrage stations, which harness the vertical rise and fall of the tides and the associated accumulation of gravitational potential energy behind dams, which extend across tidal estuaries, have been in operation longest. La Rance barrage in northwest France was commissioned in 1966 while the South Korean Sihwa plant, commissioned in 2011, has a generation capacity of 254 MW with further plans to expand to 2680 MW (Magagna & Uihlein, 2015). Barrages face environmental challenges, however, as they block a tidal estuary completely and change the estuary's marine ecology; in addition, similar to dams, barrages have siltation problems with constant flooding and draining of the estuary and need to be regularly stopped for maintenance.

Tidal lagoons are new, modernized versions of barrages which result in fewer adverse environmental effects and are quickly nearing commercialization. Tidal lagoons do not block off an estuary and instead create a man-made lagoon, often tens of square kilometres in size, and are situated in areas with high vertical tidal ranges (vertical height difference between high tide and low tide). The lagoons have a series of gates with turbines installed in them and harness the energy created through the water height differential between the inside and outside of the lagoon. The lagoon which is nearest to commercialization is called Swansea in England at 240 MW capacity (see figure 2-5).

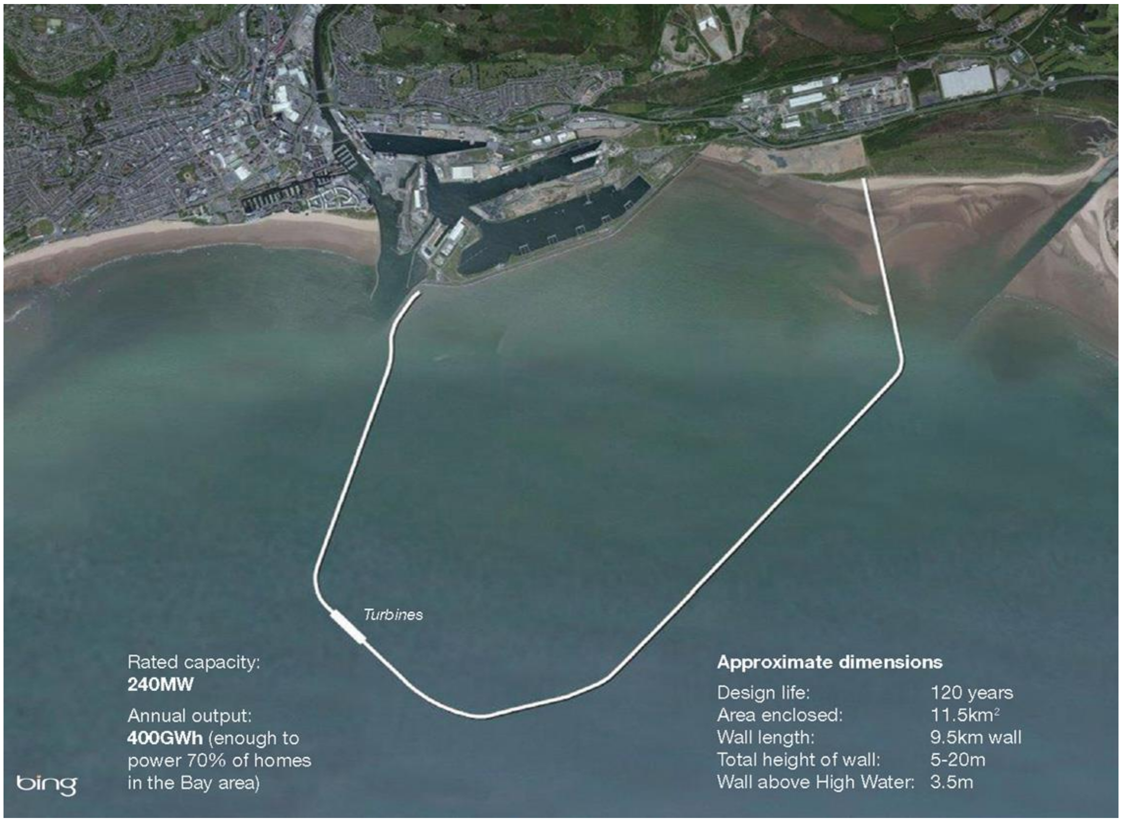

Figure 2-5: Swansea Tidal lagoon, Swansea, England. Reprinted with permission from "Carbon Brief" Source: http://www.carbonbrief.org/blog/2014/02/tidal-lagoons-a-guide-for-the-confused/

Lagoons also have advantages over barrages in that they are less expensive and are more accessible for recreation as the lagoon offers a natural harbour, and sheltered water for boating. The general premise of operation for tidal lagoons is to hold the turbine gates shut until maximum tidal height or head height between the inside and outside of the lagoon is achieved. Then, the gates are opened, releasing water and generating power until the lagoon is either filled or emptied and equilibrium is achieved between in the inside and outside of the lagoon. At this point, the gates are shut and potential is recreated by the falling or rising tide outside the lagoon (see fig. 2-6).

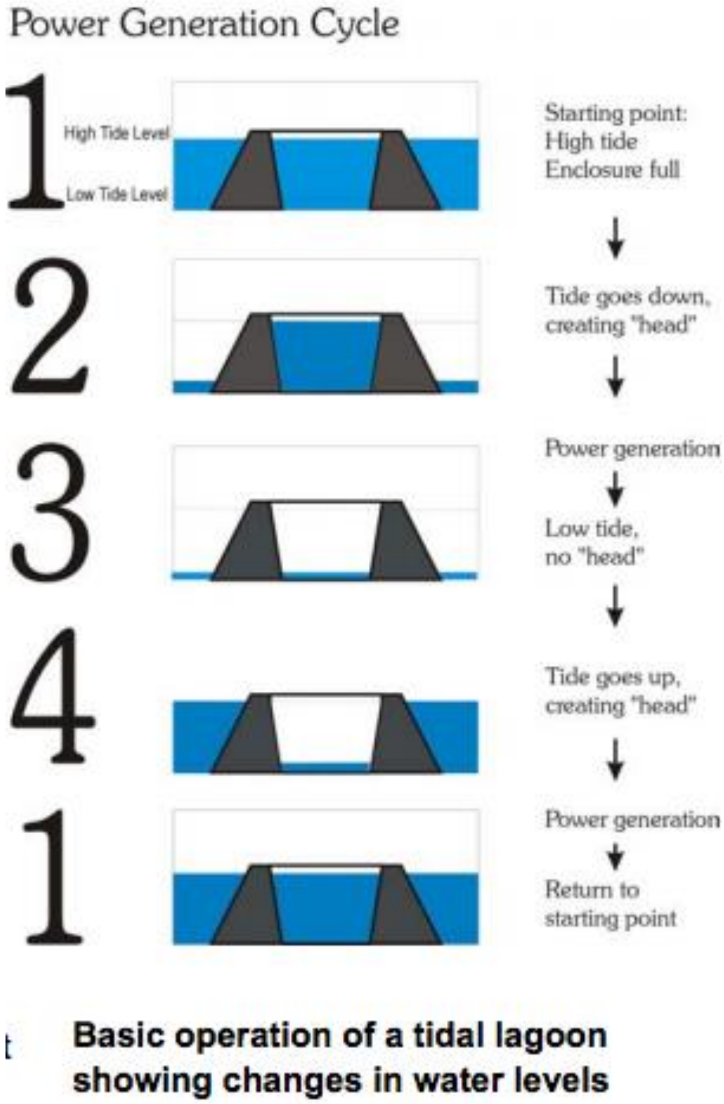

Figure 2-6: Tidal lagoon operating principles. Reprinted with permission from "Carbon Brief" source: http://www.carbonbrief.org/blog/2014/02/tidal-lagoons-a-guide-for-the-confused/

Other non-lagoon tidal energy systems are designed to harness the kinetic energy of tidal waters rushing along coastlines and through narrow channels. The technology is known broadly as hydrokinetic as it can also be employed in rivers, or more specifically in-stream tidal energy (ISTE) or simply tidal energy conversion (TEC). TECs, unlike barrages or lagoons have no storage potential and generate power solely from the moving tide. TEC installation is continuing to progress slowly around the UK and now France. Prototype testing of 0.1-2.2 MW tidal generators has been taking place since 2002 when Norway installed the first device and has since centered at the European Marine Energy Centre (EMEC) in the Orkney Islands, Scotland. The first commercial scale turbine, Seagen was installed in Northern Ireland in 2008 (see. Fig. 2-7) and has been in operation since. The large, horizontal axis, twin rotor, piling mounted turbine is rated for 1.2 MW. The company website states that the turbine is capable of generating 6,000 MWh per year given the flow characteristics at the site and the turbines' generating parameters. This would equate 32,000 MWh over a 7 year period from the August 2008 commissioning date to August 2015, yet it has only generated 9,000 MWh of energy over this period ("Performance | Marine Current Turbines," n.d.). If the turbine were functioning optimally, generating 6,000 MWh per year, it would be achieving an impressive 43% capacity factor given its rated capacity over this timeframe; however, at its current rate of generation it is achieving only 28% of this supposed potential generation.[8] The turbine was only intended as a prototype demonstration project with a 5 year lifespan and has been regarded by many in the industry to have exceeded expectations by providing the industry with many learning points. Industry sources indicate that many of these improvements have already been undertaken are implemented in Marine Current Turbines' most recent Seagen "U" turbine designs.

Figure 2-7: Seagen "S", 1.2 MW turbine in generation mode. The turbines are positioned below the water but can be raised above it for maintenance. The piling structure is "pinned" into the seafloor. The structure also has an active sonar type marine animal avoidance device which will stop the turbine blades if a signal return is detected with a certain proximity to the device. Reprinted with permission of Atlantic Resources Limited, source: www.marineturbines.com.

[8] Capacity factor = $\frac{actual\ energy\ generated}{total\ possible\ energy\ generation} = \frac{9{,}000\ MWh}{6{,}000\ MWh \times 7 years} = \frac{9000MWh}{32{,}000MWh}$ = 0.28

According to recent state of the industry reports, the technology is slated to move from prototype, single turbine emplacements to array scale installations expanding into the production of tens to hundreds of MWs, with smaller scale projects set for installation by the end of 2016 (Magagna & Uihlein, 2015) (see table 2-1). Cape Sharp Tidal (a partnership between Openhydro and Nova Scotia's utility provider, Emera) expect to have their two device array installed in 2016 at FORCE. The turbines will each be 2 MW rated capacity and will weigh 1000 tons each. Meygen is the largest funded project with eventual plans for 398 MW worth of tidal energy turbines (roughly 275 turbines) to be installed in Pentland Firth, Scotland by the early 2020s. Initial turbine installs are slated for 2016.

Table 9: Leased tidal energy projects in Europe

Name	Capacity (MW)	Status	Project Developer
Bluemull Sound	0.5	In planning	Nova Innovation Ltd
Brough Ness	100	In planning	Sea Generation (Brough Ness) Ltd
Cantick Head	200	In planning	Cantick Head Tidal Development Ltd
Esk Estuary	0.6	In planning	GlaxoSmithKline Montrose plc
Inner Sound (MeyGen)	392	In planning	MeyGen Ltd
Isle of Islay	30	In planning	DP Marine Energy Ltd
Kyle Rhea	8	In planning	Sea Generation (Kyle Rhea) Limited
Mull of Kintyre	3	In planning	Argyll Tidal Ltd
Ness of Duncansby	100	In planning	ScottishPower Renewables UK Ltd
Sanda Sound	0.035	In planning	Oceanflow Development Ltd
Sound of Islay	10	In planning	ScottishPower Renewables UK Ltd
St David's Head	10	In planning	Tidal Energy Developments South Ltd
Westray South	200	In planning	Westray South Tidal Development Ltd
Afsluitdijk	3	In development	Tocardo, Tidal Test Centre
Fair Head	100	In development	DP Marine Energy & DEME Blue Energy
Lashy Sound	30	In development	Scotrenewables Tidal Power
Nepthyd	5.6	In development	Alstom/GDF Suez
Normandie Hydro	14	In development	OpenHydro/DCNS/EDF/ADEME
Perpetuus Tidal Energy Centre	20	In development	Isle of Wight Council
Ramsey Sound	1.2	In development	Tidal Energy Limited
Fromveur	1	In development	Sabella/IFREMER/Veolia Environnement/Bureau Véritas
Norway	2	In development	Flumill
Raz Blanchard	12	In development	GDF Suez/Voith Hydro/CMN/Cofely Endel/ACE
Inner Sound (Meygen)	6	In construction	MeyGen Ltd
Strangford Lough (Minesto 2)	0.003	In construction	Minesto AB
EMEC Shapinsay Sound	n.a.	Nursery facilities	European Marine Energy Centre Ltd
Lynmouth	1.6	Interrupted	Pulse Tidal Ltd
Skerries, Anglesey	10	Interrupted	Sea Generation Ltd
EMEC Fall of Warness	10	Operational	European Marine Energy Centre Ltd
Ness of Cullivoe	0.03	Operational	Nova Innovation Ltd
Strangford Lough (Minesto 1)	0.003	Operational	Minesto AB
Strangford Lough (SeaGen)	1.2	Operational	Sea Generation Ltd

Sources: The Crown Estate 2014; France Energies Marines 2014

Projects expected to become operational by the end of 2016 · Projects of uncertain status · Interrupted projects

Table 2-1: Leased tidal energy projects in Europe to 2014. Reprinted with permission of Joint Research Centre, source: (Magagna & Uihlein, 2015).

In Canada, the province of Nova Scotia introduced FITs for tidal energy at both commercial and community grid scales and has a concerted ocean energy strategy in place and bound by law (Nova Scotia Department of Energy, 2012). In 2013 the Province announced both community and commercial feed-in tariffs (COMFITS and FITS respectively), guaranteeing the rate at which the utility provider will purchase power from the tidal energy developer. The FIT was simply for tidal energy while the COMFIT was for a variety of renewable energy projects including tidal. The COMFIT for Nova Scotia was $0.652/KWh and the FIT is $0.532/KWh (this rate is variable dependent on the development path taken by the developer); these rates were specifically designed to facilitate industry growth in accordance with the province's aim of having its energy grid 50% reliant on renewable energy sources by 2020 (Nova Scotia Department of Energy, 2012). Recently, however, Nova Scotia announced the closure of the COMFIT program to new applicants as the program had been deemed to have achieved its goals. The program facilitated development of 125 MW of community-owned, distributed power generation (80 MW already installed,125 MW installed by the end of 2015) at a cost to Nova Scotians of only $35 million, or $2.6 million per megawatt of installed capacity (Nova Scotia Ministry of Energy, 2015). The province's Ministry of Energy further stated that no new energy generation was needed in the province and that further development would negatively impact electricity rates in the province.

Meanwhile, in British Columbia (BC) there are no currently no TEC devices in the water and there is no subsidy for tidal or wave energy development, even though resource assessments pin BC's tidal energy potential alone at 4,015 MW compared to Nova Scotia's broad estimate of 2,400 MW of "safely extractable energy" (Nova Scotia Department of Energy, 2012; Tarbotton & Larson, 2006). In addition, a memorandum of understanding (MOU) exists between the Nova Scotia and British Columbia governments for sharing tidal and ocean energy technologies and information, signed in 2012 and renewed in 2014.

2.2.3: Tidal Energy Technical Theory in a British Columbia Context

Tides are controlled by the moon's and sun's gravitational fields, along with the Earth's rotationally induced Coriolis effect, which all act on the Earth's oceans to pull them in various cyclical waves about the planet (Thomson, 1981). Generally, the moon's and sun's gravities either work in-line with one another (times of full moon or new moon), or at angles to one another (occurring at times of three quarter, or quarter moons). Full moon and new moon periods induce spring tides which are stronger (greater vertical range between high and low tides) than neap tides. Neap rides occur when the moon's and sun's gravities are working at near perpendicular angles to one another (see fig.2-8).

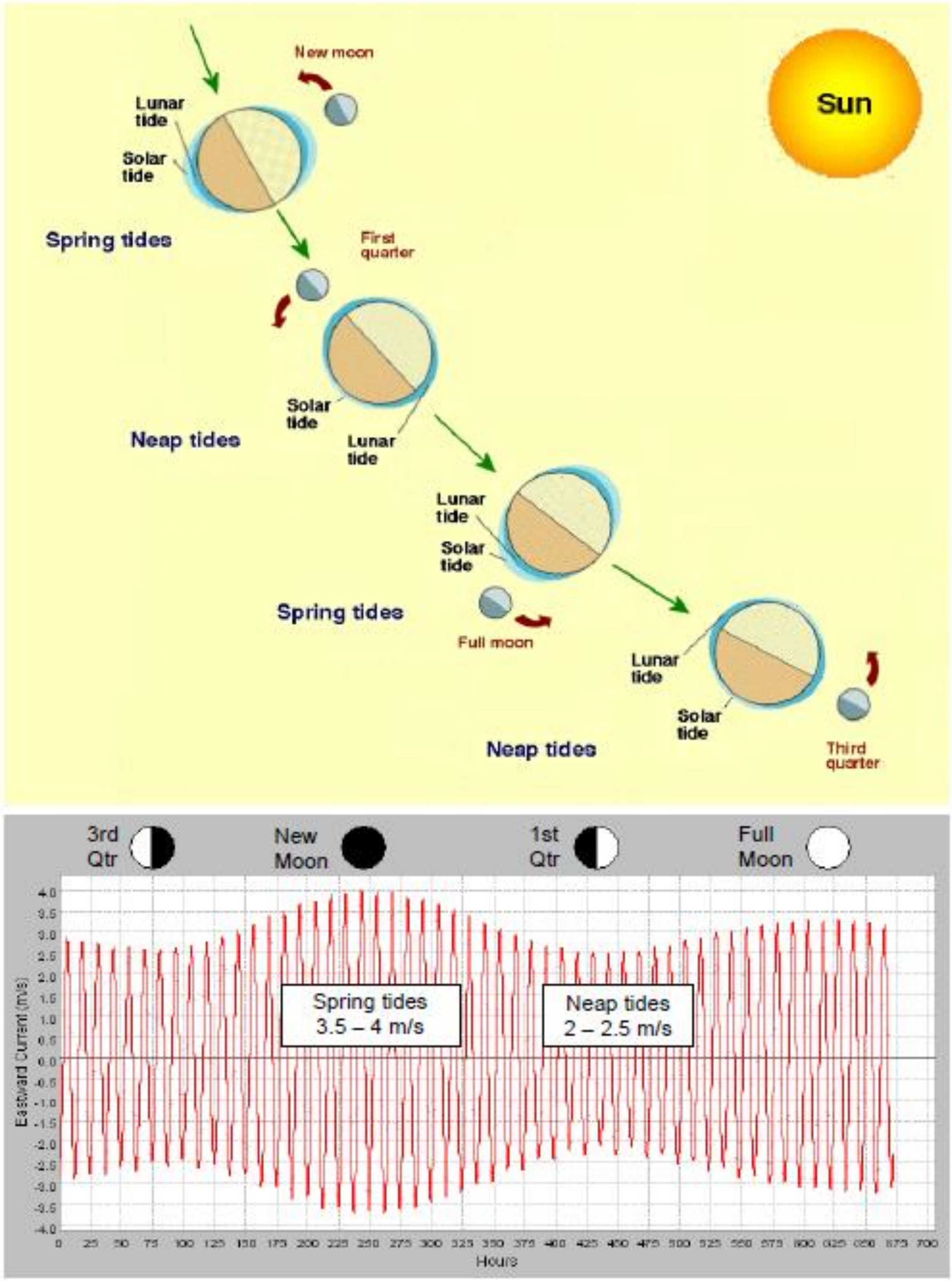

Figure 2-8: Influence of the moon's and sun's gravitational forces on the Earth's tidal cycles at various moon phases of orbit. Included are tidal flow velocities at Cape Sharp, Minas Passage in Nova Scotia Canada, showing higher tidal flows at spring tides compared to neap tides. Reprinted with permission of EPRI, source: (Hagerman & Polagye, 2006).

There are numerous complex influencing factors, each stemming from a specific combination of gravitational forces or orbital cycles from either the sun or the moon or both. These constituents combine and interact with one another in order to produce the resultant tides. Due to these gravitational forces, there exist areas on the planet with little or no tidal activity; these areas are known as amphidromic points or tidal nodes and are areas of almost zero tidal fluctuation on the ocean surface. Tidal waves (not to be confused with seismically induced tidal waves) orbit (i.e. rotate) around these points like spokes on a wheel (Thomson, 1981). The north Pacific amphidromic exists just north of Hawaii. Tidal waves extend laterally outwards from this point and rotate counter-clockwise at a rate of 29 degrees per hour, similar to a wheel, meaning that the tide essentially moves northwards along the coast of North America at a speed of roughly 750km/h from the coast of Baja California up to Alaska and out the Aleutian Islands chain (Thomson, 1981). See Fig. 2-9 for more explanation including the location and direction of rotation of all other amphidromic points in the world.

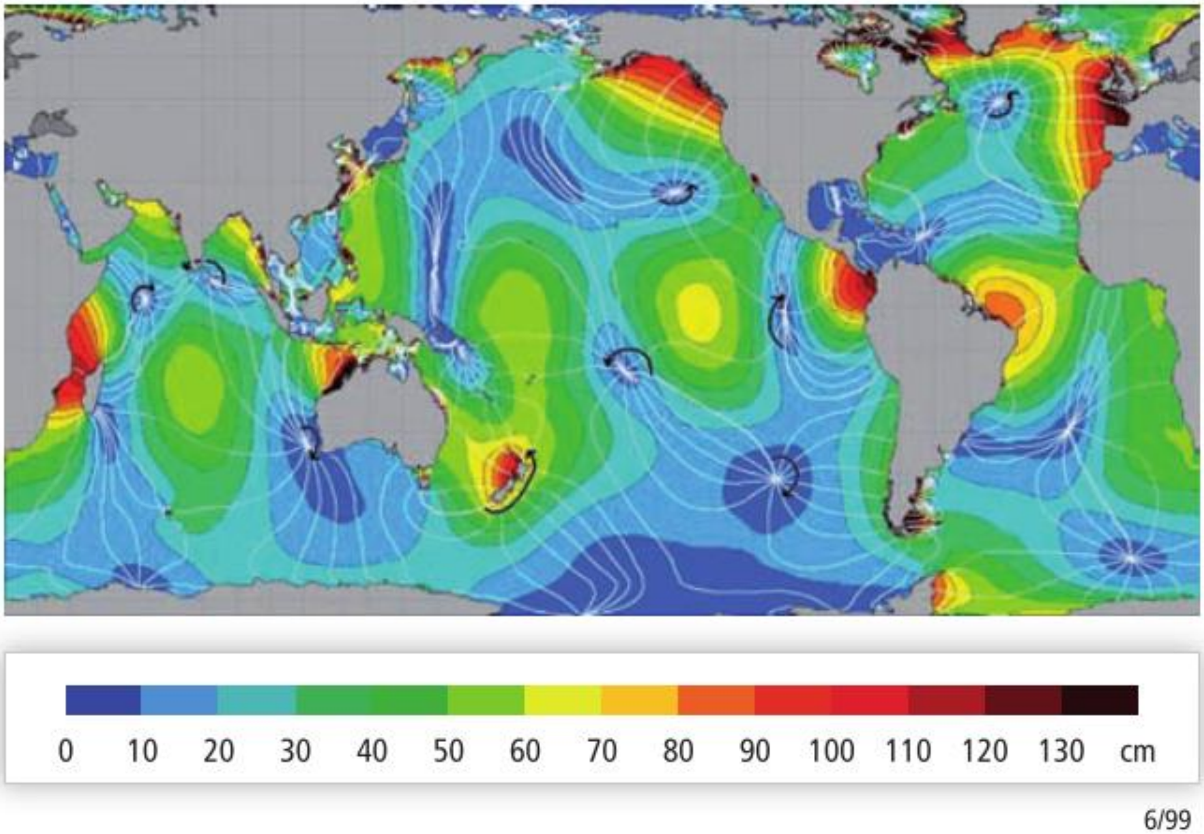

Figure 6.2 | World map of M2 tidal amplitude (NASA, 2006).

Notes: M2 is the largest (semidiurnal) tidal constituent, whose amplitude is about 60% of the total tidal range. The white lines are cotidal lines—where tides are at the same point of rising or falling, spaced at phase intervals of 30° (a bit over 1 hr). The amphidromic points are the dark blue areas where the cotidal lines meet. Tides rotate about these points where little or no tidal rise and fall occurs but where there can be strong tidal currents.

Figure 2-9: A map showing one tidal constituent, M2 deriving from the gravitational pull of the moon. Note the arrows indicating the direction of rotation of the cotidal lines around the amphidromic points. Reprinted with permission from NASA, 2006, source: http://svs.gsfc.nasa.gov/stories/topex/

As these tidal waves reach shallower areas of the ocean such as the continental shelves and eventually shorelines, they encounter friction and move as dictated by ocean bottom topography with portions of the tidal energy being reflected off of the upslope of continental shelves back into the deep ocean. In Thomson's *Oceanography of British Columbia* (1981), the author describes how tidal currents in BC function in the face of coastal topographical restrictions such as narrow channels. The tidal wave coming from open-ocean travels swiftly up the North

American coast towards Alaska; as it reaches the Straits of Juan de Fuca it bends around Cape Flattery at the northwest tip of Washington State and travels down the Juan de Fuca Straits, generally taking 2-4 hours to reach the southern extent of the Gulf Islands. On the north side of Vancouver Island the wave bends southwards, travels through Johnstone Straits and down towards the Strait of Georgia; this wave travels quicker, however, taking about 2 hours to reach Campbell River which is where the two opposing tides meet and where Georgia Strait begins (fig. 2-10). This time series progression of the tidal wave is important to note as a theoretical potential exists to achieve phased generation as tidal current velocities peak at various points along the coast at sequential times over the 2-4 hour period which the tide takes to move along the coasts (Bryans, n.d.; Clarke, Connor, Grant, & Johnstone, 2006; Neill, Litt, Couch, & Davies, 2009). Phased generation basically means having various generating stations spaced geographically apart along the path of the incoming tidal wave, thus allowing for longer periods of peak power generation and less time of zero generation, which occurs once an incoming tidal wave has passed, and slack water is experienced.

Figure 2-10: Vancouver Island. Juan de Fuca Straits are at the bottom of Vancouver Island. Campbell River and Cape Mudge, where the two opposing tides meet, are indicated by the arrow. Reprinted with permission of Open street map, source: www.openstreetmap.org

As the wave flows around bends in channels and is forced into narrower and shallower areas, it is forced upwards and "stacks up"-especially at the entrance to tidal narrows, many of which are found along the coast of BC. This accumulated head height, along with the remaining momentum of the wave, forms the kinetic energy which resides in tidal rapids. In these cases, the "slope" of the water from one end of a stretch of tidal rapids to the other can actually be physically seen, in places such as Skookumchuck Narrows near Egmont, BC, where tidal velocities can reach 15 knots on a spring tide. Even though the bottom topography of the channel may not be sloped like a river, the water builds up and rushes through it, very similar to a river, complete with back eddies, upwellings, turbulence and main channel flows.

Tidal streams, also carry a good deal of momentum and keep moving even after the hydraulic head height has dropped to zero. Friction due to the bottom topography of a channel reduces flow to zero immediately next to the solid surface, and as a result tidal stream velocities diminish towards channel edges and near the bottom. Also, the Coriolis force pulls tidal streams to the right from their direction of travel, although this mostly only happens in larger, more open channels. Residual momentum of the tidal stream at the end of its cycle often carries onwards and flows (either left or right, or at different depths) around the next incoming tide, thus sometimes producing different, opposing water flows in a single channel around the time of tide change which can last several hours. These opposing bodies of water can be stratified either by depth or left/right separation-or both, often creating a complex mixing effect (Thomson, 1981).

Harnessing the kinetic energy in those tidal flows is possible through a variety of surfaced and underwater hydrokinetic turbine designs. Energy production does depend on the cyclic flow of water and so is not dispatchable in the same way that large hydro plants or coal plants are. However, those cycles are predictable and thus tidal energy does not have the same issues that wind or solar have in terms of prediction of energy output. Some examples of hydrokinetic turbine designs are shown below (fig. 2-11, 2-12).

Figure 2-11: Mavi Innovations Mi1 22KW floating style turbine. Reprinted with permission from Mavi Innovations Inc., source: http://mavi-innovations.ca/technology/

Figure 2-12: Race Rocks Clean Current experimental, horizontal axis turbine near Victoria, British Columbia. Reprinted with permission from Race Rocks Tidal energy project, source: http://www.racerocks.ca/energy/

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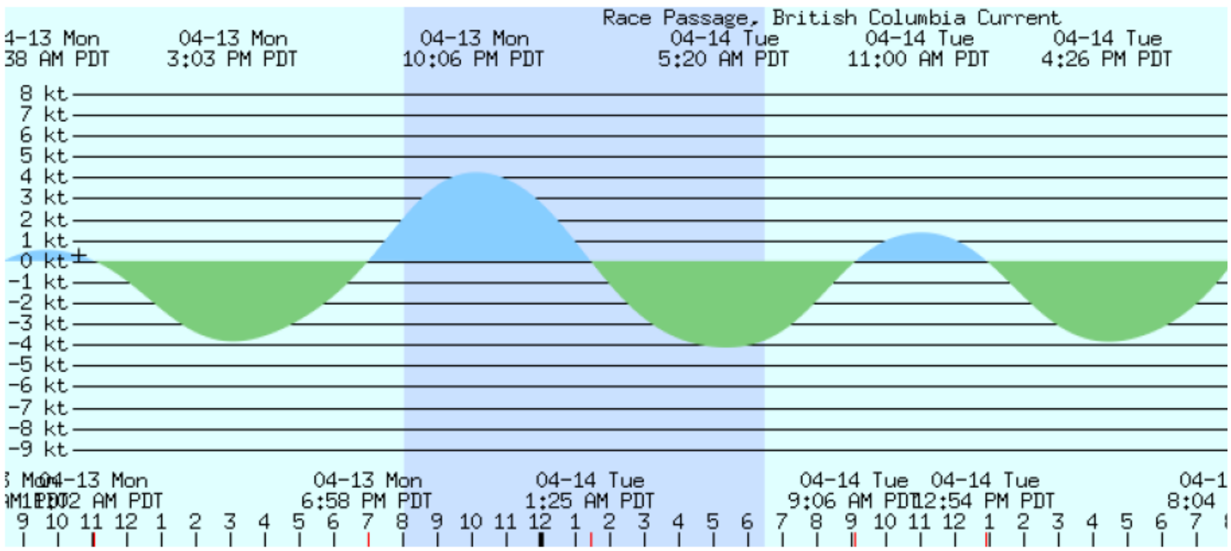

Figure 2-13: Tidal Current graph at Race Rocks, BC. Reprinted with the permission of Jeff Dairiki, source: http://www.dairiki.org/tides/daily.php/rac

Figure 2-13 shows tidal current velocities at Race Rocks, BC over several days; 1 knot (kt.) is equal to roughly 0.5 m/s velocity. Capacity factor, or the amount of time which a TEC generates power in relation to its rated capacity corresponds directly to its generating parameters in relation to the tidal current flows within the channel. Generally, capacity factors of 35-40% are common today while factors as high as 50% are theoretically achievable in the future (Magagna & Uihlein, 2015). Figures 2-14 and 2-15 are from Lewis et al.'s (2015) work on examining tidal currents in relation to generator output on the Marine Current Turbine's Seagen device which has a rated power of 1.2 MW at 2.68 m/s of tidal flow. Essentially, the generator can be seen to cut-in or start generating at 1 m/s and increase its power output exponentially until it reaches its rated capacity of 1.2 MW at a current velocity of 2.68 m/s or about 5.4 knots. The tidal current velocity is exponentially related to the kinetic energy available as explained in the equation below, where power output, in watts is equal to the product of a particular cross sectional water flow area, A in m^2, times the water density, σ, reckoned in kg/m^3, and v^3, the cube of the instantaneous velocity of the current (averaged over the course of a year and usually over the depth of a channel) (Hagerman & Polagye, 2006):

$$Power\ output = \frac{1}{2}\sigma A v^3 \tag{2.1}$$

In a channel, tides will flood, or rise, in one direction in a channel and then fall, or ebb, in the opposite. Figure 2-15 also shows the slight difference in power output from an ebb tide to a flood tide. Lewis et al. (2015) find the flows in this particular channel are not rectilinear, or coming from exactly opposite directions, thus producing slightly varying power outputs from the Seagen device (described earlier), which is fixed in position and cannot yaw to face changes in tidal current direction.

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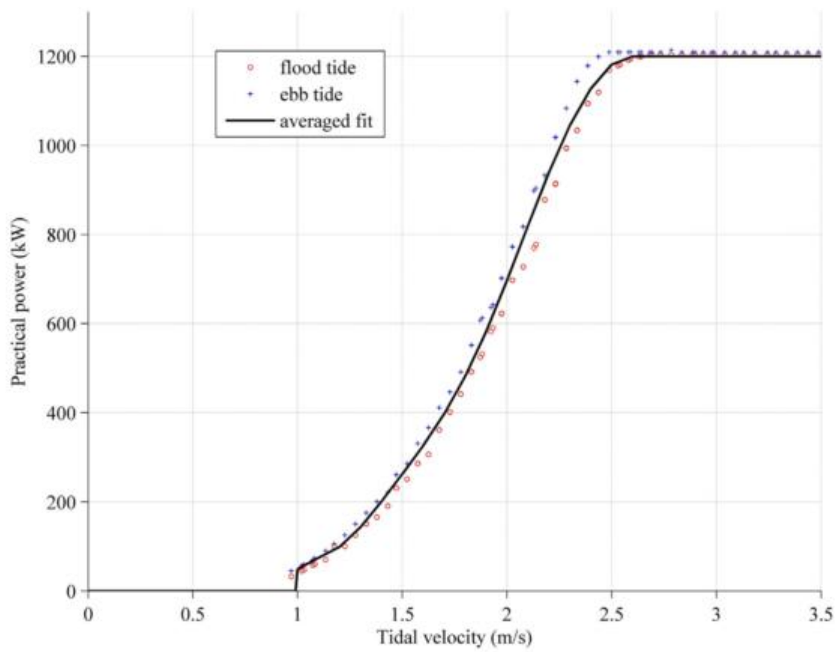

Fig. 4. The measured power curve of the 16 m diameter, twin drive train 1200 kW rated (at 2.68 m/s) Seagen-S tidal-stream turbine (available here www.marineturbines.com) – with our flood-ebb averaged power curve shown as a black line (averaged fit).

Figure 2-14: Power tidal velocity curve for both ebb and flood tides and an averaged best fit line for a 16m diameter, twin drive Seagen turbine located in Strangford Lough, Northern Ireland. Reprinted with permission under a Creative Commons CC-CY-NC-ND license, original source: (M. Lewis, Neill, Robins, & Hashemi, 2015).

Figure 2-15 shows the amount of tidal energy over a 14 day spring–neap tidal cycle. It takes roughly 14 days to go from a spring tide to a neap tide, and then another roughly 14 days to go back to a spring tide again (Hagerman & Polagye, 2006). Thus, an entire lunar month of about 29.5 days will have 2 spring-neap cycles. In the figure below, the tidal velocity, kinetic energy, energy density and power output of the turbine can be seen to drop off in the neap period of the cycle and then return again at the spring tide.

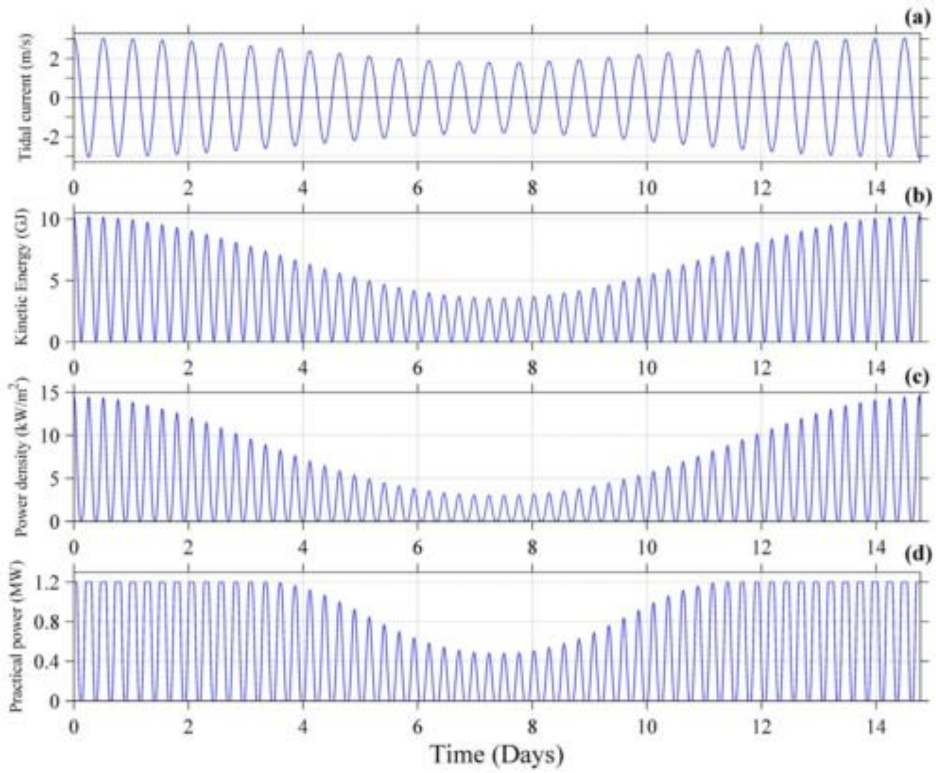

Fig. 3. Estimated tidal-stream energy available using three methods applied to the velocity time-series of a pure spring-neap tidal cycle (panel a) at 53.305 °N, 4.721 °W (see + in Fig. 3); power density (b), the instantaneous kinetic energy available (c), and (d) the practical power available using the 1200 kW Seagen-S power curve (see Fig. 4).

Fig. 2-15: Tidal energy and power output, again from the 1.2 MW Seagen tidal turbine over a 14 day pure spring-neap tidal cycle. The cycle starts at the spring tide, moves to a neap tide in 7 days and then returns to a spring tide 7 says later. As a note, most tidal cycles are not this apparent and can have more mixed results. Reprinted under permission of a creative commons CC-CY-NC-ND license, original source: (M. Lewis et al., 2015).

It can thus be seen from these data that the Seagen device achieves full power roughly 8 out of the 14 days within the cycle. Each day however will generally have 1-2 high tide to low tide cycles, depending on the location in the world. These daily cycles are known as diurnal (1 high-low cycle), semi-diurnal (2 high-low cycles), or mixed semi-diurnal (a combination of the two). The complex interactions of the tidal constituents produce these cycles which are predictable years in advance and perfectly repeat themselves every 18.6 years (Hagerman & Polagye, 2006).[9]

2.2.4: Tidal Energy Resource Assessment and Large Scale Energy Extraction

Kinetic flux tidal energy estimates (equation 2.1) are based on the theoretical tidal energy that would be available if the full tidal force passing through a channel as a whole were to be exploited by fencing off the whole channel with tidal turbines. Any proposals to install tidal

[9] This 18.6 year repeatable cycle is due to the maxima and minima of the lunar declination, as seen from the Earth, which is a result of the tilt of the moon's orbit in relation to the Earth and the tilt of the Earth on its axis (Hagerman & Polagye, 2006).

devices that seek to harness the full generating potential of the tidal flow through a channel would also severely restrict passage of human traffic as well as biological organisms through that channel and would therefore not be feasible from an environmental sustainability perspective. In addition, as hydro kinetic turbines harness and extract kinetic energy from a tidal stream they exert friction on that stream, thereby slowing it down and creating an increased water head height at the entrance to the channel. Mathematical modelling in this regard continues to evolve, but is still limited in its ability to effectively estimate the theoretical maximum amount of extractable energy from a tidal stream, and still maintain sufficient flow velocities to sustain ecosystems (Isaacman, Daborn, & Redden, 2012).

More recent research highlights the increased energy potential of a tidal system at the Bay of Fundy, based on the volumetric flow rate of the tide (as opposed to the mean depth averaged velocity considered earlier) and the gravitational energy accumulated by the incoming tidal wave, as it rises up in response to shallowing bottom topography and narrowing channel constraints (Karsten et al., 2011). Based on modelling, the report suggests that some 2000 MW of tidal energy could be sustainably extracted from Minas Passage, which is a part of the Bay Fundy that is especially energy-dense. This level of extraction would only reduce channel flow rates by less than 5%, and the first 800 MW extracted would only reduce flow rates by a mere 1% (Karsten et al., 2011). Based on existing research, it is estimated that some 15% of the total available kinetic energy in a tidal stream can be harnessed whilst keeping flow rates within acceptable ecological levels (Hagerman & Polagye, 2006). The approach used by Karsten et al. (2011) in the Bay of Fundy offers larger energy estimates that the straight v^3 power equation (equation 2.1) cited earlier.

Karsten states that the average extractable power, P_{avg}, is defined by the amplitude of the forcing tide on the ocean side of the channel, a, the density of water, σ, the acceleration of gravity, g and the mean volumetric flow rate of the water in the channel prior to any turbines being installed, Q_0, yielding the relation:

$$P_{avg} \approx 0.22\sigma g a Q_0 \tag{2.2}$$

The results of this relation dictate that the amount of power present in a tidal channel is far greater than originally thought, increasing total power estimates from 1,900 MW utilizing Triton Consultants' methods (equation 2.1) to 7,200 MW utilizing equation 2.2 (Karsten et al., 2011).

Another interesting result of using equation 2.2 is that, as a significant channel blocking effect is achieved by installing large numbers of turbines which exert a drag force on the water, the hydrostatic head height outside of the channel is actually increased, thereby leading to corresponding increased power output within the channel. The impacts of Karsten's work has unknown ramifications on BC's previous total tidal energy potential estimate; however, given the findings in Minas Passage, it is likely that an increase in total available power by several factors is possible.

Boronowksi (2009) used theory similar to Karsten's and specifically considered tidal energy conversion and associated flow rates for Massett inlet on Haida Gwaii based on earlier modelling work done by Garrett and Cummings (2006) and expanded upon by Blanchfield et al. (2008). The work examined a bay linked to an open ocean by a channel utilizing characteristics and effects of the tidal wave as it approaches a narrow channel and the shape of the bay itself:

> "Results from this case study suggest a maximum average extractable power of 87 MW is available in Masset Sound; however, extraction of this amount would reduce the volume flow rate through the channel to approximately 58% of the undisturbed state. It was found that limiting the average power extracted to approximately 37 MW would reduce the volume flow rate through the channel by 10%, a more acceptable level. These values represent the maximum average extractable power and are, therefore, significantly higher than estimates based on the energy flux [equation 2.1] method." (Boronowski, 2009)

2.3: Relevance of Tidal Energy in British Columbia: Demand and Supply

There is incentive for developing tidal energy in BC from both a demand and supply perspective. BC has the technical potential for tidal energy development in both remote, off-grid communities and larger scale, grid connected projects, demonstrating significant levels of supply in the Province. As well, British Columbia's current grid-based power supply, which comes mainly (about 90%) from large hydroelectric facilities is arguably vulnerable to climate change when balanced with other water resource users and thus may create a demand for alternative power sources in the future. BC's hydroelectric system is largely dependent on heavy annual snowpack, which provides a gradual release of water into reservoirs over the summer and early fall months. This water offers essential capacity for power generation, as well as water for fish, agricultural irrigation and human consumption, and it can become noticeably scarce during prolonged drought periods. A most recent example of this was seen in BC's most recent summer of 2015 where severe water restrictions impacted many towns and cities in BC. Many recent studies now indicate that Western North America, is already experiencing lower than average snowpack levels, earlier spring melts, and lower stream flow levels during the year due to climate change; with temperatures projected to only get warmer (Jost & Weber, 2012, 2013; Merritt et al., 2006; Payne et al., 2004). For instance, in the case of the McNary dam on the Columbia River in Oregon, the US Corp of Army Engineers which operates the dam, has had to sacrifice electrical generating capacity in order to provide sufficient water for salmon downstream (Payne et al. 2004). Projections show that hydroelectric firm generating capacity on the watershed will decline 9-35% (based on the use of various climate change warming models used in the study) due to climate change impacts by mid-century. The authors cite that the entire Columbia River basin houses some 36,400 MW of installed hydroelectric generating capacity and powers some 70% of the United States' Pacific Northwest region. In addition, BC Hydro's massive Mica and Revelstoke dams as well as several others fall within the Columbia River Basin on the Canadian side of the border; in total this watershed represents 49% of BC Hydro's total generating capacity and thus is also subject to the same predicted losses of 9-35% by mid-century. This watershed also supplies the bulk of energy to BC's major load centres in the Lower Mainland and on Vancouver Island (BC Hydro, 2015). Jost and Weber (2012) state that climate change models and their predicted impact on BC Hydro watersheds indicate that BC's south coast watersheds are particularly vulnerable to global warming and subsequent run-off losses in the summer months. In particular, the study noted that the Strathcona watershed on Vancouver Island which supports 3 hydroelectric dams (total generating capacity of 242 MW) and represents some 67% of the island's generating capacity is projected to lose up to 60% of its summer inflows by the year 2050, representing a significant seasonal water (and power) loss (BC Hydro, 2012). Thus, while BC may be currently blessed with an abundant hydropower resource, it will very likely decline in viability over time, especially when additional demands from other water resource users, both human and ecological, are placed on it. This pressure on hydropower may create more demand for other, alternative sources of power.

In BC Hydro's 2009 Long Term Electrical Transmission Inquiry (conducted once every 6 years), Kei Wood Leidal Associates Ltd., who conducted the work for BC Hydro based on the BC Utilities Commission's original Section 5 Long Term Electrical Transmission Inquiry, cited the Campbell River area as a major potential electrical generation resource cluster comprising some 45% of its capacity as tidal power (BC Hydro, 2009). In addition, the cluster was one of only two situated on Vancouver Island and one of only four situated in the lower mainland and Vancouver Island area, the region which is home to some 78% of BC's population (BC Stats, 2014; see figure 2-16). As mentioned above, the lower mainland region's water supplies are already being threatened by climate change and lack of snowpack, possibly rendering the long term viability of hydropower during summer months (a major component of 2 of the 3 remaining clusters) questionable. This is a significant concern as predicted in BC Hydro's recent report on the impacts of climate change on its watersheds (Jost & Weber, 2012, 2013). These conclusions render clusters 11 and 12 situated on Vancouver Island, which comprise mostly wind, tidal, natural gas and wave power, as potentially important to BC Hydro's future regional power supplies.

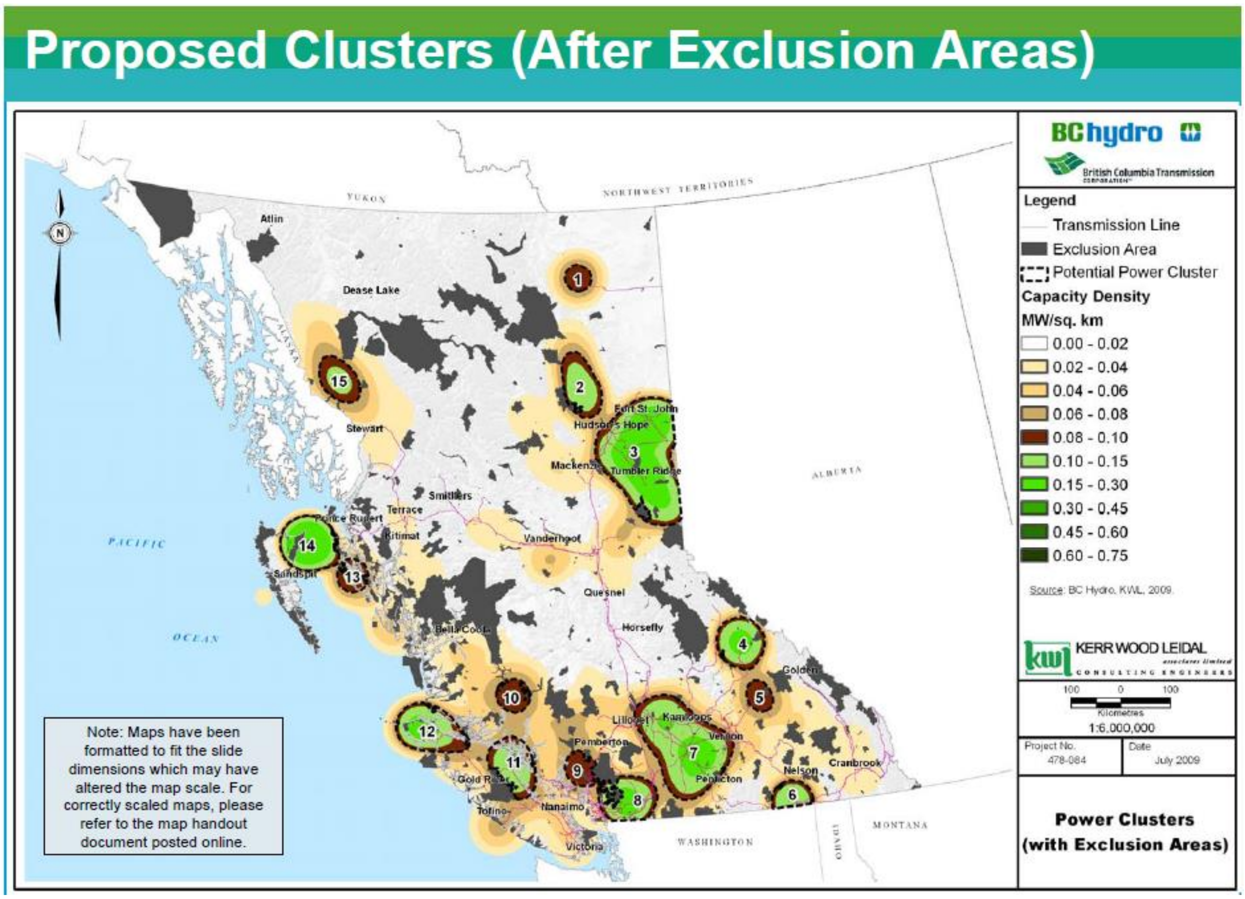

Figure 2-16: Proposed energy generation clusters based on generation capacity density, access to electrical grid and conservation area exclusion zones in BC. Cluster 11 reflects the area considered in this study and 45% of its capacity is comprised of tidal energy. Reprinted with permission from Kerrwood Leidal Associates, source: (BC Hydro, 2009; British Columbia Utilities Commission, 2009).

Meanwhile, in an off-grid context BC has some 24,000 people living in 82 off-grid settlements defined as "remote", of which about 90% use diesel as fuel for generating electricity, although the number of sites located on or near viable hydrokinetic tidal or river sites is currently unknown (Aboriginal Affairs and Northern Development Canada; Natural Resources Canada, 2011). While many of these remote communities qualify to be under BC Hydro's Remote Community Electrification Program (RCEP), BC Hydro has recently cut many projects from this program due to high costs (Mast, 2015). In addition, there are roughly 130 salmon aquaculture licenses on the BC coast (and roughly 75-80 farms in operation at one time) and over 500 shellfish aquaculture licenses (PNCIMA, 2011). While the data are difficult to find, it is believed that the vast majority of at least the salmon aquaculture farms are off-grid and run on diesel generators (BC Ministry of Agriculture and Lands; Ministry of Environment, 2008). As discussed in section 2.1.2, rates paid for diesel power are high, thus naturally creating a market pull for tidal and other alternative energies. In addition, as Wilson (2012) cites, diesel and other fossil fuel power generation can lead to poorer air quality and health impacts from emissions in communities, creating further incentive for renewable power generation.

In terms of supply, Triton Consultants (2006) and the Canadian Hydraulic Centre's National Marine Renewable Energy Inventory (2006), identified over 42,000 MW of mean tidal energy potential alone throughout Canada. The same report along with the 2002 and 2006 Triton Consultancy reports, commissioned by BC Hydro in efforts to quantify BC's tidal energy potential, found a theoretical tidal energy capacity of 4,015 MW at some 89 coastal sites in the province; only sites with greater than 1 MW or greater potential were considered (Cornett, 2006). The vast majority of the energy, some 3,500 MW, is situated around Vancouver Island (fig. 2-17). In particular, Seymour Narrows and South Discovery Passage Campbell River, British Columbia (figure 2-17) were identified as having 1,113 MW of theoretical tidal power, again based on the average current speeds in the passages and narrows and the cross sectional areas of the channels (Tarbotton & Larson, 2006). More detailed resource assessment work utilizing different methods has been carried out in Johnstone Straits area with comparable results to the Triton reports (Sutherland, Foreman, & Garrett, 2007). In addition, several studies examining resource potential and ocean energy grid penetration capability in the Queen Charlotte Islands (also known as Haida Gwaii) have been carried out suggesting the islands' total sustainably extractable tidal resource potential at roughly 37 MW; however, maximum levels of grid penetration were determined to be only a few megawatts due to the small size and isolation of the two grids, one for the north island and one for the south (J. B. Blanchfield, 2007; Boronowski, 2009). Finally, it should be emphasized as well that Karsten's (2011) work summarized in equation 2.2 and discussed in section 2.1.7 could very well increase tidal energy estimates for BC's coastal channels and warrants further research.

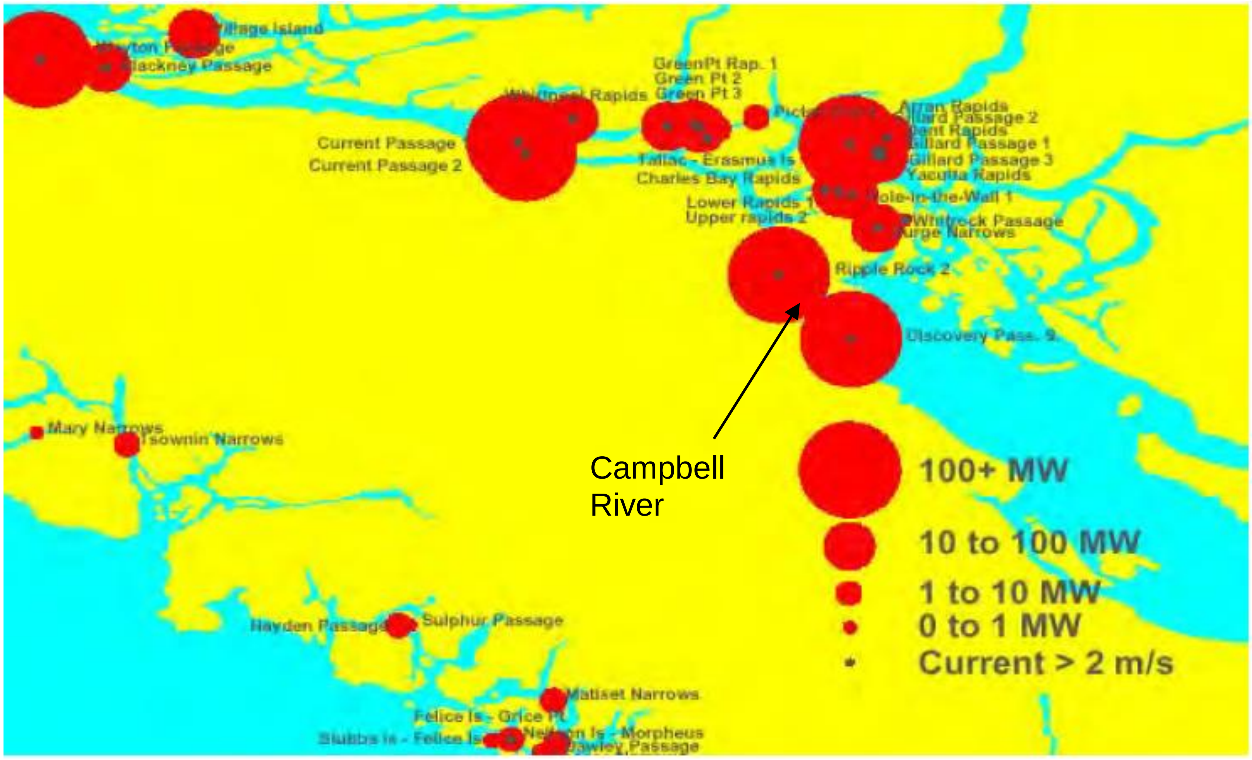

Figure 2-17: A map indicating potential tidal energy Sites around Vancouver Island by MW capacity. Seymour Narrows and South Discovery Passage are indicated by two large red circles at Campbell River. Reprinted with permission from Triton Consultants Inc., source: (Triton Consultants Inc., 2002)

2.4: Stakeholder Risk Perceptions and the Importance of Marine Spatial Planning (MSP)

The technical aspects of MRE and tidal energy are important. However, recent studies and state of the industry reports have identified the importance of marine spatial planning and regulatory approval measures in relation to tidal and ocean energy developments as well (Alexander et al., 2012; Huckerby, J. and Brito e Melo, 2012; Kim et al., 2012; Magagna & Uihlein, 2015). As of yet, there is a lack of information on the actual social, economic and ecological implications of putting turbines in the water. While tidal and ocean energy are in their infancy in terms of commercial scale deployment, shallower water sites are being sought, typically in the 20-50m depth range; unfortunately, these areas are also of high human and ecological importance as well (Huckerby, J. and Brito e Melo, 2012). Consequently, significant potential conflicts can arise between ocean energy projects and shipping, fishing, oil and gas developments as well as sensitive ecological zones. As is the case for many resource development projects, the adjudication of regulatory permits and licenses for tidal energy development projects, place a high value on the resolution of potential resource use conflicts with a proposed development

(Alexander et al., 2012). Magagna & Uihlein, 2015 and Ocean Energy Systems, 2015 consider regulatory and resource use conflicts to be the biggest non-technical barrier to ocean energy development worldwide. Marine spatial planning, maritime spatial planning (as it is called in Europe) or integrated coastal zone management are all processes for managing the allocation of ocean and marine areas for various stakeholder uses and ecological services now and in the future. In a coastal zone environment, MRE proponents should work collaboratively in a marine spatial planning context with other marine users to account for their issues, concerns and perceptions, otherwise a proposed MRE project that is technically feasible could face substantial opposition with potential long delay in regulatory approvals or at worst non-issuance of regulatory permits or licenses (Alexander et al., 2012; Kim et al., 2012). Ocean Energy Systems' 2011 annual report on marine spatial planning in relation to the ocean renewable energy industry consisted of four articles on the topic (Huckerby, J. and Brito e Melo, 2012). From these articles, particularly O'Hagan (2011), several overarching concepts and steps for conducting MSP relating to ORE sites are discussed and can largely be summarized for relevance to this study as follows:

- Establish strategic zones suitable for MRE development which can expand and be adapted to scientific and technical advances in the field
- Be aware that strategic level MRE development zones may very well span various regulatory and jurisdictional areas such as: internal (provincial in Canada) near-coastal waters, coastal territorial (federal in Canada) waters and even exclusive economic zone waters which extend out 200nm from shore.
- Zones should take into account proximity to existing marine and terrestrial infrastructure such as ports, heavy lift shipping and electrical grids and substations
- Consider MSP in three dimensions for MRE: other marine users can co-exist with MRE by using different depth stratums than the depths where the MRE is situated.
- Placing definitive geographical boundary lines around ocean energy projects is not always appropriate and can present regulatory and enforcement challenges
- Consider and define the general type(s) of stakeholder(s) or other marine ecological usages and habitat which occur in an MRE area (e.g. commercial and recreational fishing, finfish and shellfish aquaculture, ecologically sensitive areas, marine transport, tourism, oil and gas development, First Nations, etc.)
- For specific MRE projects, consider refining project plans based on stakeholder input
- Remain open and transparent in consultation processes and avoid bias

- Carry out regular updates and meeting with the identified stakeholders, First Nations and government agency representatives
- Define a plan of action for the future incorporating continued engagement
- Keep terms used for MSP for MRE projects consistent. Words such as pilot, demonstration, temporary, investigative lease and license of occupation can all be misinterpreted to mean different things by different people and can lead to conflicts.

These components are presented in detail in chapter 3 of this thesis, with specific reference to local scale marine spatial planning for proposed MRE sites in the Campbell River area including extensive stakeholder engagement and detailed MRE site assessment approach that may be relevant to both BC waters and beyond.

2.4.1 General MSP Concerns in BC

MSP concerns in relation to tidal energy conversion and other types of MRE facilities must be considered in a broader regional context comprising coastal geography, oceanography, weather and other marine resource uses occurring in the area, and not simply at a local site level, or broader national one (Dalton et al., 2015; Huckerby, J. and Brito e Melo, 2012). For BC in particular, Vancouver Island offers a sheltered shipping route known as the Inside Passage which is favoured by many types of heavy commercial transport shipping as well as recreational boaters (Campbell River Econmic Development Corporation, 2013). In addition, salmon, regarded economically and recreationally by some British Columbians as being the "backbone of the coast", migrate through this restricted channel by the millions each summer and fall contributing substantially to local livelihoods and tourism industry in the Campbell River area. Along with these fish come porpoises and whales, such as orcas, and humpbacks and significant amounts of eco-tourists who follow them ((Marine Planning Partnership (MaPP), 2015). BC is well known for its pristine wilderness and ample recreational activities; consequently, proponents for proposed MRE projects in this area should expect that they would need to demonstrate that little to no ill effects are likely to result from MRE installations in BC waters.

One of the most key and remarkable areas for tidal energy development in BC is Seymour Narrows and Discovery Passage in the vicinity of the City of Campbell River. These areas contain over 1100 MW of potential tidal power, more than any other areas in the province, yet are also home to a very busy shipping, fishing and ecotourism areas. Figures 2-18 and 2-19 from the BC Marine Conservation Atlas (BCMCA) indicate vessel traffic densities based on hours of presence, showing how these passages are the main marine traffic routes in the region.

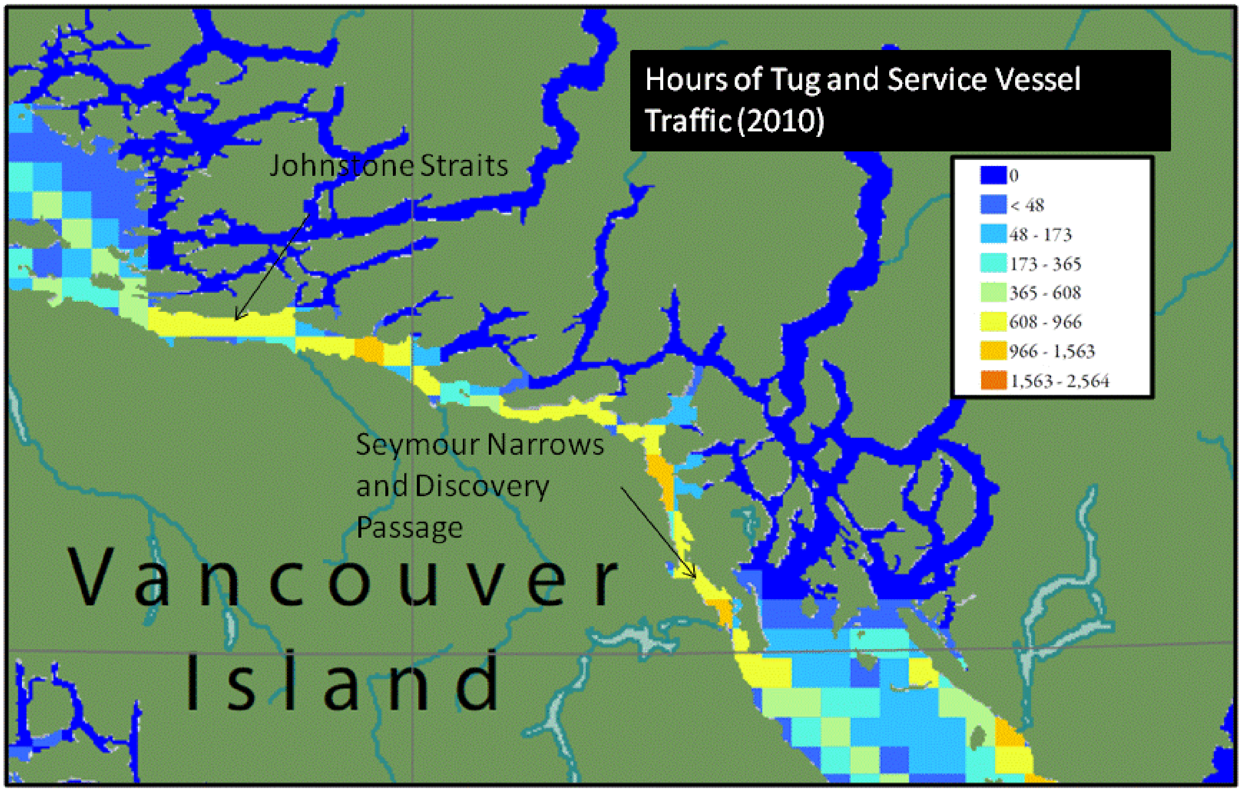

Figure 2-18: Hours of tug and service vessel traffic in BC in 2010. Reprinted with permission from British Columbia Marine Conservation Atlas, source: (British Columbia Marine Conservation Analysis Team, 2011).

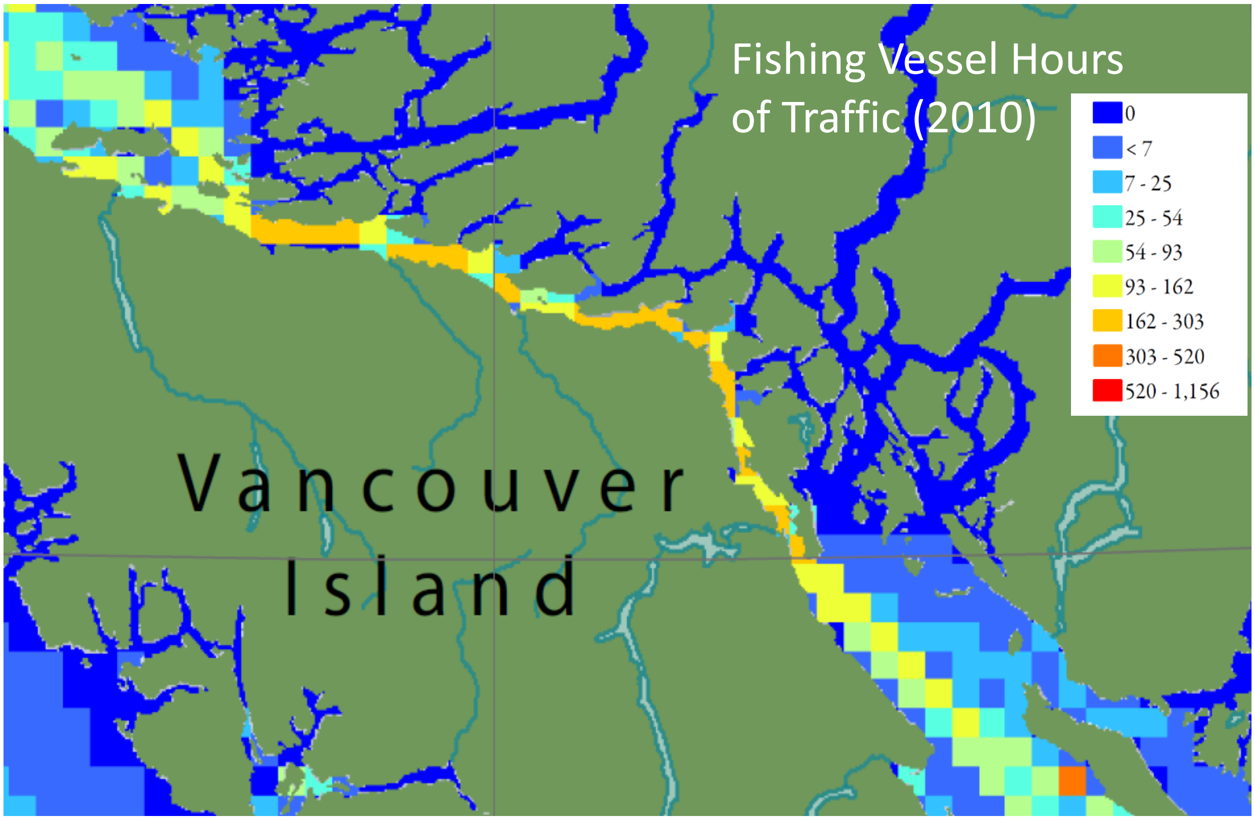

Fig. 2-19: Hours of fishing vessel traffic in BC in 2010. Reprinted with permission from British Columbia Marine Conservation Atlas, source: (British Columbia Marine Conservation Analysis Team, 2011).

2.5: Conclusion

Tidal energy represents a potentially robust and reliable renewable energy technology, however its rates of development have been low thus far, worldwide. This trend is possibly attributable to tidal energy's high development costs, uncertainty around its environmental impacts and operational challenges associated with installing the turbines. With recent developments in Europe, Nova Scotia and Southeast Asia, however, a large number of small array installations should be installed in 2016. A wealth of research exists on single turbine tidal energy emplacements, but much of it is limited in scope or confined to one discipline and considerably more practical in-water experience is needed. From an environmental perspective the MRE industry needs research on installed and operating multiple turbine arrays to determine what environmental effects and potential resource use conflicts are likely to occur from multiple generators. As well, a better understanding of channel blocking effects of turbines and corresponding effects on total power output and associated water flow reductions as discussed with Karsten's (2011) and others' work is needed. Along with this work, study of the potential ecological effects of these water flow reductions is also needed in further depth and regional context for BC. In addition to the effects of multiple turbine arrays in one site, broader spatial and temporal scale consideration of the cumulative effects of many arrays present in a region should eventually be considered (perhaps after the effects of a single array are determined). However, well defined MRE installation targets in the UK, Nova Scotia and elsewhere along with structured MSP and regulatory processes and a growing number of technology developers, should help facilitate the understanding of these potential effects and areas of research as the industry grows in size.

In BC, a substantial potential off-grid tidal energy market exists as an alternative to diesel fuel. As well, potential losses of hydropower from on-grid sources due to global warming and concomitant runoff losses due to reduced snow pack in spring and summer may lead to a larger scale search for power alternatives in BC in the future. However, technology development and strategic environmental, regulatory, economic and policy initiatives to support tidal energy are either in their infancy, or are completely lacking. If tidal energy is to progress and become a significant generation resource in BC, at least some, if not all of these concerns need to begin to be addressed.

Chapter 3: A Case Study and Risk Perceptions Analysis of Tidal Energy Sites near Campbell River, BC

3.1 Introduction

Narrow channels are some of the densest tidal energy locations in the world as they constrict and force the tidal stream through a small area. Tidal energy conversion devices, which often look like windmills, are situated underwater to harness the high velocity water flows present in these environments (see fig. 3-1). Inside of Vancouver Island, British Columbia, on the west coast of Canada are a plethora of these passages and a moderate to high tidal range (equating to roughly 3.5 GW of theoretical tidal energy). British Columbia has a unique marine transportation and tidal energy environment in that Vancouver Island offers a natural open ocean barrier resulting in a sheltered and busy route for shipping and migratory animals (i.e. salmon and orca) on the continental side of it. The co-location in a small area of both important natural and economic uses of the marine environment and exploitable tidal energy presents a potential for resource conflict that would require mitigation in order to apply the technology. This study focused on the coastal area around the City of Campbell River, home to some 32,000 people including several First Nations, as well as the bulk of BC's tidal energy resource. Seymour Narrows and South Discovery Passage located in the study area, account for 1.1 GW of theoretical energy, comprising roughly one-quarter of BC's tidal power potential (Cornett, 2006). As cited in section 2.2, BC Hydro has identified these waters as being home to nearly half of a large potential future generation cluster located at Campbell River. Known as cluster 11, the area is 1 of 10 identified as having high capacity, or power generation, density, and is listed comprising 45% tidal energy, as well as natural gas generation (BC Hydro, 2009).

Figure 3-1: An Alstom tidal turbine. Reprinted with permission from Subsea World News, source: http://subseaworldnews.com/2013/07/31/alstoms-tidal-turbine-reaches-full-power-in-offshore-conditions/

This chapter examines perceptions of impacts and benefits surrounding potential tidal energy development in a narrow channel, high marine resource use environment at Campbell River. General perceptions of energy systems in BC are examined first, followed by ranking of tidal energy in relation to other energy options in the province. In the next section, notions of spatial conflict, spatial interference and localized perceptions of risk associated with tidal energy, as well as more diffuse, perceived regional benefits from its implementation are discussed. Thirty-nine stakeholders and First Nations individuals with commercial, recreational and cultural interests in the Discovery Passage were interviewed from June-December of 2014 examining levels of support, perceived risks and benefits, areas of spatial usage (measured using GIS) and areas of conflict in relation to two proposed tidal energy investigative license (IL) sites located there. The ILs are held by the engineering project management company SRM Projects of Nanaimo, BC. Governed by the BC Ministry of Forests Lands and Natural Resource

Operations (FLNRO), the ILs do not permit development of the sites, only investigative activities related to them, and are valid for a 5 year period which began in February 2014. The purpose of this study was to inform location and timing of potential conflict between proposed TE installations and existing users of Discovery Passage.

3.1.1 Background

Much work has been done on perceptions of different types of renewable energy, energy system change, as well as how to foster policies to encourage public support for renewable energy development (Demski, Butler, Parkhill, Spence, & Pidgeon, 2015; Parkhill, 2013; West, Bailey, & Winter, 2010; Wüstenhagen et al., 2007). Most of the comprehensive works, including explorations of the concepts of NIMBYism (not in my backyard), socio-political, community and market based acceptance have focused on land based renewables, particularly wind power (Wolsink, 2007; Wüstenhagen et al., 2007). Wolsink (2007) in particular discusses how support for land based wind power projects was found to be relatively high in the conceptual design phase, but declined in the detailed project planning phase, with an eventual recovery of support once the turbines were actually built. This finding is important and has begun to be applied in the ORE sector (Reilly, O'Hagan, & Dalton, 2015). Some more recent work has started to incorporate perceptions of ORE, principally off-shore wind, wave and tidal energies.

A recent review of the literature surrounding ORE technologies examined different measures for assessing the viability and value of an ORE project, in this case a wave or tidal project. Dalton et al. (2015) finds that important intersections existed between traditional private sector economic viability assessments such as levelized cost of electricity (LCOE) and net present value (NPV), and public sector assessments of stakeholder perceptions of ORE at the site where the project is proposed, as well as possible environmental impacts. Mention is given in the study to the distributed benefits, yet localized impacts, typical of renewable power projects, and land-based wind projects' traditional means of overcoming local opposition to these impacts. These means typically include encouraging community energy system ownership, creating financial funds stemming from the project or engaging local contracting and services in the construction of the projects. Dalton et al. (2015) goes further to link both strategic and local level environmental assessment for ORE developments to provisioning and valuation of ecosystem services associated with the projects, thus creating a three way linkage between social, economic and environmental measures for assessing ORE projects at both local, regional and national scales in the UK.

Utilizing ecosystem services as a vehicle for assessing the impacts and benefits of ORE sites is based largely on work done on their valuation in marine spatial planning contexts (Guerry et al., 2012; Klain & Chan, 2012). Klain and Chan (2012) in particular utilize an interactive marine spatial planning approach, interviewing stakeholders and allowing them to indicate and value their important resource usage areas. Kim et al. (2012) also examines wave energy resources off the West Coast of Vancouver Island, contrasting them with existing fishing, shipping, tourism and ecological areas as defined in the British Columbia Marine Conservation Atlas (BCMCA). NPV values of wave energy were determined using typical development costs along with expected annualized power sales based on wave data. Results were that high-density wave energy was found far offshore yet cost of submarine transmission cable rendered the more nearshore sites most viable, a common occurrence among ORE projects. When overlaying positive NPV sites with other ocean usage feature counts as described in BCMCA, it was found that shipping and transport, followed by commercial fishing had the highest median overlap with high NPV wave areas, rendering them as the most important resource uses to consider in relation to these ORE sites.

More general marine spatial planning (MSP) and risk perceptions based work relating to ORE are also developing. Several studies have been done on perceptions of fishers towards ORE (includes offshore wind, wave, and tidal) indicating that the fisher stakeholder group tends to be most affected by ORE projects yet doesn't always necessarily have high amounts of opposition towards them (Alexander, Wilding, & Jacomina Heymans, 2013; Reilly et al., 2015). In addition, innovative MSP studies have shown that significant mixed zone usage of ORE and static gear fishing can be achieved with minimal costs to both sectors (Yates, Schoeman, & Klein, 2015). Further, some new evidence of ORE arrays acting as *de facto* marine protected areas (MPAs) now exists adding a potentially very important aspect to the benefits of ORE technologies (Ashley, Mangi, & Rodwell, 2014; Inger et al., 2009; Yates et al., 2015). Thus, the data gathered so far indicate that fishers and shipping may be the most important stakeholder groups to consider and consult in relation to MRE arrays. The distinction between sport and commercial fishery is also important to note from a socio-economic standpoint as loss or curtailment of a commercial fishery where incomes derive primarily from fishing is arguably more substantial than a similar scale loss or curtailment of a sport fishery where fishers' primary incomes are generally not entirely derived from the fishery and can be supported by other means. Within this study area, only line and trap sport fishing were conducted as no licensed commercial net fishery was present. While this occurrence certainly does not negate the impact of ORE on a sport fishery, it arguably has less of a socio-economic impact than loss of commercial fishery would.

The most thorough and comprehensive efforts at IMSP in relation to tidal energy is Alexander et al. (2012). That study explores optimal tidal array siting, utilizing interactive marine spatial planning techniques in the Mull of Kintyre, Scotland, examining the interests of fishing, boating and ecotourism stakeholders. Alexander et al.'s (2012) site was relatively unconstrained, in comparison to Campbell River, being situated in a roughly 20km wide channel. The site extends roughly 4km off of the Mull of Kintyre headland to the border of a commercial shipping lane and then runs some 22 km along the lanes (see fig. 3-2). The established shipping lanes also generally exclude large shipping traffic, reducing the number of shipping stakeholder considerations. The study utilized spatial decision support systems and interactive marine spatial planning, engaging with stakeholders in order to assess levels of conflict in relation to several proposed scales of tidal energy arrays at 40 MW, 100 MW and 200 MW. Each scale of energy penetration yielded larger map areas to consider for stakeholders.

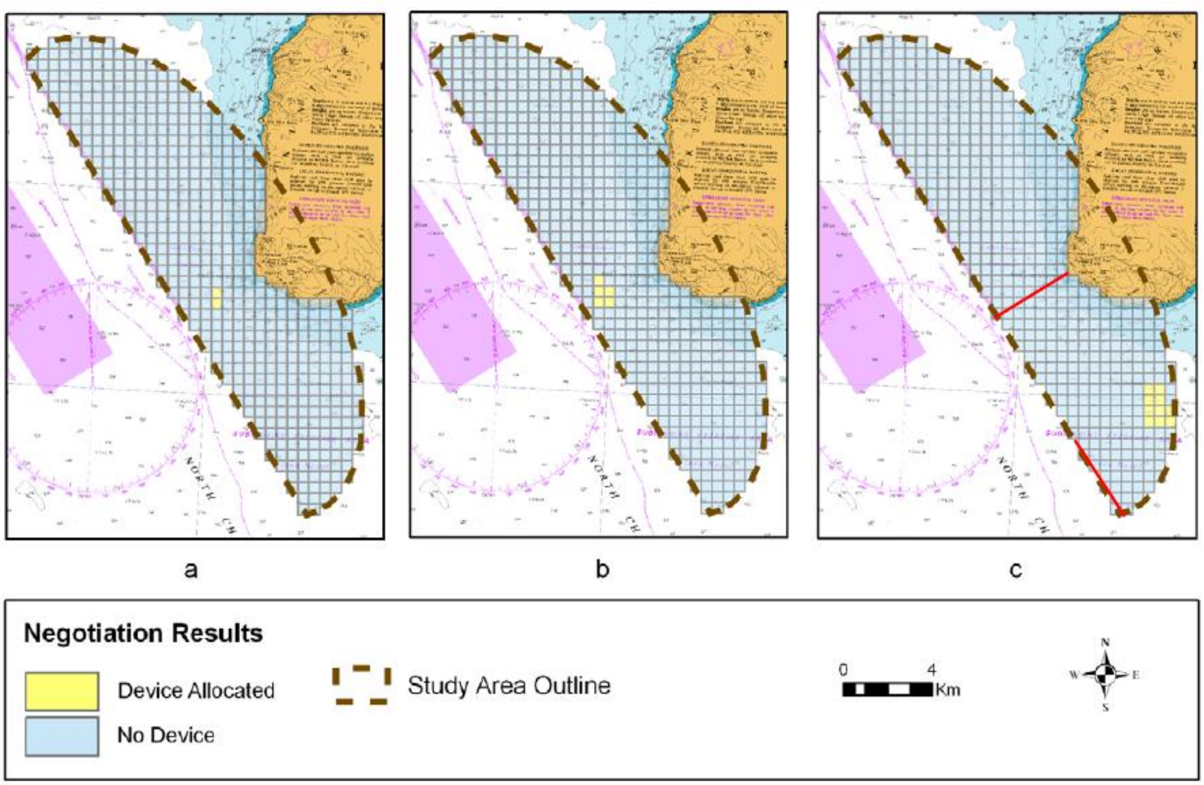

Figure 3-2: The Mull of Kintyre study area showing tidal turbine device allocation areas in yellow for a: 40 MW, b: 100MW and c: 200MW. The red line extending southwest from the headland in c represents 4km distance. Reprinted with permission under a Creative Commons Attribution License Source: (Alexander et al., 2012).

Alexander et al.'s (2012) methods were very comprehensive in that they used a wealth of existing secondary mapping data on fishing, shipping, yachting and important ecological zones in order to generate baseline maps for tidal energy, commercial shipping, commercial fishing, recreational shipping, tourism and the environment. These maps were then used over a common grid plot and assigned weights of importance. Stakeholders were brought together in two focus groups; the first to personally refine their resource usage map and the second to negotiate their position in relation to multiple other stakeholders including renewable energy representatives (in this case, Scottish Renewables, a multi-sector renewable energy company, however not a tidal energy developer). The study is very effective in this regard as it combined a variety of stakeholders and was able to apparently successfully determine suitable areas for the tidal energy arrays. What was unclear from the study's methods however, was whether tidal energy development expertise was actually represented at these negotiation workshops. In all three resultant scenarios, the tidal energy sites were in greater than 50m of water depth (in the only case cited and mapped specifically in the paper, the site depth appeared to be in excess of 100m). These depths present inherent challenges for a tidal energy developer, especially as they exceed 70-80m. Any diving operations at these depths necessitate mixed gas operations and extensive decompression driving up operating costs for developers. The other notion worth considering is whether the methods used would be successful within a much narrower channel such as Discovery Passage with greater heavy shipping usage. Alexander et al.'s (2012) methods, while certainly worth considering for future studies, seemed to rely more on spatial agreement between stakeholders and the assumption that all stakeholders, and not just fishers, could not co-exist in the same space as tidal energy, which is not necessarily true. The study's results include notions of loss of use, the vulnerabilities of fishers to tidal energy arrays and the strong possibility that tidal energy arrays would require fisheries exclusion zones around them. Alexander et al. (2012) does not mention the possibility that tidal energy devices could be submerged at a depth safe for boating and shipping, thus rendering their only potential conflicts to marine life impacts (which could affect tourism) and fisheries (and not necessarily all fisheries, as traps fishing can be argued to be able to co-exist). As well, there is no mention of depth specific marine spatial planning whereby certain shallower ocean strata could be allocated to various stakeholders, with tidal turbines situated in sufficiently deep water to enable avoidance of OREs by boat and ship operators.

While existing literature on perceptions of stakeholders towards ORE and tidal energy is useful, as is the application of interactive marine spatial planning in conjunction with ORE site selection, applying the practice to narrower, higher use marine channels has apparently not yet been done, nor have any such studies been conducted in British Columbia previous to the one reported in this Thesis. Campbell River, Discovery Passage and Seymour Narrows are representative of many potential narrow channel ORE sites present in British Columbia which require consideration of not only fishing, boating and tourism, but sometimes also heavy shipping, including tug boats, cruise ships and freighters. Routes and shipping lanes for these heavy vessels cannot be separated from ORE sites simply due to a lack of available space to do so, and therefore must be, for the most, part co-located where passages are restricted. These additional geographic and stakeholder considerations are encompassed in this Thesis.

3.1.2 Study Area

The study area is located in Discovery Passage from Separation Head to Cape Mudge, between Quadra Island and Vancouver Island (see fig. 3-3, 3-4). Discovery Passage is a relatively narrow (average channel width is 2km, narrowest point is 800m) marine waterway between Vancouver Island and a group of islands to the east. It is part of the Inside Passage, connecting major ports from Puget Sound in Washington State to the Alaska Panhandle. This study area was selected because it encompasses the ILs of SRM Projects and the surrounding areas where users could be potentially affected by the installation or operation of tidal energy systems. The foreshore area was deemed part of the study area as proposed tidal energy installations would need subsea electrical cables to transmit the power to onshore locations. If any of these proposed projects are realized their transmission cables would likely have to be buried where they cross intertidal and backshore areas.

Figure 3-3: Vancouver Island, British Columbia. The study area at Campbell River is indicated. Reprinted with permission from Open street map, source: http://www.openstreetmap.org/.

Richard Thomson's *Oceanography of the British Columbia Coast* (1981) depicts tidal and current flows as well as a brief marine history of the region. As discussed in greater detail in section 2.1.6, the tidal currents in the region are powerful and one of the main reasons why tidal energy development is being considered there. As the tide rises (or floods) it moves southwards through Seymour Narrows past Campbell River and Cape Mudge (see fig. 3-4). When the tide ebbs it reverses direction and travels in a northbound direction. This cycle repeats itself twice daily producing two flood tides and two ebb tides per twenty-four hour period. The strength of the currents moving through Discovery Passage is considerable: in the wider portions of the passage, maximum currents reach 7-8 knots (roughly 3.5-4 metres per second), while in the Seymour Narrows (narrowest point in the passage of 800m) currents reach up to 15-16 knots (roughly 8 metres per second) on full moon/new moon cycle. Due to the large amount of tidal flushing through the area, the water is highly oxygenated, mixed and nutrient rich contributing to a rich marine ecosystem.

The bottom topography of south Discovery Passage is relatively uniform with a deep level channel running throughout, resulting in fast but relatively laminar water flows compared to Seymour Narrows. By contrast, the undersea floor around Seymour Narrows is populated by large rock formations, rising upwards of 30-40m from the sea bottom. The pre-eminent member of these formations, Ripple Rock, sits right in the middle of Seymour Narrows at a depth of 14m at lowest low water. However, it was once only 3m below the surface causing numerous shipwrecks (roughly 100) and was partially destroyed by explosives in the late 1950s in order to reduce risk to shipping. Due largely to the bottom topography, the flows of the tidal stream here are turbulent, producing upwelling, whirlpools, overfalls and large eddies (Thomson, 1981). The eddies are important, as local mariners know and use them frequently to help move outside of the main currents.

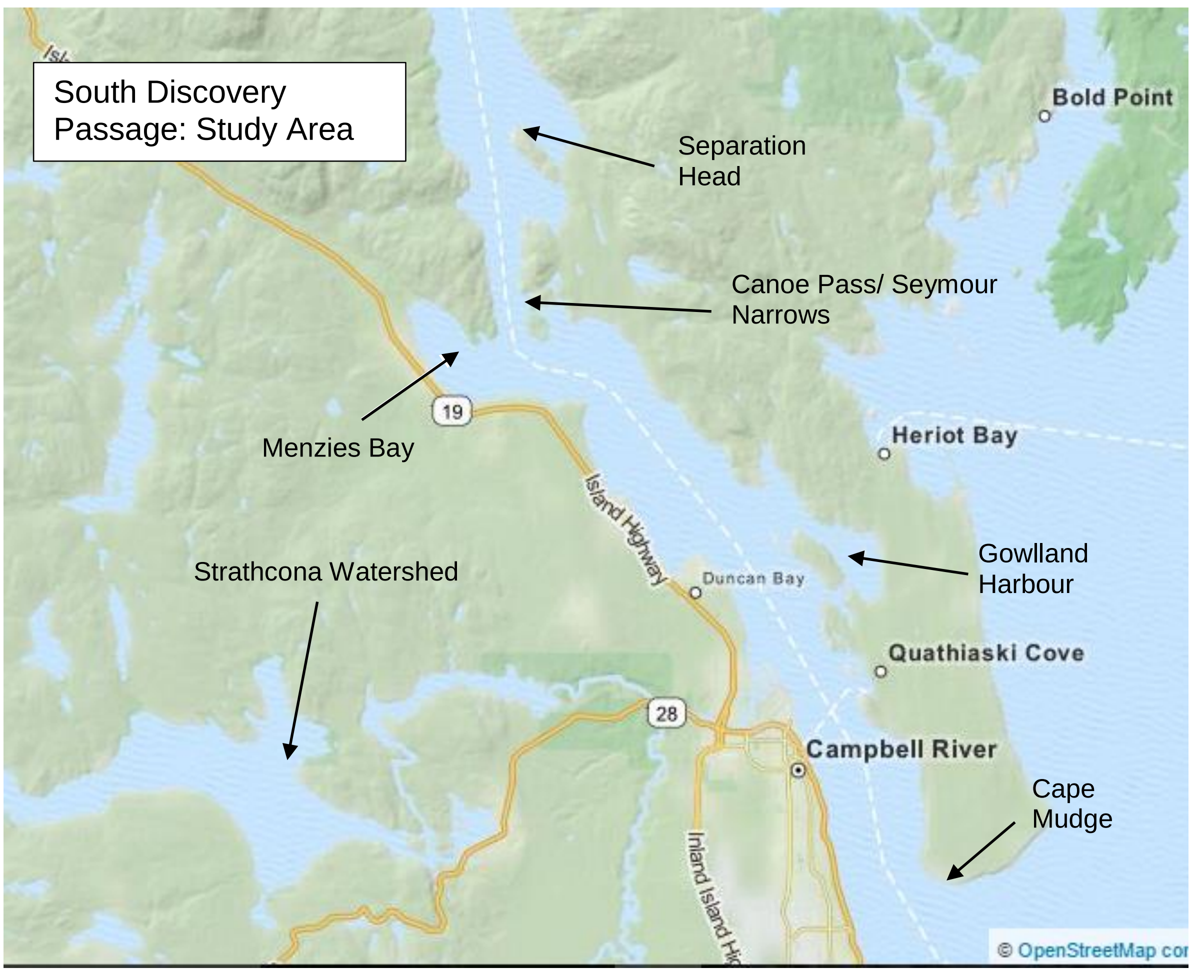

Figure 3-4: The study area in detail, from Separation Head south to Cape Mudge on Quadra Island. Canoe Pass, adjacent to Seymour Narrows was under development as BC’s only tidal energy site under construction in 2014, at the time of study. Map reprinted with permission of open street map, source: www.openstreetmap.org

3.1.3 Community Context

The City of Campbell River is a community of 29,565 people located adjacent to Discovery Passage (Statscan 2006, 2011). The Campbell River area also includes territory of two First Nations, the We Wai Kai (or Cape Mudge Indian Band) composed of about 1100 members, including 500 residing on reserve lands and the Wei Wai Kum (or Campbell River Indian Band) composed of roughly 665 members ("Campbell River", 2009). The City's population is aging with 34% of it aged 55 years or older, a number that increased 27% between the 2006 and 2011 censuses (Statscan 2006, 2011). The workforce between the ages of 20-54 encompassed 56% of the population and declined slightly between the censuses. Average annual income from the 2011 census was $69,342, up 15% from 2006 (Statscan 2006, 2011).

Campbell River is a city historically dependent on a primary resource economy including fishing, forestry and mining, and the Discovery Passage waterway is often used to move these goods. In more recent years, however, the traditional forest industry has declined, as evidenced by closure of the Catalyst pulp and paper mill in 2010 and its subsequent sale in 2013 to Quicksilver Resources, a Liquid Natural Gas (LNG) company. Aquaculture is now the leading Campbell River area employer in the primary resources sector[10], supplying 549 direct jobs, followed closely by the mining and forestry sectors (Campbell River Econmic Development Corporation, 2013).

The city is also home to much of the region's recreational, commercial and industrial fleets of vessels, which dock in the one large private and one federal government marinas located within the city limits. These facilities service an estimated 800 plus ships and boats of various sizes, as well as numerous other smaller privately owned marinas. The industrial ports of Campbell River include two coal and ore loading docks and two log sorts in Menzies Bay and Gowlland Harbour (see fig. 3-4). These mineral loading ports are used for shipping ore from the local North Vancouver Island mine near Buttle Lake (Westmin Mines), coal from the Quinsam Coal mine, log booming and general barging and marine industrial shipping for a multitude of fishing lodges, remote industrial camps, run-of-river hydroelectric energy operations (i.e. Toba Inlet and other proposed sites), as well as some 30 aquaculture farm leases present in the Discovery Islands area (Marine Planning Partnership (MaPP), 2015). The sizable commercial and sport

[10] Primary resource sectors traditionally include industries such as forestry, mining and fisheries and are drivers of local economies, helping to create supporting sectors such as health care, education, local government and retail.

fishing fleet harvests 5 different species of Pacific salmon that use Discovery Passage as their main migration route. This mass migration of fish, usually numbering in the millions, leads to Campbell River billing itself as the “Salmon Fishing Capital of the World.” In addition, large volumes of shipping traffic move directly past the shores of the city as they make their way along the Inside Passage; these vessels include cruise ships during the summer season, heavy log barges, freighters and regular heavy container barges heading to or from BC’s north coast and Alaska. All barges are towed by various sized tugs, up to the large ocean-going class of tugs, using heavy steel wire and chain bridles. The Pacific Pilotage Authority mandates that all internationally flagged vessels over 350 gross tons and all private internationally flagged vessels over 500 tons transiting BC coastal waters carry a BC Coast Pilot, who is a marine navigation expert specializing in local marine knowledge of the area (Ministry of Justice, 2015).

The BC Ferry Corporation operates a year round mid-sized vessel run from the city of Campbell River to Quathiaski Cove on Quadra Island immediately across Discovery Passage from Campbell River. Quadra Island also has another ferry route, transiting between the island’s eastern shores, and Cortes Island. The 2006 census stated Quadra Island’s population at about 2472 and Cortes’ population at 1042 (Statscan, 2006). Thus, these two ferry routes serve a substantially sized population whose point of departure is through Campbell River’s waterfront. While there are a number of other tidal energy ILs in the area, both being applied for and already granted, and fifty being applied for throughout the province, only one company to date has received long-term tenure for a commercial tidal energy projects in British Columbia. This installation, located at Canoe Pass between Quadra and Maude Islands near Campbell River, is currently under construction (see fig. 3-4).

3.2 Methodology

Interviewees for this study represented a variety of sectors and were selected based on their commercial, recreational or cultural usage of Discovery Passage and its foreshores. Interviewed groups included: First Nations, museums, sport fishing guides and lodges, water taxis, BC ferries, marinas and harbour authorities, eco-tourism operators including whale and wildlife viewers and SCUBA diving operators, various city planners and government officials, including Department of Fisheries and Oceans (DFO) and the Canadian Coast Guard (CCG), the region’s several aquaculture companies and industry groups, and numerous tug and tow operators, both locally and regionally based, as well as regional heavy vessel navigation specialists (see fig. 3-5). A total of 39 interviews were conducted, 36 in Campbell River, 2 in Vancouver and 1 via telephone to Seattle, Washington.

Spatial data and risk perceptions data were gathered in a semi-structured interview process as described below. The spatial data were used to inform location, intensity, and seasonality of marine usage by stakeholder and First Nations groups, as well as levels and areas of conflict in relation to the proposed IL sites and were principally used to inform results in Chapter 4. Risk perceptions data were used to inform general levels of support for, perceived derived benefits from, and types of concerns surrounding tidal energy development within the area.

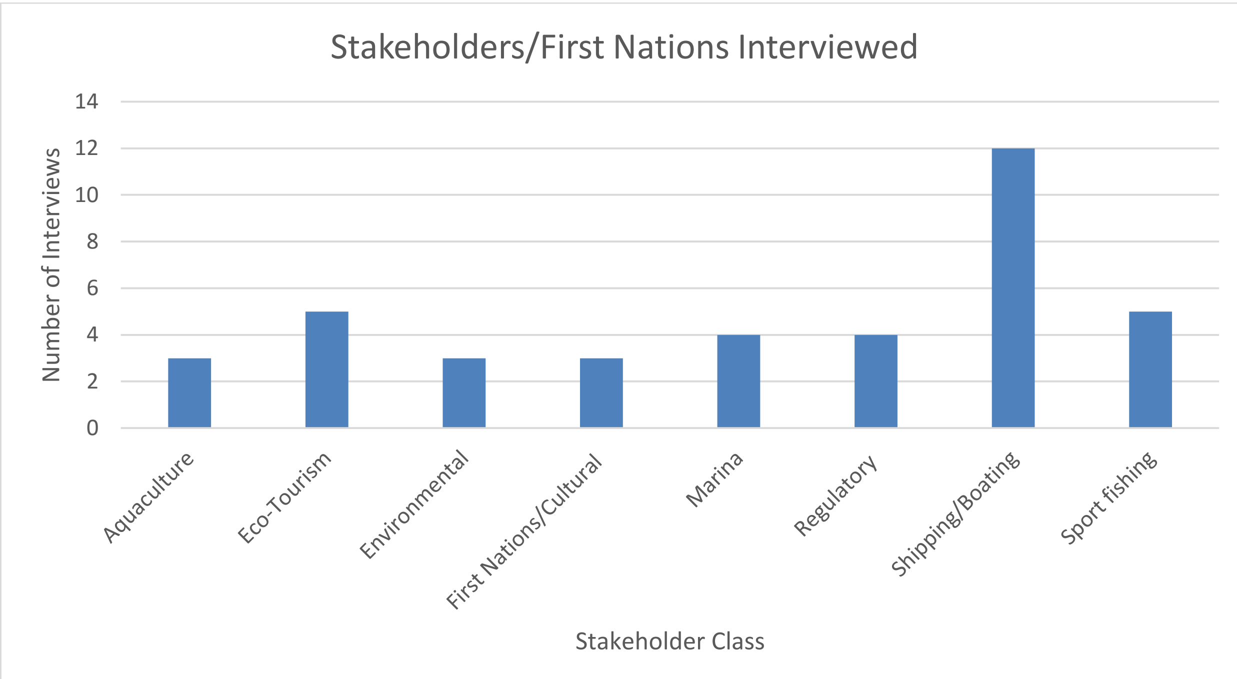

Figure 3-5: Total number of interviews conducted, by stakeholder group n=39.

Interview subjects were informed in advance via a letter of recruitment that the study was in relation to proposed tidal energy developments in South Discovery Passage between Separation Head and Cape Mudge, described as the “study area.” Also, in advance of the interview, subjects were sent an information briefing on tidal energy and energy in general in BC; the briefing included a 2 min 40 second live and animated video showing an Open Hydro commercial scale tidal turbine being lowered into the water from a barge and a view of it underwater from a remotely operated vehicle (ROV) at depths up to 30m as indicated in the ROV’s display footage. The video also showed an animation of the turbine’s blades slowly rotating at roughly 15 rpm and reversing with the direction of the tidal stream over time. This speed of rotation is common amongst most commercial scale tidal turbines.

The interviews were conducted on location, mostly in Campbell River during the summer of 2014. The researcher brought a paper marine chart showing the study area (CHS chart 3539: "Discovery Passage"), as well as an IPAD with a Google Earth map showing the study area and the IL sites for later in the interview. The interview protocol itself was conducted in five parts related to marine spatial planning, general energy information, pre-interview briefing, interview questioning regarding tidal energy in general, and questions about specific tidal energy sites.

The first part comprised marine spatial planning (MSP) questions which asked the subject to identify their organization's top three areas of usage, or predominant shipping routes at different points of the tidal cycle. The subjects were asked to assign a level of value (indicated by theoretical tokens) to each of these sites as well as their seasonality and frequency of use. The second part of the interview had questions related to energy sources in BC, and gave some information on where power in BC comes from and some of BC Hydro's plans for the future, including infrastructure upgrades and the Site C dam. Questions were generally posed in this section using "likert" scales to measure levels of support for various policies, or by asking respondents to rank various attributes associated with energy systems in BC. Mean levels of response and standard deviations were calculated for each question across all stakeholders. The third part of the interview was the information briefing given to the respondent in advance of the interview; the researcher asked whether the respondents had any questions on the handout; in some cases the respondents had not read the handout or watched the video and this was then done during the interview.

The fourth part of the interview asked the respondent a series of questions relating to their perceived risks and benefits surrounding tidal energy and then asked them to rank tidal energy in relation to various other energy technologies. Risk and benefit perceptions were measured through choice prioritization questions which gave each respondent 30 theoretical tokens to divide up between numerous different possible risks or benefits of tidal energy (measured in two separate questions). Respondents were also given the option of adding in risks or benefits they thought applicable. Responses were then averaged across all respondents and by specific stakeholder groups (such as fishing, shipping, eco-tourism, regulatory, etc.). Following this, respondents were asked to rank tidal energy in relation to 10 other energy technologies according to various criteria. Mean responses to these questions were taken across all stakeholder groups. The section concluded by asking respondents whether they thought tidal energy was a worthwhile idea or not, whether it was affordable, did it have impacts on marine life and what was their willingness to pay extra money on the hydro bill in order to facilitate development of tidal energy in BC. These questions all used “likert” scales and responses, were averaged (and standard deviations calculated) across all respondents and by respective stakeholder groups, and essentially measured levels of support for tidal energy development prior to the introduction of the IL sites in section 5.

The fifth and final section of the interview introduced the actual IL sites where the tidal energy is proposed to be developed, showing them to the subject on an IPAD Google Earth map, and providing them a brief description on how SRM Projects plans on developing these sites. Included in this description, among other points, were the stipulations that all tidal energy converters (TECs) in the sites would operate completely submerged at a depth approved as safe for shipping by Transport Canada, environmental impacts and turbine footprints would be minimized for the devices and would likely be a small fraction of the IL areas, further stakeholder and First Nations engagement would take place if development were to proceed, and community and First Nations ownership of the tidal energy sites would be encouraged. Respondents were then asked if their organization had a conflict with the IL areas as a “yes” or “no” option and then as a general likert scale question measuring their perceived degree of conflict from 1-5, with 1 being no conflict and 5 being high amounts of conflict. Finally, respondents were given the opportunity to draw on any particular areas of conflict they saw existing between their organization’s needs and the proposed tidal energy sites. Respondents were asked to rate these polygons on severity from 1-5 and the seasonality of the conflict, if any. These responses, including number of conflict polygons cited per stakeholder, as well as mean conflict polygon severity scores, were averaged across all respondents. Thus the main data points collected in section 5 were the general conflict score, rated from 1-5, and the spatially specific polygon conflict rating score also rated from 1-5. These scores were averaged by stakeholder group, with mean general conflict scores and mean conflict polygon severity scores.

3.3 Results

3.3.1 General Energy Knowledge in BC, Ranking of Tidal Energy

Respondents were asked to assess their own knowledge of tidal energy as well as their level of support for ongoing electrical infrastructure upgrades and construction of new generation assets being carried out in the province by BC Hydro, the province’s dominant utility provider. BC Hydro provides 95% of the province’s electrical energy demand from a generation portfolio that is currently over 90% hydroelectric. Some 62% of respondents rated their knowledge of tidal energy as being “a little”, the second option on a 5-point scale ranging from “none” to “total knowledge.” Some 92% of respondents indicated either a 4 (45%) or 5 (47%) level of support for BC Hydro’s current $10 billion, 5 year upgrade program on a scale of 1-5 (1 being not at all supportive and 5 being highly supportive). These upgrades include generation station and transmission infrastructure upgrades, such as the ongoing $1.1 billion seismic upgrade of the John Hart Dam, directly adjacent to the city in the Strathcona watershed (see fig. 3-4). BC Hydro has stated that BC’s energy demand will increase 20-40% in the next 20 years and that it plans to meet this growing demand by encouraging demand side management (energy conservation) as well as increasing its generation capacity through the construction of the recently approved 1100 MW Site C dam in northeastern British Columbia. Site C has received mixed levels of support in BC with concerns about its high $8.8 billion construction cost and environmental impacts, which include the loss of traditional aboriginal as well as valuable agricultural lands (Feinstein, 2010). When asked whether they had heard of Site C, 73% of respondents said yes. The mean level of support for construction of Site C was 3.19 on a scale of 1-5 with 1 being “not at all supportive” and 5 being “highly supportive” (see fig. 3-6).

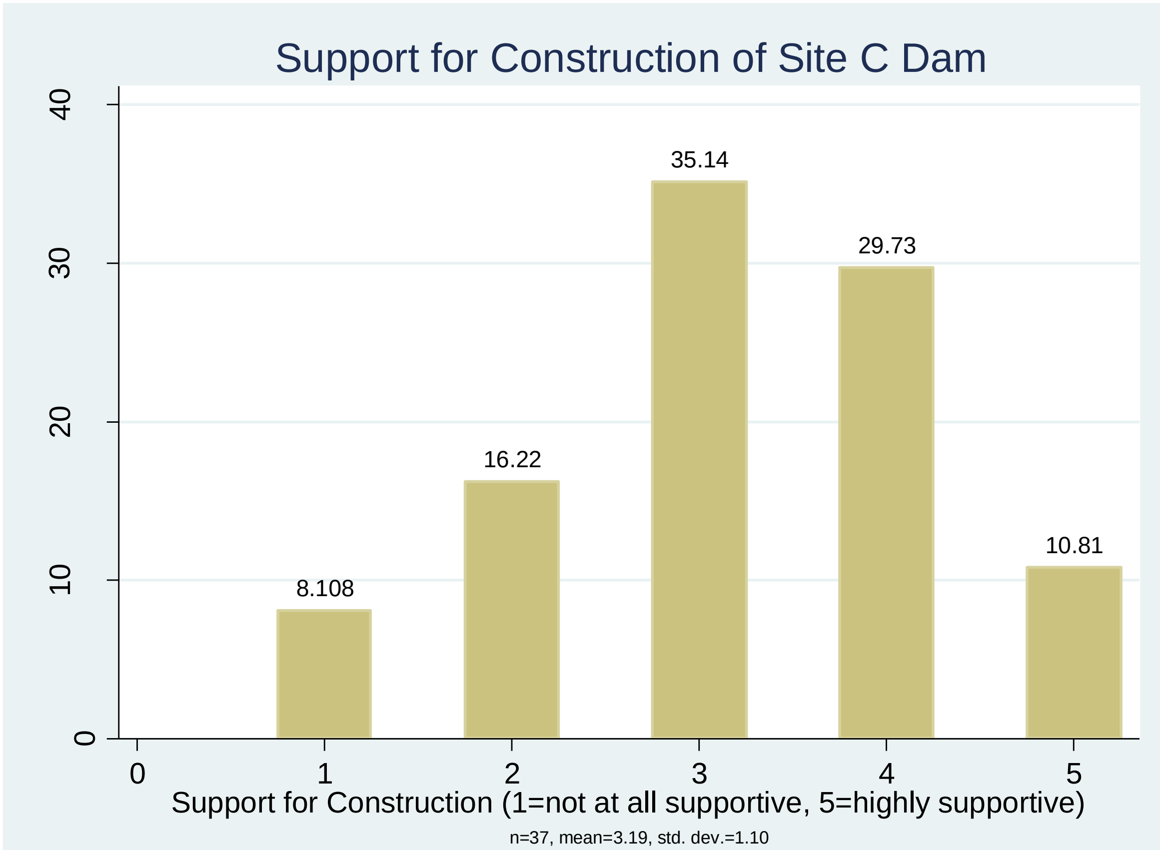

Figure 3-6: Respondents' support for the construction of the Site C dam in BC's northeastern region in order to meet increasing power demand.

Respondents were finally told about the centralized nature of BC's power grid. Roughly 80% of BC Hydro's generation assets are located either in the southeast (Columbia River Basin) or northeast (Peace River) extremities of the province, at distances of 400-800km from the predominant load centres of lower mainland Vancouver and Vancouver Island. These two areas combine to hold 3.6 million people or 78% of BC's population, yet they only have about 17% of BC Hydro's generation capacity (BC Hydro, 2015; BC Stats, 2014). In fact, Vancouver Island on average generates only 10-20% of its own energy and only 3.9% of BC Hydro's average total energy generated (BC Hydro, 2013; BC Hydro pers. comm., 2014; see fig. 3-7). Between BC Hydro's Island based heritage hydroelectric assets (max generating capacity 459 MW) and the Island Gas private Natural gas generating company (max generating capacity 200 MW), Vancouver Island can only generate a maximum of 28.6% of its load requirements assuming an average mid-load of 2,300 MW (BC Hydro, 2013a). Unless BC Hydro's EPA with Island Gas is renewed in FY 2022, BC Hydro may be required to either increase transmission capacity from the mainland or develop more localized generation assets (see fig. 3-7).

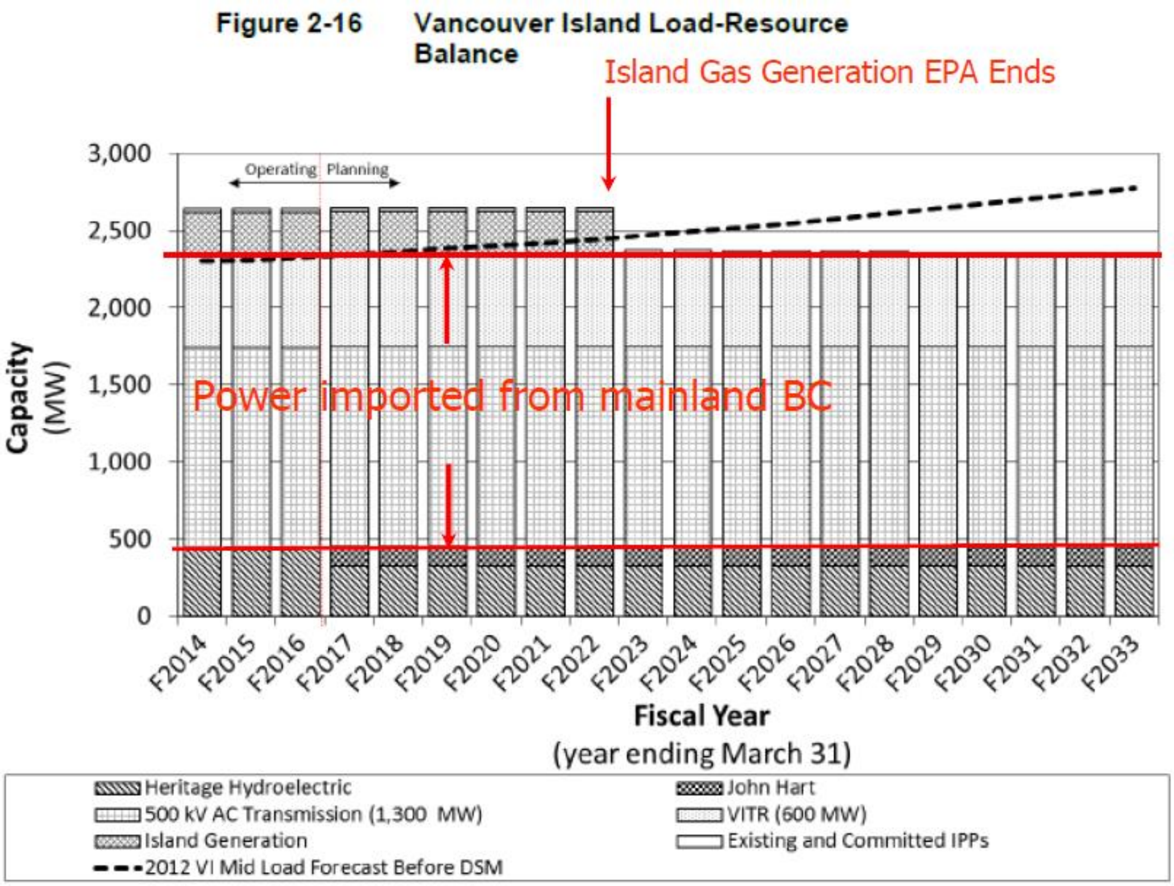

Figure 3-7: Vancouver Island's electrical generation load resource balance. The dashed line refers to the Island's load forecast before any demand side management or energy conservation measures. The areas above and below the red lines represent power generation assets indigenous to the island, including Island Gas natural gas fired plant, which generates and sells power to the BC Hydro grid and whose electricity purchase agreement with BC Hydro is set to end in FY 2022, as well as indigenous hydroelectric dams. The result is that, by FY 2022, if BC Hydro does not renew the PPA with Island gas or increase its transmission capacity from the mainland, it may have to develop additional generation assets on Vancouver Island. Reprinted with permission from BC Hydro, source: (BC Hydro Integrated Resource Plan, 2013).

While BC Hydro maintains a highly reliable electrical grid, the extensive wildfire season of 2014 saw the utility evacuate 200 workers from two of its largest hydroelectric dams, the W.A.C Bennett and Peace Canyon dam, which represent 30% of the utility's generating capacity (BC Hydro, 2015). BC Hydro operating orders reveal that in order to fight forest fires along a transmission line right of way, lines must often be de-energized for safety of personnel in the area, especially in the event that: "flames and smoke may cause a conductive path to be formed between the lines and the ground, the conductive flame retardant may be dropped near the lines by aircraft, or damage to structures may cause line failure" (BC Hydro, 2011, p. 2). Evidently, if forest fires approach transmission lines they could either damage the lines themselves or cause the lines to need to be de-energized in order to ensure personnel safety, possibly causing power shortages or interruptions. Given the long distance which the bulk of

BC's power is transmitted, BC's transmission system is arguably vulnerable to forest fires and possible subsequent outages.

While forest fires were in the news during the study period, the only information which was introduced in the interview was the low amount of power being generated on Vancouver Island and the long distance which power lines have to run from the interior of the province to the coast and then underwater to Vancouver Island in order to provide electricity. Respondents were also asked how reliable they felt their electrical system was in relation to this information. Across all stakeholder groups, a mean rating of 3.45 out of 5 (σ=0.92) was given, with 1 meaning that the grid was not at all reliable and 5 meaning that it was very reliable (see fig. 3-8). Reliability was defined to the interviewees as being the amount of time which the electrical system was fully operational and providing energy to its customers in the face of natural or other man-made disasters. When asked whether they wanted more generation assets on or near Vancouver Island, subjects gave a mean response of 4.23 (σ=0.79) out of 5, 1 being not at all supportive and 5 being highly supportive indicating their strong support for the idea.

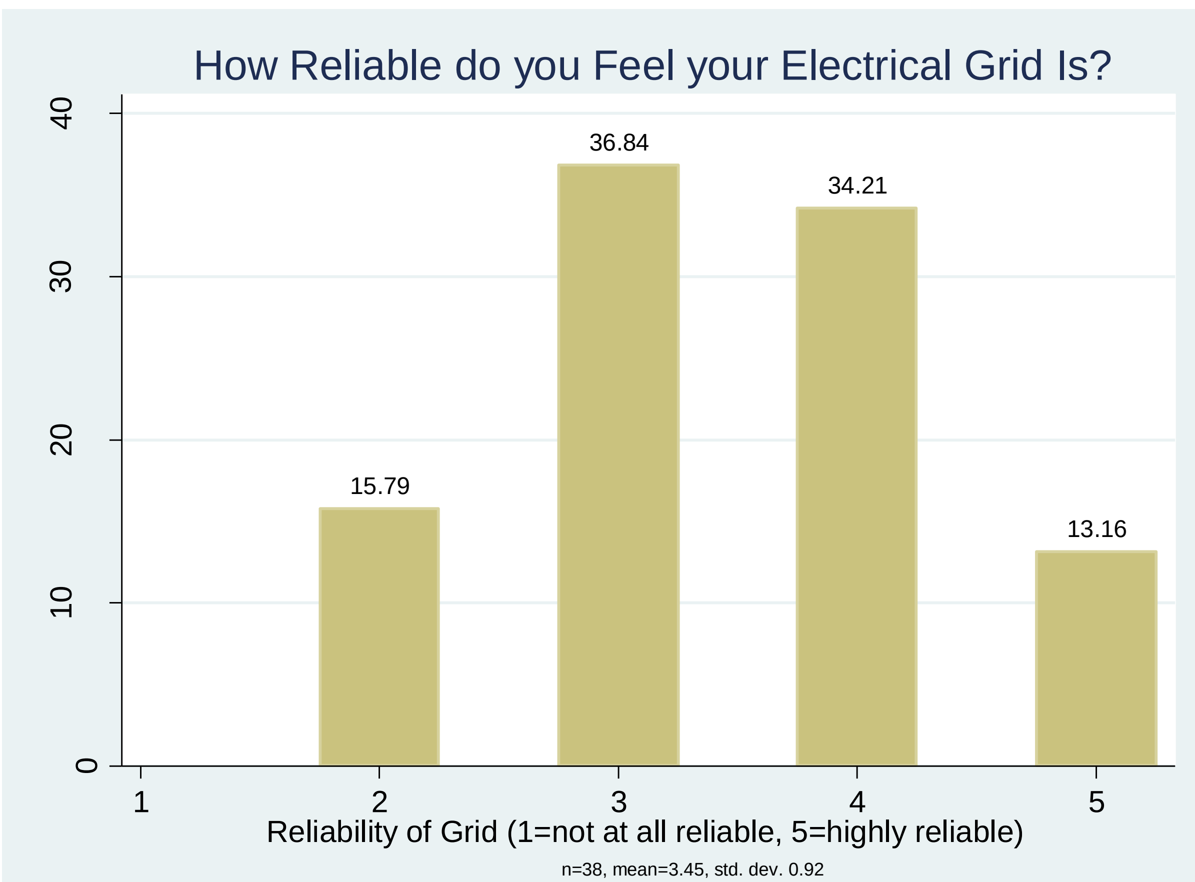

Figure 3-8: Perceived reliability of the local power grid. Reliability was defined to respondents as “the amount of time that the electrical system is fully operational and providing energy to its consumers in the face of natural disasters or other man-made disasters.”

Respondents were given some additional information around where BC Hydro procures its power from: in 2014, 20% of it was generated from independent power producers (IPPs), 60% of which came from run-of river hydroelectric plants (BC Hydro, 2014). Subjects were then informed of BC’s other energy alternatives such as wind, geothermal, biomass, natural gas, wave, nuclear and tidal power and then asked to rank which attributes they felt were most important considering where their power came from. There were a total of nine options, which subjects were asked to rank in order of importance to them from one to nine, one being the most important choice and nine being the least important. Respondents ranked low environmental impacts, low GHG emissions and low cost, as well as high reliability as most important; having one’s power supplied by BC Hydro versus a private or community owned independent power provider (IPP) and the self-sufficiency of BC’s power supply were seen as least important (see table 3-1).

Mean Ranking (all respondents)	Preferred Energy Attributes Ranked in Order of Importance
2.78	Local environmental effects of energy developments
3.11	Cost to me on my monthly power bill
3.28	Reliability of energy technology
4.33	GHG emissions from energy sources
5.03	Impacts of climate change on the energy sources
5.17	Cost of developing green energy sources as alternatives
5.47	Self-sufficiency of BC's power supply
7.64	Having your power from BCH vs. private IPP
7.97	Having your power from BCH vs. community owned IPP

Table 3-1: Mean ranking across all respondents of preferred energy attributes when considering “where your energy comes from in BC.” (Rank 1-9, 1 being most important, 9 being least important).

In section 3 of the interview, subjects were given more information on energy in BC and introduced to tidal energy (they were sent this information briefing in advance of the interview as well). The basic operating principles of heavy storage hydroelectric in BC were discussed along with the projected significant impacts of climate change on hydropower in the future due to loss of snowpack from global warming, as well as some research on methane emissions from hydroelectric reservoirs and the high global warming potential of this gas. Tidal energy was introduced including basic operating principles, research on impacts to marine life, state of the industry worldwide, BC's tidal resource potential and a brief discussion on the currently high costs of tidal.

Following section 3, tidal energy was ranked as one of eleven different energy technologies on the criteria of environmental impacts, economic benefits, technical feasibility, cost and reliability. Tidal was ranked reasonably favourably in all 5 categories. Tidal ranked 4th behind storage hydroelectric, natural gas and run-of river in terms of providing economic benefits. Economic benefits were qualified as "boosting the local economy and providing reliable long term jobs in BC". Given the amount of press coverage given to hydro dams and LNG (as well as traditional natural gas, or NG, which has long operated in BC prior to LNG) it is not surprising that these two technologies received high ranking as they are the current incumbents of the BC energy sector, along with run-of-river hydro. The economic benefits to developing tidal energy in Campbell River was also clearly a priority amongst respondents, a notion which will be further examined in the next section of this paper. Respondents were asked to rank energy technologies from worst to best in terms of having "adverse environmental effects in BC." Tidal ranked 9th, just in front of wind and solar power which ranked lower in terms of environmental impact. Coal, nuclear fission, natural gas and large storage hydroelectric were ranked as most damaging to the environment. It is worth noting that natural gas and large hydropower also ranked high for economic benefits and that the John Hart Dam upgrade project was underway at the time of the survey and Quicksilver LNG had also recently bought the closed pulp mill site for a potential LNG station in Campbell River.

Costs Perceptions and Estimates for Tidal

Tidal energy ranked 5th for its perceived costs of development in BC behind nuclear fusion, nuclear fission, geothermal and wave energies. Respondents were asked to rank the technologies in terms of "cost to build, install, operate and maintain the technology in BC." The part 3 information briefing cited research from the UK which stated that costs of tidal energy development were currently between \$0.37-0.57/KWh but indicated that with about 400 MW of TE development, these costs could fall by as much as half as a result of principles of economies of scale (Carbon Trust, 2011). Parallels were drawn between tidal energy and wind 35 years ago, showing levelized costs of energy (LCOE) and installed capacity for land based wind energy in the US dating back to 1980.[11] The graph presented showed dramatic installed

[11] Levelized costs of energy systems generally take into account the capital cost of constructing the plant as well as the fixed and variable operation and maintenance costs, and cost of borrowing the capital, amortized over the

capacity increases and unit cost reductions as time progressed (see fig. 3-9). Finally, BC Hydro's stated levelized costs of energy for the Site C project were mentioned at $0.082/KWh over the 100-year lifespan of the dam, showing the far cheaper cost of heavy hydroelectric in BC. It was also mentioned, however, that BC Hydro is in the midst of a 28% rate hike over 5 years, which will render the average consumer's electrical rates higher than the stated levelized cost of Site C. In addition, any cost of carbon for possible reservoir methane emissions are not factored into the calculation, nor are potential hydropower revenue losses due to dwindling snowpack and summer runoffs in the Peace River watershed. Finally, BC Hydro's discount rate and assumed cost of borrowing is far lower as a publically funded utility at about 5% (BC Hydro, 2013b). In comparison, tidal energy projects in the UK assume a much higher discount rate and assumed cost of borrowing of 15%, due to higher financing costs at private banks and other sources, which charge more interest than government institutions (Carbon Trust, 2011).

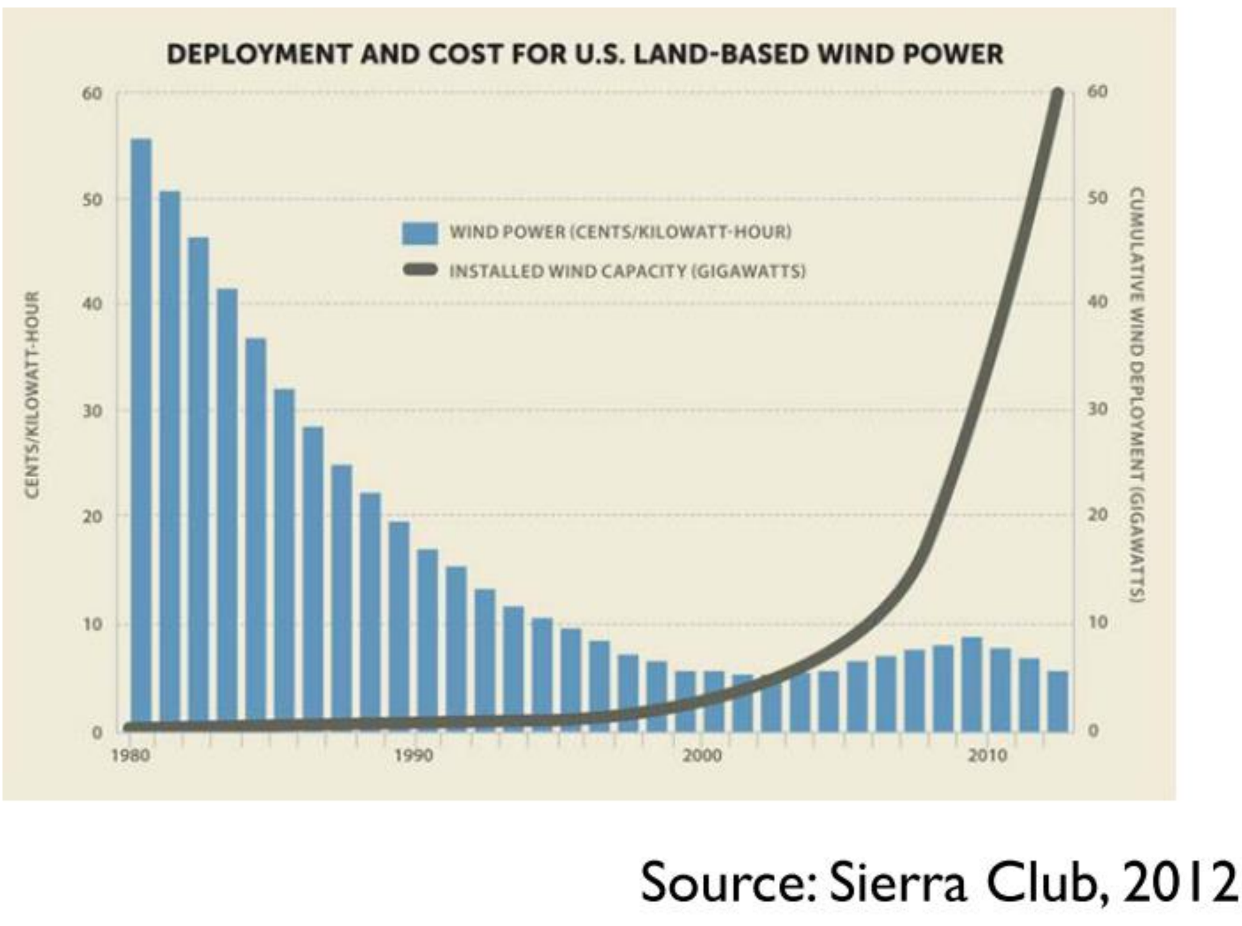

Figure 3-9: Unit levelized costs (USD) and installed generating capacity (GW) for wind in the United States 1980-2012. Reprinted from Sierra Club website with permissions from Sierra Club. ©[2016] Sierra Club. All Rights Reserved. Source: www.sierraclub.org.

lifespan of the project. This product is then divided by the total estimated energy generated by the plant, producing an average unit cost of electricity, in dollars per KWh or MWh of energy generated (Rubin, 2001).

As an example, a financial calculation of the LCOE of Site C versus a 111 MW tidal site, situated in the ILs areas near the City of Campbell River will be considered here. 111 MW was used as it is 10% of the total estimated kinetic energy present at both Seymour Narrows and Discovery Passage, a ratio estimated to be ecologically sustainable by early research (Hagerman & Polagye, 2006; Karsten et al., 2011). Based off the latest tidal techno-economic literature out of the UK, the nascent nature of the industry and the lack of any array scale multi-turbine installations makes it difficult to estimate operations and maintenance (OM) costs (Carbon Trust, 2011; Magagna & Uihlein, 2015). Thus, the calculations presented below will not include OM costs. In addition, calculations will assume a 5% discount/interest rate and a uniform annual cost of borrowing.

- Based off a current total estimated capital cost of $8.8 billion for the 1100 MW Site dam, the cost per MW of installed capacity is $8 million. The plant is estimated to generate 5100 GWh of energy per year, meaning it will be running at about a 53% capacity factor on average and will generate a total of 5100 TWh of energy over its planned 100 year lifespan.[12] This average level of generation does not factor in reduced future reservoir inflows due to climate change, which is a real potential generation loss for the dam especially far into the future.
- Tidal energy plants are currently being constructed at estimated capital costs of about $6-7 million per MW, capacity factors of 35-40% and project lifetimes of 20-25 years (Magagna & Uihlein, 2015).
- Assuming that BC Hydro borrows the $8.8 billion at a 5% interest rate repaid over a 50 year timeframe, their uniform annual cost of borrowing is $558 million. Over 50 years this number equates to a total cost of borrowing of $27.9 billion in present day dollars.[13]
- Thus, based solely off the capital costs, cost of borrowing and total estimated energy generation of 5100 TWh over the 100-year life of the project, the levelized cost of energy for Site C is $0.072/KWh. This number is slightly lower than BC Hydro's estimate of $0.083/KWh due to the lack of incorporation of OM costs in order to compare with a similar tidal energy project (BC Hydro, 2013b).[14]

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[12] 1100MW x 8760 hrs./year=9.6 GWh/year at 100% capacity. 5.1 GWh/9.6 GWh = 0.53 or 53% capacity factor.

[13] Uniform annual cost of borrowing $= U = \$8.8\ billion \times (\frac{0.05}{1-(1+0.05)^{-50}})$ = $558 million/year × 50 years = $27.9 billion.

[14] Site C LCOE= $\frac{CAPEX+OPEX}{ENERGY} = \frac{\$8.8\ billion + \$27.9\ billion}{5100\ GWh \times 100\ years}$ = $0.072/KWh

- A 111 MW tidal project with a lifespan of 25 years operating at 40% capacity factor will produce a total of 9,720 GWh of energy.[15]
- At $6 million/MW, capital costs for the total plant will be $666 million. At a 5% interest rate amortized over a 15 year loan, the uniform annual cost of borrowing will be $64 million/year for a total cost of borrowing of $962 million in real present day dollars.[16]
- Given the cost of borrowing, capital cost and total energy generated, the LCOE for this tidal plant would be $0.167/KWh, just over double the costs of the Site C dam.[17]

Clearly, there have been numerous assumptions made in order to come to these conclusions, namely a lack of OM costs, decommissioning costs, as well as uncertainties over capital costs, capacity factor and project life for tidal. In particular, OM costs for tidal would likely be substantially higher than a heavy hydro project, due to the corrosive effects of seawater on equipment. Granted, the two projects' lifespans are not the same, however, assuming present day real dollars are used throughout all calculations, multiplying tidal energy's capital costs, costs of borrowing and energy generated by a factor of 4 in order to match Site C's lifespan, will produce the same LCOE as over 25 years. The LCOEs for both tidal and storage hydroelectric highlights the importance of both interest and discount rates and the general cost of capital in financing renewable energy projects. The comparison also shows that commercial scale tidal would be far cheaper to do with publicly backed money. Finally, it must be noted that uncertainty around long term Site C energy generation in face of climate change was not built into this calculation and that it would very likely negatively impact generation due to loss of snow and glacial pack and therefore would drive levelized costs up. Also, the storage capacity of the reservoir would certainly decrease over time due to erosion and siltation and also contribute to reducing generating capacity over time. It was unclear from the documents reviewed whether BC Hydro factored these additional external factors into their calculations.

Remaining Energy Ranking Questions

In terms of technical feasibility, meaning "how easy it is to build, develop, and bring into mainstream operation in BC", tidal energy was ranked 4th on average, behind wind, storage hydroelectric and run-of river hydroelectric, being ranked from most feasible to least feasible

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[15] Tidal total energy = $111MW \times 8760\frac{hours}{year} \times 0.40\,cf \times 25\,years = 9{,}720\,GWh$

[16] Uniform annual cost of borrowing $= U = \$666\,million \times (\frac{0.05}{1-(1+0.05)^{-15}})$ = $64 million/year × 15 years = $962 million.

[17] LCOE tidal = $\frac{CAPEX+OPEX}{ENERGY} = \frac{\$666\,million+\$962\,million}{9{,}720\,GWh} = \frac{\$1{,}628\,million}{9{,}720\,GWh}$= $0.167/ KWh

(see table 3-2). It should be noted that several respondents asked "what feasibility meant" and chose to incorporate their own beliefs as to whether such technologies would be able to achieve social license for development in BC. For example, coal, nuclear fission and nuclear fusion were ranked last, not necessarily because they weren't deemed technically feasible by respondents, but because, upon questioning, many indicated that they perceived them as not having enough social license in order to be built in British Columbia.

Energy Source	Mean Ranking (most feasible to least feasible)
Wind energy	3.51
Storage hydroelectric	3.77
Run of River Hydroelectric	3.97
Tidal energy	4.43
Solar	5.03
Natural gas	5.74
Geothermal	6.40
Wave	6.49
Coal	7.40
Nuclear energy (fission)	8.71
Nuclear fusion	10.54

Table 3-2: The average ranking of feasibility to develop11 different energy systems with potential for installation in BC. Respondents were asked to rank all 11 energy technologies in order from 1 to 11, 1 being the most feasible and 11 being the least.

Finally, tidal was ranked 2nd behind only storage hydroelectric for reliability, meaning "the amount of time which the technology is producing consistent electricity available for human consumption." Tidal was followed by natural gas, wind, run of river and solar power. Being that most respondents were familiar with the tidal flows within the study area (the Discovery Passage flows right past the shores of downtown Campbell River), their perception of reliability may have been heightened. Respondents were told in the information briefing that tidal energy was reliant on the moon and sun's gravitational fields and therefore very predictable, but were also told that our current, storage hydroelectric grid is highly reliable and secure. They were also told that wind and solar power are not predictable.

3.3.2 Factors Affecting Support for Tidal Energy

Levels of support for TE development within the community were found to be closely tied to and contingent upon two key factors: the perceived impacts and benefits of the technology. The livelihood risks were perceived by respondents to negatively impact them directly (i.e. create risks for their equipment, require changes in the operations, etc.) while the perceived benefits were more diffuse and would accrue to the region in general, should the projects be constructed. The risks and associated impacts of tidal energy were largely perceived due to the direct physical risks posed by the turbines or their installation possibly impeding or striking marine traffic or animals and otherwise obstructing the channel. The perceived benefits were more associated with regional scale socio-economic and environmental benefits including hydroelectric reservoir water conservation, job growth and regional energy independence.

3.3.3 Perceived Impacts

Perceived negative livelihood impacts included: TE arrays affecting spatial usage, such as in the case of sport fishers where the fishers perceived an inherent spatial incompatibility between their fishing and TE. Secondly, marine spatial interference was perceived as being a problem, as in the case of TE operations obstructing a channel during install and maintenance periods, or causing towline snags and corresponding dangers to the towboat community once they were installed. Thirdly, impacts of TE on marine life were defined by users as being a significant concern; this could be attributed to the reliance which much of the city had on fishing and eco-tourism. Finally, high possible cost of TE development was also seen as a possible livelihood impact by interviewees. Sportfisher conflicts were defined as being "spatially incompatible" as it was apparent that the sportfishing practice in Campbell River could not co-exist in the same space as tidal energy. The term "spatial interference" was used for shipping as it was apparent that shippers were likely more able to co-use the tidal energy space despite some specific conflicts.

Stakeholder Group	Mean Perceived level of conflict (1-5)
Sportfishing	3.00
Environmental	2.33
First Nations/ Cultural	2.33
Shipping	2.00
Eco-Tourism	2.00
Marina	2.00
Regulatory	1.75
Aquaculture	1.33

Table 3-3: General conflict scores, averaged by stakeholder group. 1 meant no conflict was perceived to exist between the stakeholder's operations while 5 indicated a high degree of perceived conflict existed.

It should be noted that measures of support for tidal energy were made prior to the interviewees seeing the ILs, and levels of conflict were measured after. Levels of conflict were measured both generally on a 1-5 scale (see table 3-3) and stakeholders were also given the opportunity to draw up to 3 conflict polygons onto the IPAD in relation to the ILs and were then asked the severity of these polygons (again on a 1-5 scale), as well as the reasons for the conflict areas. With many stakeholder groups, high levels of support and willingness to pay for tidal energy were observed prior to seeing the ILs. However, these opinions often changed after seeing the ILs with perceptions of general levels of conflict increasing. This concept is common with renewable energy projects and has been observed in a u-shaped curve in studies documenting support for wind projects in their planning and proposal phase but then declining support in the actual project description and implementation phase, with a final recovery of support in the actual successful subsequent development of the sites (Wolsink, 2007).

Spatial Incompatibility: Sportfishers

Sportfishers perceived a high degree of general and spatial conflict between TE and their activities to the extent that the two resource uses would likely be incompatible within the same space in this study area. Their rating of general conflict was the highest amongst all 8 stakeholder groups (see table 3-3). As well, their mean number of conflict polygons identified was 1.2, which was the 3rd highest, and the group's mean conflict polygon severity score was 2.6 out of 5, and the 4th highest. In addition, the anecdotal accounts and the conflict severity rankings amongst the direct sport fisher guides amongst the group were even higher, as opposed to "indirect sport fishers" or members of the group who did not fish the IL areas frequently or directly. The two active sport fishers were commercial fishing guides, whose job was to take customers out in small boats and help them catch salmon. The remaining 3 subjects interviewed were related to the sport fishing profession, such as being tackle store owners of sportfishing club managers, but did not directly make their living based on their ability to catch fish on a frequent basis. A good sport fishing guide could make upwards of $800 (CAD) per day of guiding work and generally would work every day from June until October when salmon season was at its peak. Hence, their livelihood was arguably most directly connected to the ability to freely fish within the study area and their conflict scores specifically reflected this: both direct fishers cited large conflict polygons spanning the bulk of southern Discovery Passage and assigned conflict severity scores or 4 and 5 respectively and their general conflict scores were also 4 and 5 respectively, citing concerns around "snagging downrigger cables." These guides described salmon fishing in Campbell River as being a "bottom of the ocean thing", and their gear was utilizing downriggers, or heavy lead balls attached to their boats by thin steel wire, in order to put their lines on or near the ocean bottom in order to catch the largest salmon. The stated risk they saw of snagging their downrigger balls and cable onto a tidal turbine, especially in strong tidal currents could be to “capsize their boat”, “snap their wire” or otherwise cause serious damage or injury to themselves or to the tidal turbine (see fig. 3-10).

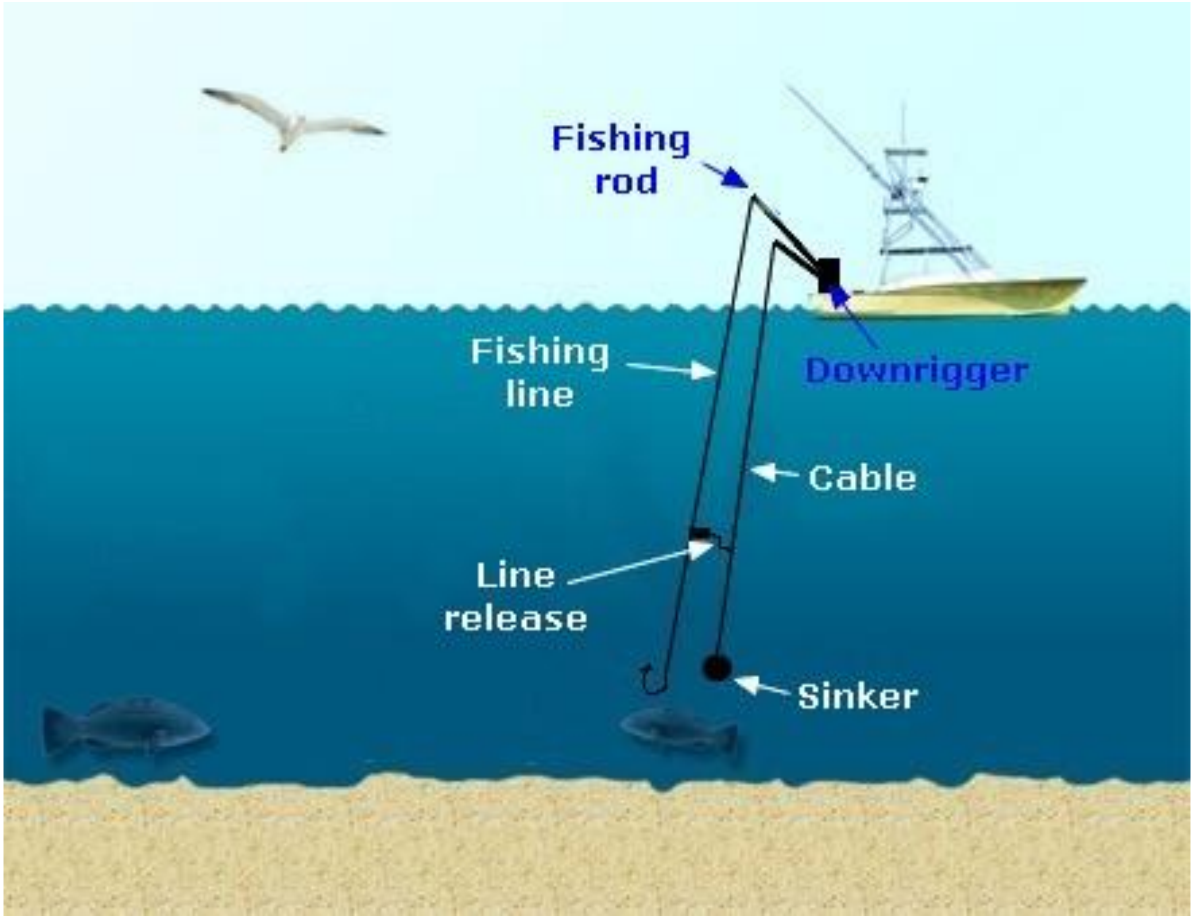


Figure 3-10: An artist’s depiction of a sportfishing boat engaged in downrigger fishing. The sinker is typically about a 10 lb. lead ball attached to the boat by a steel wire. Sport fishers in the study area reported fishing right near the bottom of the ocean. Reprinted with permission of Hookline, source: www.hookline-fishing.com.

Specific perceived risks amongst the entire sportfisher stakeholder group (not just the direct sportfishers) were most clearly associated with a “barrier effect” being caused by tidal turbines or the snagging of fishing gear on such tidal turbines. Also, while fishing gear snagging was not a listed risk in the risk perceptions choice prioritization question, one of the guides did list it and gave it 20 tokens. The sport fisher group did not overly concern themselves with the possibility of the turbines directly harming the fish, only with the risk of barrier effect, fishing gear snags and excessive expense to the ratepayer of developing tidal energy as the top three responses (see fig. 3-11). Barrier effect is explained further in the section “Barrier Effect and Impacts of TE on Marine Life”, located in this chapter.

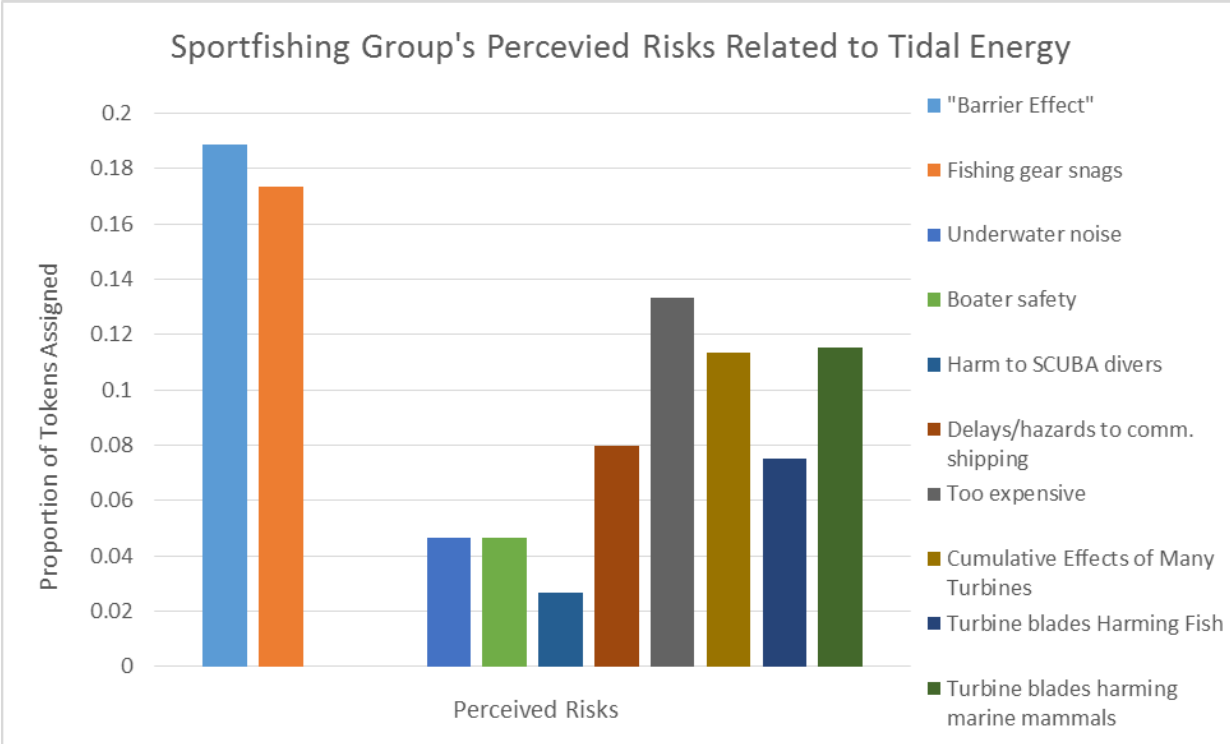


Figure 3-11: Response amongst Sport fishing stakeholder (n=5) group to top perceived risks associated with tidal energy development. Respondents were given 30 tokens to divide amongst nine listed risks; respondents were also able to add their own risk categories if they wished. Added risk categories included fishing fear snags, construction impacts, and no risks (latter two not indicated here due to zero response).

Spatial Interference: Boating and Shipping

Secondly, spatial interference to boating and shipping traffic was perceived as being a problem relating to tidal energy. The video shown to all respondents, depicted a tug and barge lowering a large turbine into place on the sea floor. Many stakeholders and First Nations viewed the potential tidal energy install and maintenance operations as being inherently obstructive of shipping and general boating activities. As well, there was concern from all large shipping operators over the depth of the turbines and the resulting surface clearance, particularly amongst the tug boat community whose tow cables reportedly sometimes droop low into the water column, apparently even dragging and snagging on the sea floor on occasion.[18] Overall, amongst all stakeholder groups, “delays and hazards to commercial shipping” ranked 4th highest amongst possible risks associated with TE development in BC, while barrier effect was the highest rated risk across all respondents, even though its concept was largely theoretical and unproven and would only pertain to a very densely positioned array of tidal turbines (see table

[18] The risk of tow cables snagging as with all other identified risks in this Thesis are based solely on the comments from the stakeholders surveyed. No secondary field or desktop research was carried out by the Author in order to determine the frequency of tow cables snagging the bottom or the depth that tow cables may droop, within or near the study area, in order to further quantify this risk.

3-4; discussed further in section “Barrier Effect and the Impact of TE on Marine Life”). When examined amongst the shipping stakeholder group alone, however, which accounted for nearly one-third of study respondents, delays and hazards to commercial shipping got a large allocation of tokens as being the greatest risk of TE installations in the area (see fig. 3-12). It should be noted as well that these responses were elicited prior to the interviewees even seeing the IL sites where the turbines were proposed to be installed.

Risk Perception	Mean Proportion of Tokens Used
"Barrier effect"	0.15
Too expensive	0.14
Cumulative effects of many turbines	0.14
Delays and hazards to commercial shipping	0.12
Harming mammals from blade strikes	0.11
Harming fish from blade strikes	0.09
Too much underwater noise	0.08
No perceived risks*	0.07
Recreational boater safety	0.04
Snagging fishing gear*	0.02
Harming SCUBA divers	0.02
Construction impacts*	0.02

Table 3-4: Ranking of perceived risks related to tidal energy development amongst all respondents in terms of proportions of tokens allocated. Respondents were given 30 theoretical tokens to divide between their risks of choice with more tokens being assigned to their riskiest risks. N=37. *Denotes risks which were added to the survey by respondents.

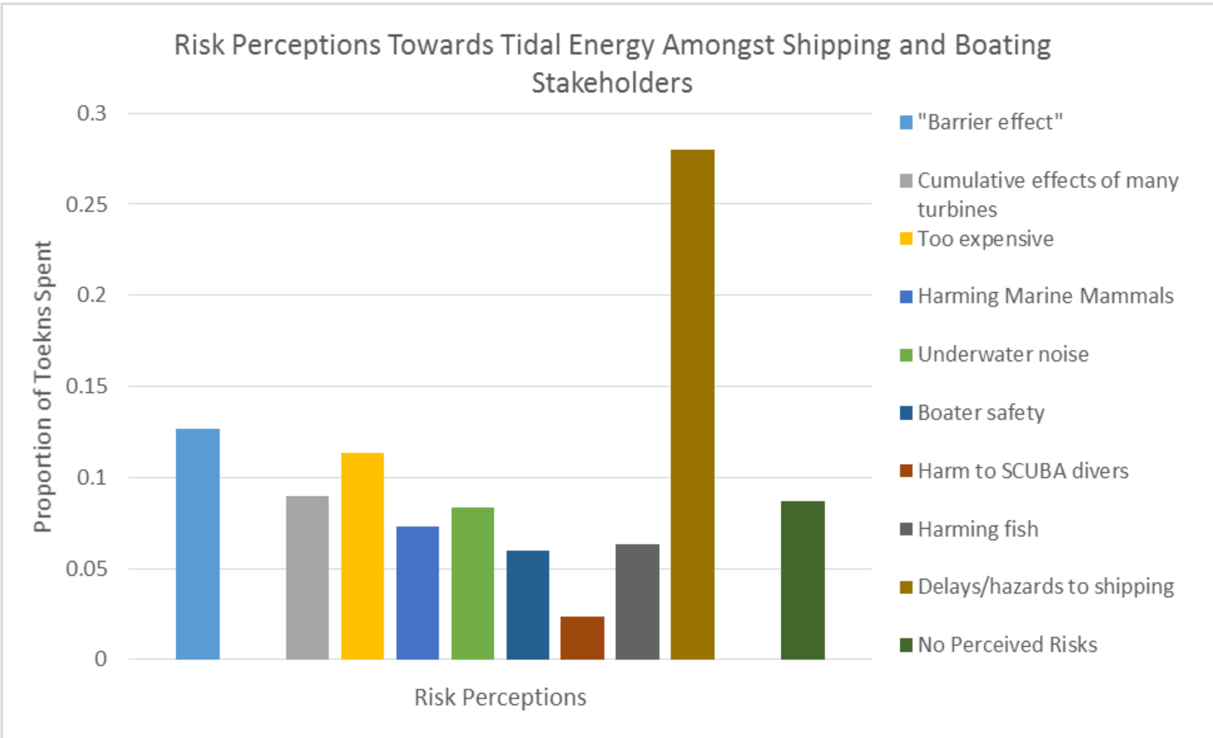


Figure 3-12: Ranking of perceived risks related to tidal energy development amongst shipping respondents only, in terms of proportions of tokens allocated. Respondents were given 30 theoretical tokens to divide between their risks of choice with more tokens being assigned to their riskiest risks. N=10.

The large number of tug boats towing barges regarded their tow cables as a significant risk and a navigational hazard in relation to any proposed tidal energy installations. Tug boats and barges of various sizes transit the area with anywhere from 75-396m of steel cable connecting the tug to the barge. While the cable is generally fairly taut and within 10m of the surface as described by 2 of 4 tug boat operators interviewed, there was concern that in areas of tidal eddies and turbulence that the barge could surge closer to the tug and cause the cable to sag down and potentially snag a turbine. Such a risk was described by tugboat operators as very serious and some of them assigned high degrees of general conflict and spatially specific conflict in relation to the IL locations as a result. However, it was also determined that areas of "towline surge" risk were generally at corners in a channel and areas where significant eddies, turbulence and tidelines occurred, causing different bodies of water to move at differing speeds and the tug and towed vessels to correspondingly shift positions and cause towline surge and potential risk of snagging (see fig. 3-14). This information was thus very important for tidal energy developers as it clearly identified areas where risk of towline surge occurred, and that these areas would likely be advisable to avoid for tidal turbine installations.

Figure 3-13: A photo of an ocean going tug boat towing its container barge, very similar to the class of tugs and barges used through the Discovery Passage study area. The likely position of the tow cable is indicated in red. The catenary (dip) in the cable is caused by its heavy weight and is deliberately intended to provide elasticity in the system to prevent shock loading. Reprinted with permission from Clark Crawford, source: www.marinetraffic.com

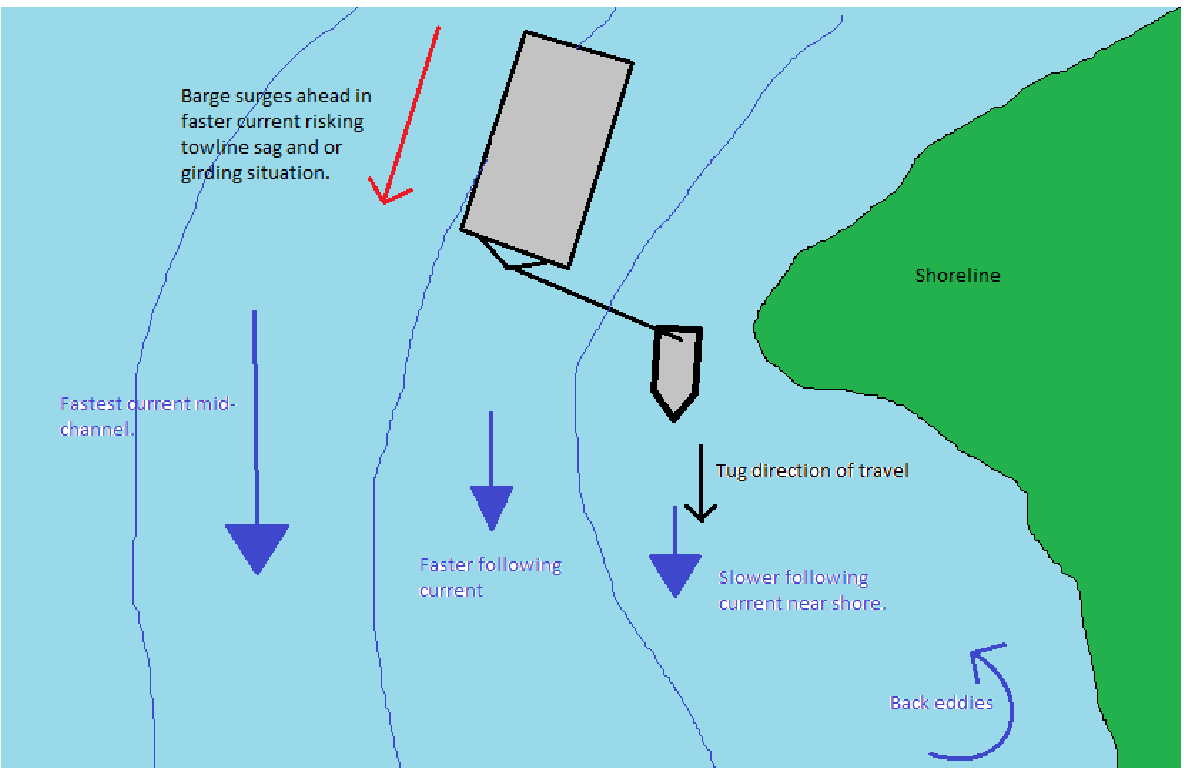


Figure 3-13: A theoretical situation depicting towline surge, whereby the tug and the barge are caught in different portions of the tidal stream which are moving and different velocities, thus causing the barge to surge closer to the tug. This condition is very dangerous for a tugboat operator as the tow cable can either sag deep into the water and possibly snag, or become taut if the barge veers far away from the tug. A taut tow cable can cause a "girding" situation whereby the barge can capsize its tug. Source: author.

In the final part of the interview, when respondents were shown the site ILs specifically, identified spatial conflict related to marine traffic interference was even more pronounced. Some 72% (28 of 39) of all respondents identified a spatial conflict area after they were shown the IL sites. 11 out of these 28 respondents cited marine traffic interference as the primary reason for their conflict area, while another 4 respondents cited snagging tow cables or risks of marine emergency as a concern and 3 more respondents cited technical feasibility as being a major issue. Technical feasibility was regarded as the inherent difficulty which several respondents believed existed related to installing any tidal turbines in the study area due to the dangerous currents, whirlpools and previous marine accidents. Many of the respondents were expert mariners with strong knowledge of local waters and they shared their perceptions that the development of a tidal energy installation at the northern IL site, known as Seymour Narrows, would be a high risk to navigation. They also expressed the danger of situating any TE working vessel within the Narrows for any length of time due to very short periods (reportedly 15-20 minutes) of slack water. In total, technical feasibility, marine traffic interference and towline snags/marine emergencies accounted for 18 out of 28, or 64%, of stakeholder and First Nations conflict polygons related to the proposed tidal energy installations. The majority of the these conflict polygons were also associated with the northern IL at Seymour Narrows, indicating greater perceptions of marine traffic interference and hazards related to that particular site than the southern, Cape Mudge IL site.

During interviews, the local Coast Guard station staff expressed the unofficial opinion that if tidal energy operations were to be conducted within Seymour Narrows (location of the northern IL), marine traffic would have to be restricted from transiting through the Narrows for safety reasons for the duration of the operations. This statement, however, did not necessarily reflect the policy or views of Transport Canada or the Canadian Coast Guard. The notion of potentially restricting the narrows to marine traffic during periods of tidal energy installation and maintenance was subsequently shared with 7 other interview subjects during discussions on the ILs. For all of these 7 interviews, the information was introduced during part 5 of the interview. It soon became apparent that the sharing of this information elicited strong negative responses, from one respondent in particular, and may have heightened conflict perceptions amongst some stakeholders. Given that the Coast Guard official's opinion did not represent Transport Canada or Coast Guard policy, the researcher did not subsequently mention the Coast Guard staff's opinion, on the grounds that it could bias the responses of stakeholders during the remaining interviews.

Analysis for potential bias was therefore subsequently undertaken, comparing responses within part 5 of the interview between the 7 interviewees who were told the CG officer's opinion and the remaining 32 interviewees who weren't. Results show that on the 3 questions in part 5, results of the 7 were very similar to those of the remaining 32 (see table 3-5). In comparison to table 3-4, of the remaining 32 respondents, a lower 59% indicated having "no" conflict with the ILs (indicating slightly higher conflict with the sites), while the mean general conflict score was also slightly lower at 2.27 (indicating slightly lower conflict), and an almost identical 72% indicated a conflict polygon (indicating similar conflict levels). While the sample size of the potentially biased 7 respondents was much lower and not statistically significant, their responses are remarkably similar to the remaining interviewees. Nevertheless, one interview clearly had a score changed in response to the interview, and saw a marked change in the respondent's behavior in response to the closure information. Thus, this one score was removed from the part 5 results for this study.

subject	conflict with the ILs?	general conflict score (1-5)	# of conflict polygons cited	mean severity scores (1-5)
tug 2	no	3	1	4.5
*cited marine traffic interference is primary reason for spatial conflict				
boat yard 1	no	1	0	0
fish 1	no	1	0	0
cetacean 2	no	2	1	3
aquaculture 1	no	2	1	1
wildlife 1	yes	3	1	5
*cited technical feasibility as primary reason for spatial conflict				
taxi 2	yes	5	1	5
*cited marine traffic interference is primary reason for spatial conflict				
mean score	71% stated no conflict	2.43	71% indicated a conflict polygon	2.64

Table 3-5: The 7 interviewees which had the CCG information on closing the narrows introduced to them and their answers to the Part 5 questions. Red selections indicate strong conflict responses, yellow moderate ones, and green low responses. The final subject was the one who changed their general conflict score from 2 to 5 upon hearing the Coast Guard information. Based on the changing of a score in response and the high positive conflict responses in all questions, the last subject's scores were removed from the study for part 5 questions only.

This finding is important to note as well that, slack water, especially in narrow high velocity tidal channels, is an important opportunity for local and non-local shippers to transit the area, and one they do not wish to lose. Every regional heavy shipping operator interviewed from heavy log barges, to cruise ship navigators, to Alaska bound tugs stated that they would arrive at Seymour Narrows within 45 minutes to 90 minutes either side of slack water in order to transit their vessels safely with minimal tidal activity. In addition, many local, smaller operators indicated that if any type of tidal energy related barge operations were occurring in the Narrows, it would potentially endanger their travel in the Narrows. It was also discovered that May through October represents the high season for fishing, boating and shipping in Discovery Passage and that marine traffic-related conflicts would likely be mitigated by conducting any tidal energy work outside of this period. This marine temporal spatial planning analysis is discussed more in Chapter 4 of this thesis.

Barrier Effect and Impacts of TE on Marine Life

Barrier effect was described to respondents as the theoretical possibility that a large number of tidal turbines deployed within a channel could scare marine life that would be passing by the area where they are located, literally causing an ecological barrier effect and interrupting species migration patterns. There is no empirical evidence cited in the literature of barrier effect actually occurring, largely because there is only one set of multi-turbine arrays installed in the world at East River in New York State and limited data has been gathered on it (Federal Energy Regulatory Committee, 2012). However, barrier effect is a theoretical possibility based on field observations of seals and porpoises diverting around a single commercial scale turbine in operation in Strangford Lough and at the European Marine Energy Centre (EMEC) (Copping, A., et al., 2013; Keenan, Sparling, Williams, & Fortune, 2011). With the turbine in operation, radio transponders were placed on seals, while underwater video cameras and active sonar fish finders observed marine mammals diverting their movements around the operating turbine. While the observations indicated no barrier effect per se, it could theoretically occur should numerous turbines be placed in close proximity to one another, due to many repeated small diversions by the marine mammals (Copping, A., 2013; Polyage, Brian, 2010). Thus, for the purposes of this study, the potential risk of barrier effect occurring was described in this interview as “the risk of tidal energy converters (TECs) in a channel scaring marine life from passing by them, thus causing a “barrier effect” within the channel not allowing marine life to pass by.”

There are several important distinctions which must be considered with barrier effect, however, which will be briefly discussed here. First, is the height of the turbines in relation to the depth of the water column; for example, a 25m high turbine sitting on the seafloor in 75m of water would occupy the lower third of the water column only, and would not block the entirety of it, thereby leaving ample vertical sea room for the animals to divert over top of the turbines. Further, research into optimal tidal energy array spacing indicates that turbines are generally spaced at roughly 5 diameters lateral spacing and 10 diameters longitudinally (Bai, Spence, & Dudziak, 2009; Gomez, 2008). This spacing is due to the wake effects of the turbines as they disrupt the tidal stream create a drag force on it and subsequent turbulence downstream. In figure 3-15, typical turbine array spacing is shown for a 10m diameter turbine, indicating lateral spacing of 5 diameters, or 50m, between the edges of the turbine blades and 11 diameters, or 550m, longitudinally between the rows of turbines, with rows being staggered laterally as well. If the turbine array additionally only occupied one-quarter to one-third of the water depth, then ample space could be argued to exist for safe passage of marine life.

Excessive channel blockage by tidal turbines actually functions to cause drag forces on the moving water, slowing it down, rendering its remaining kinetic energy both unsustainable for marine life and uneconomical for the tidal energy project (Bai et al., 2009; Gomez, 2008; Sutherland et al., 2007).[19] The counter argument to this type of spacing, however, is that lower velocity flows are typically present in the bottom 10% of the water column due to surface friction, rendering less kinetic energy there. Therefore, in a 75m deep channel the lowest 25m of it may not present economically developable energy levels and turbine devices may have to instead be positioned higher in the water column. This topic also relates to three dimensional marine spatial planning and is discussed further in Chapter 4 of this thesis.

[19] The formula for kinetic energy from moving water is $P = \frac{1}{2}\,\sigma A v^3$, where A is swept area of the turbine, σ is the density of the water and v is the velocity of the moving water. The cubic function of V dictates that the power output of the tidal or river turbine is exponentially proportional to the speed of the water.

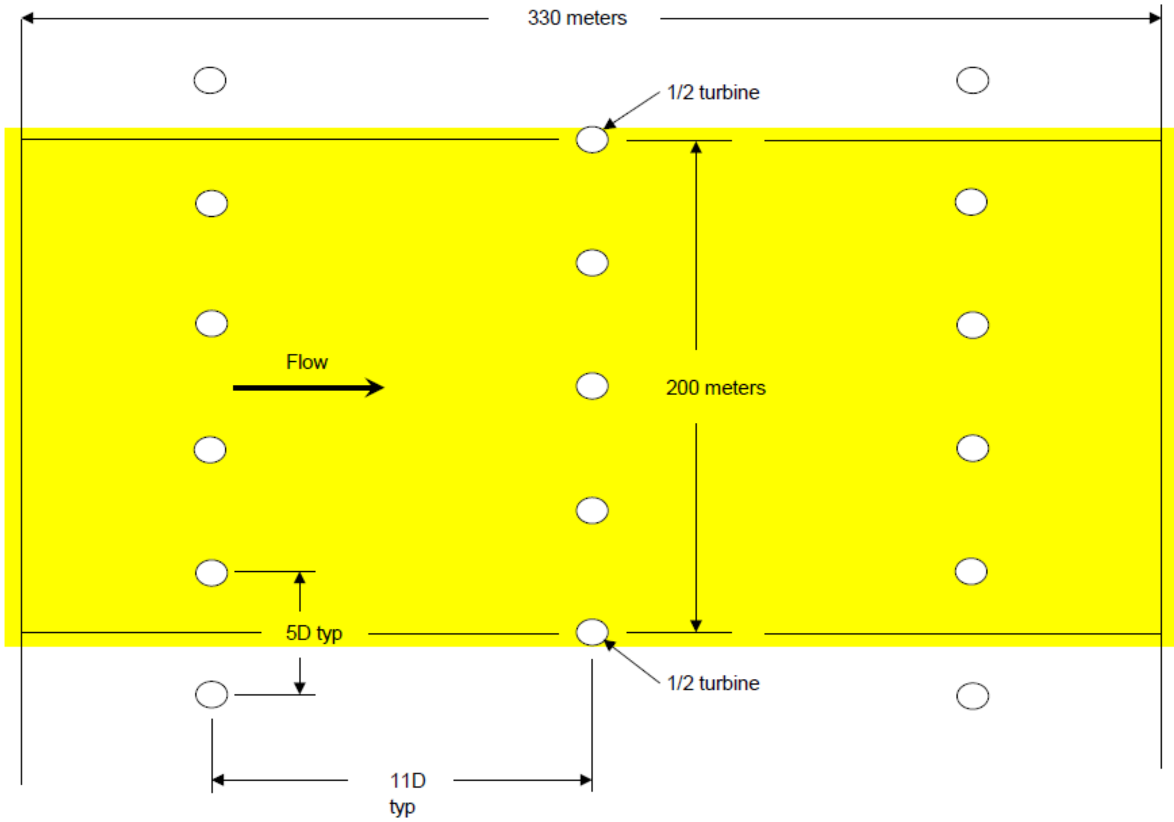


Figure 3-15: Example tidal array spacing diagram assuming 10m turbine diameters. Turbines are spaced 5 diameters apart laterally and 11 diameters apart longitudinally with rows staggered in an effort to minimize turbine wake effect between rows. Source: author.

There was some concern on the specific risks of TE harming fish and marine mammals in the area, particularly amongst eco-tourism operators. This could be attributed to the reliance which much of eco-tourism group had on cetacean and general wildlife viewing. The group consisted of two whale watching companies, one general wildlife watching company and two SCUBA diving companies which operated either recreational or commercial diving schools. Clearly, amongst the group, impacts of TE on marine mammals was the largest concern, followed by cumulative impacts, barrier effect and cost (see fig. 3-16).

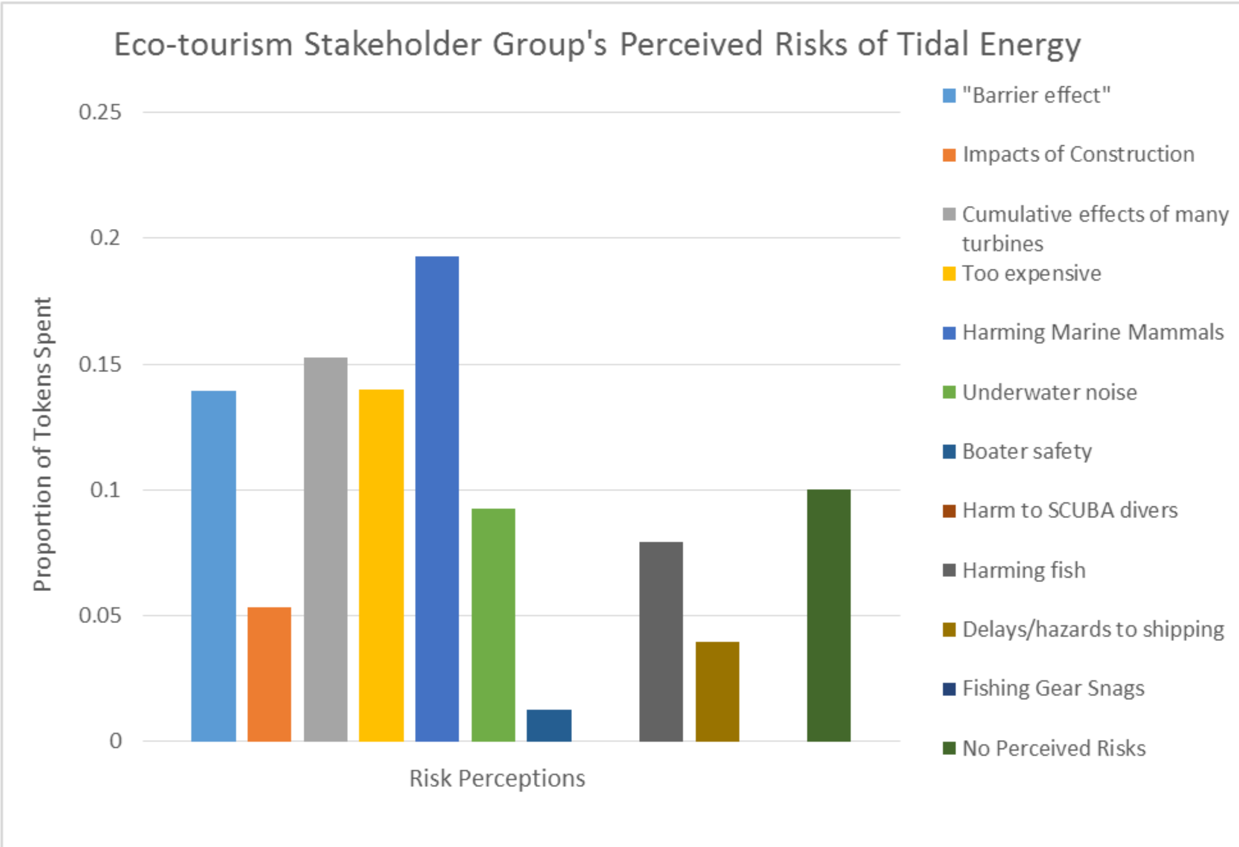


Figure 3-16: Perceived risks in relation to tidal energy development in BC, amongst the eco-tourism stakeholder group.

Overall, the ecotourism group was very supportive of TE, ranking it 4.7 out of 5 as being "a good idea to develop in BC", which was tied for the second highest rating given amongst all 8 stakeholder groups. They also rated it as 2.8 out of 5 as being harmful to marine life (1 being not at all harmful, 5 being very harmful), the second highest rating amongst all groups. After seeing the IL locations, the average ecotourism stakeholder gave a mean conflict polygon severity score of 2.8 out of 5 (5 being the most severe), second highest amongst all stakeholder groups.

Respondents were presented with research on marine life impacts in the information briefing section of the interview which sampled field and laboratory experiments on impacts of TE on marine life assembled by the Ocean Energy Systems group and Thethys database, sponsored by the US Department of Energy Wind and Water Power Division as well as the International Energy Agency. The studies all showed little to no impacts, based on several in-situ observations of active ocean deployed tidal turbines as well as flume tank lab experiments examining fish survivability while passing through tidal turbines tanks (Copping, A., 2013).

During the information briefing, the slow turning speeds of tidal turbines were mentioned (typically 15-20 rpm for commercial scale turbines), as well as marine animals' tendency to divert around turning turbines, but also congregate near them in other instances. Finally, it was stated in the briefing that a lack of multi-turbine deployments has also meant a lack of research on the cumulative impacts of tidal energy developments.

Impacts of the Cost of Tidal Energy

Overall, the perceived risk of cost of TE was the second highest rated risk next to barrier effect, yet was not dominantly favoured amongst any particular stakeholder group except the aquaculture stakeholders (n=3). Respondents were given cost estimates of tidal based on the most current research from the UK (Carbon Trust, 2011). Also, BC Hydro's levelized and capital cost estimates for the Site C dam were provided as comparison. However, when asked how affordable they thought tidal power was for BC, respondents' mean score was 3.36 out of 5 (σ=0.96) with 1 being not at all affordable and 5 being very affordable, indicating fairly moderate perceptions of affordability and cost of tidal energy, contrary to the perceived risk of it being expensive.

Similarly, given some of the extensive BC Hydro rate hikes (16% over the first 2 years of a 10 year rate hike plan), respondents were very willing for some of this money to go towards tidal energy development in BC, indicating a mean score of 4 out of 5, with 5 being very willing and 1 being not at all willing (see fig. 3-17). There was also a significant correlation between support for developing tidal energy and willingness for BC Hydro to allocate money from the rate hikes to developing tidal energy ($p=0.0005$, $r^2=0.30$). When asked how much they would be willing to pay on their monthly electrical bill to develop tidal energy in BC, given the options of 0, 1, 2, 3, and 5 dollars, respondents indicated a mean dollar value of $3.36 ($\sigma$=1.46). However, the average monthly electrical amongst those surveyed was relatively large at $216 ($\sigma$=175, n=27).

It can be noted that when asked what attributes they valued in their energy systems at the beginning of the interview, respondents indicated cost as the second most important option behind local environmental impacts. These findings seem to indicate that while subjects are willing to pay a small amount for tidal energy and would like for some of their electrical rate increases to go towards it, they still perceive cost as a significant risk and value having economically efficient energy systems.

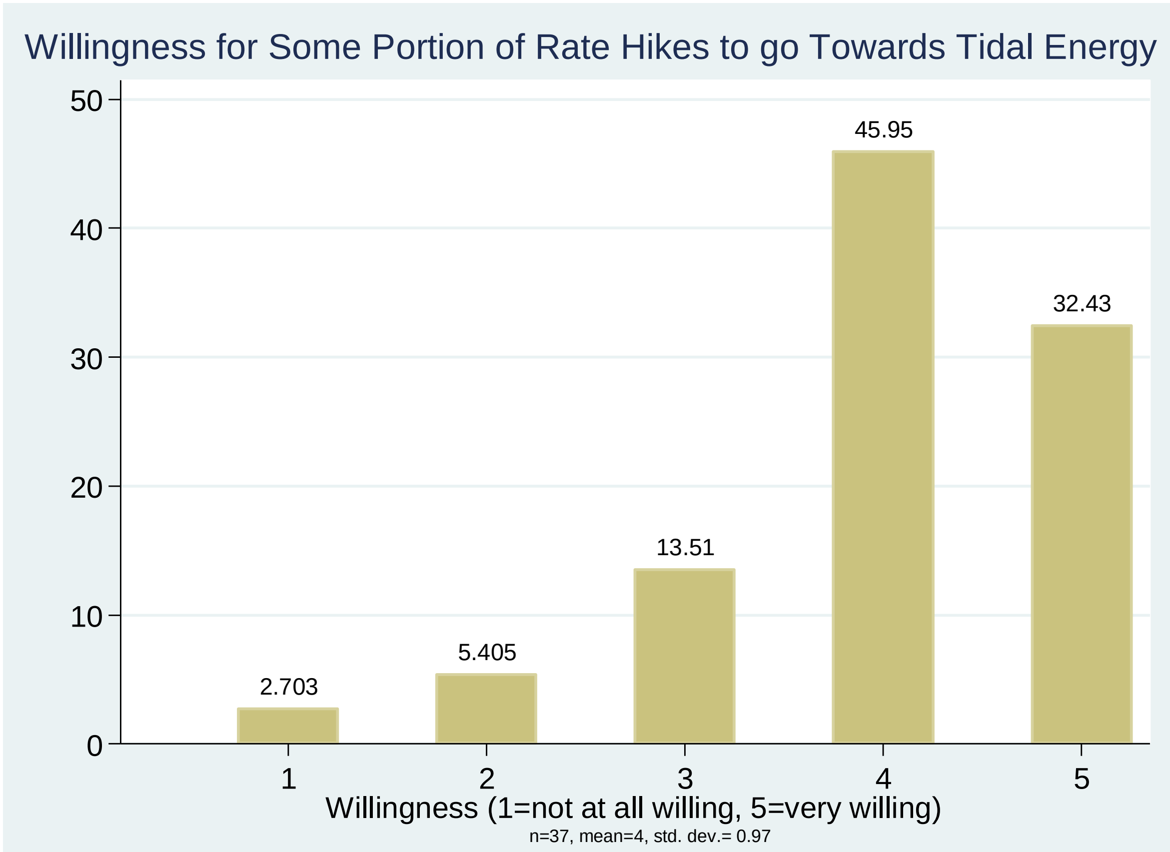


Figure 3-17: Respondents' willingness for some of their utility bill rate hikes to go towards tidal energy development in BC. 1 indicates not at all willing, and 5 indicates very willing.

3.3.4 Perceived Benefits

The most important perceived positive benefits from development of TE were the spillover effects of the technology aiding the local, water-constrained hydroelectric industry by enabling down-ramping (using less water to generate power) in low flow summer months and thus conserving reservoir capacity, promoting fish health and conserving drinking water supplies. Following this, local job creation and economic growth were deemed important, as well as displacing off-grid diesel generation through tidal energy development and developing more power locally on Vancouver Island (see table 3-6). The perceived benefits of water conservation were also fairly evenly distributed across most stakeholder groups, although several groups also showed higher support for other benefits (see fig. 3-18a, 3-18b).

Mean Proportion of Tokens Given	Possible Benefits of Tidal Energy
0.18	Save water in local reservoirs to preserve fish health
0.16	Save water in local reservoirs for drinking
0.14	Economic growth, local job creation
0.13	Develop TE for off grid applications to minimise diesel usage
0.13	Generate more power locally
0.11	Avoid construction of more run-of-river projects
0.11	Avoid large dam construction, such as Site C
0.06	Save water in local reservoirs for recreational purposes

Table 3-6: Perceived benefits of tidal energy chosen by respondents apportioning a mix of 30 tokens to the perceived most beneficial options. The mean number of tokens apportioned across all respondents is shown here (n=37).

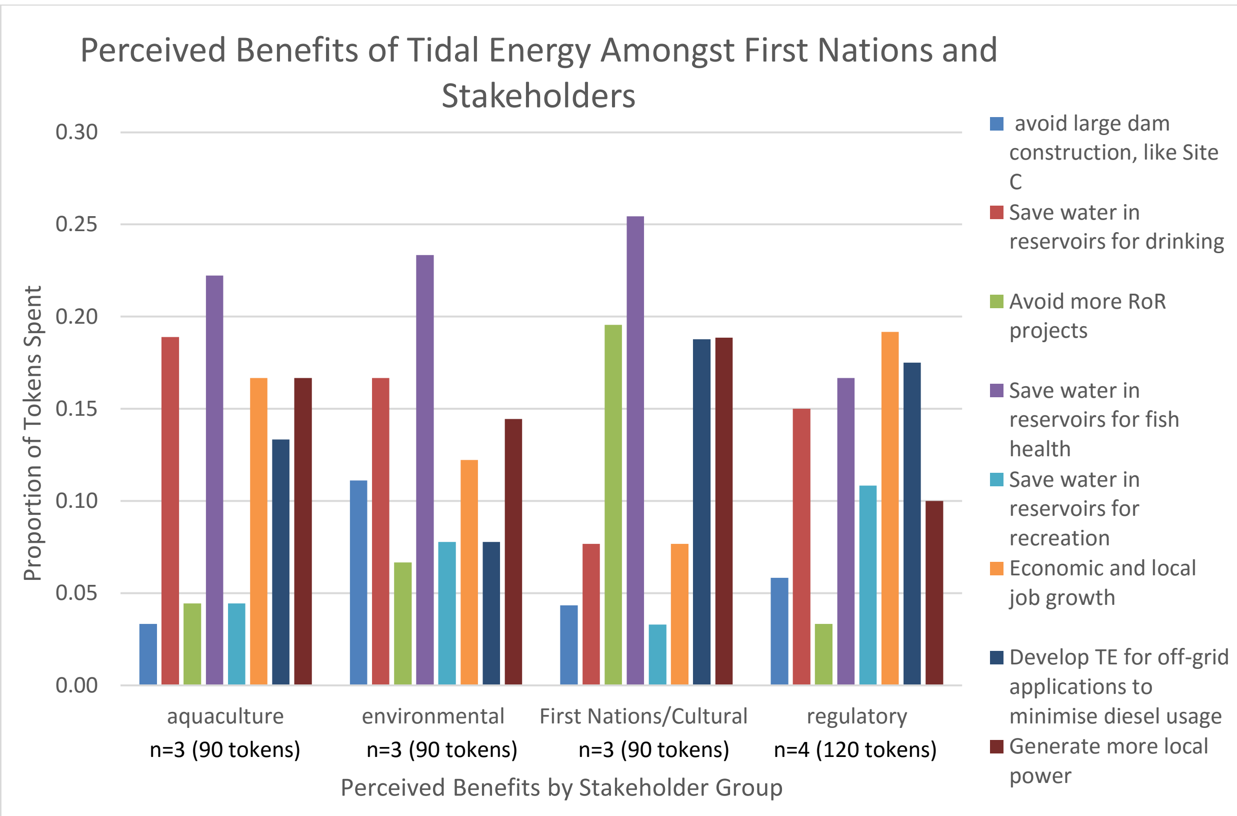


Figure 3-18a: Perceived benefits of tidal energy amongst 4 of the 8 stakeholder and First Nations groups.

Possibilities for Fresh Water Conservation

The benefit options of tidal energy possibly aiding in conserving water in the local reservoirs were described to respondents as being theoretically possible given sufficient penetration of tidal energy into the local power grid, thereby enabling BC Hydro to conserve water during the drier summer months. Respondents were also given data from BC Hydro on the projected impacts of climate change on the local Strathcona watershed, including information that by the year 2050 it could experience up to 60% inflow losses during the summer months due to loss of snowmelt from global warming (Jost & Weber, 2012). While respondents were not given any more information on the topic than this, the water conservation benefits of commercial tidal energy generation, are likely possible and are briefly described below.

As stated earlier in the cost comparison between tidal energy and hydropower in section 3.4.1, tidal energy sites in Discovery Passage and Seymour Narrows could produce about 389 GWh per year. The local John Hart dam, will have a full generation capacity of 130 MW once its refurbishments are completed. Assuming a 75% capacity factor, the dam would then generate 854 GWh per year. Thus, based on these calculations, a 111 MW tidal energy plant operating at 40% capacity factor could displace up to 45% of the John Hart Dam's energy generation requirements, thereby possibly enabling significant dam down ramping and water conservation during the drier periods of the year, if needed, or a general augmentation of the grid's generation capacity.

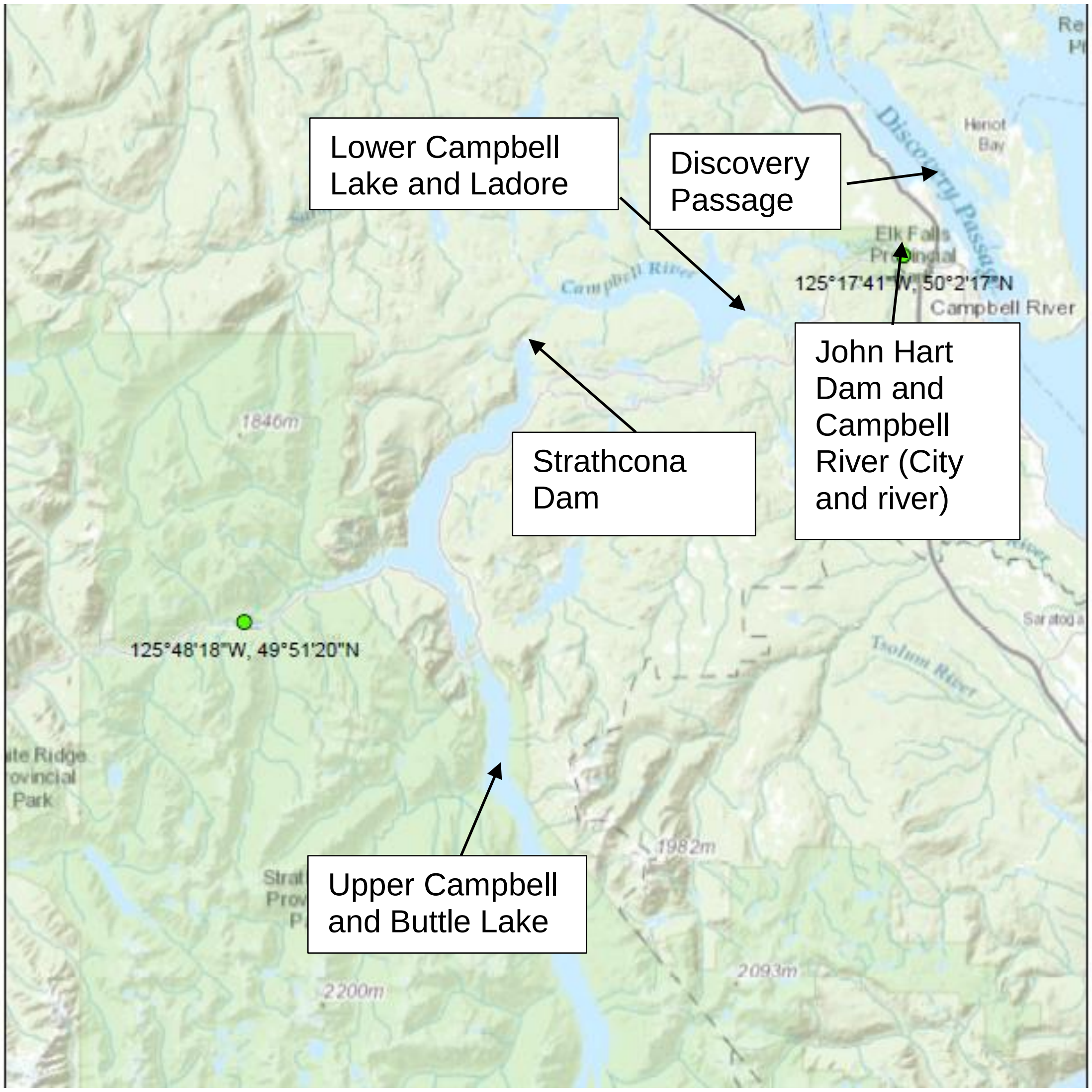


Figure 3-19: A map of Strathcona watershed indicating the size of the Upper Campbell Buttle Lake reservoir, impounded by the Strathcona dam. Source: author.

The shortage of water in the Strathcona watershed can be seen in the discharge rates from the largest dam and reservoirs (Strathcona dam and associated Upper Campbell and Buttle Lake reservoirs). Figure 3-19 shows that when the surveys were completed, between 1 June to 31 August in 2014, mean dam discharge rates were the second lowest discharge rates in the 22 year dataset, possibly explaining why reservoir conservation was so highly valued amongst respondents.

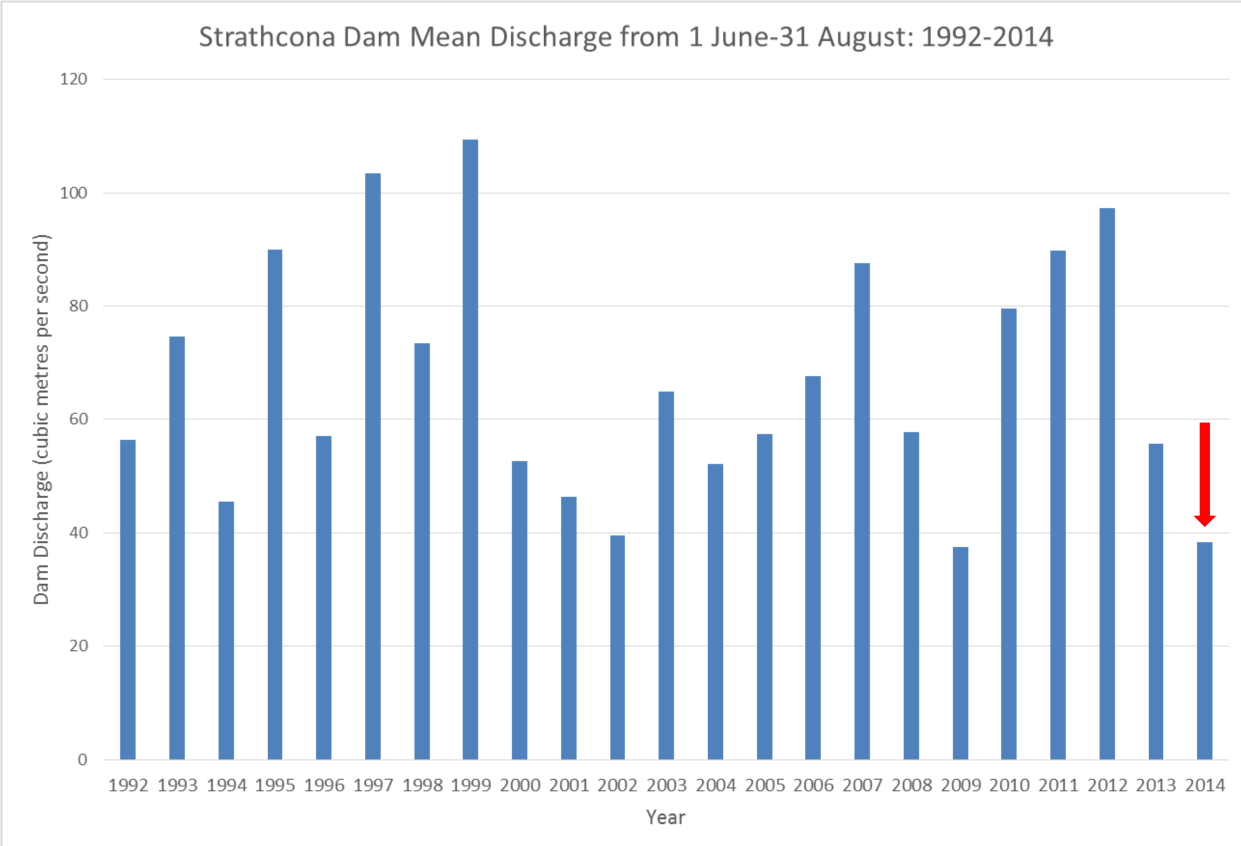


Figure 3-20: Strathcona Dam mean discharge rates in cubic metres per second (cms) from 1 June-31 August for the years 1991-2014. Source: BC Hydro, 2015.

Economic Benefits and Local Power Generation

Behind water conservation, economic development and job creation together were perceived as the next highest ranked benefit. Given the proximity of the tidal energy resource to the City of Campbell River and the number of marine stakeholders interviewed, the level of familiarity with the strong tidal currents was high. Given that Campbell River is a marine community with numerous tugboat companies, marinas, ports, and a significant marine industrial capacity, it was apparent that respondents recognized and valued the economic possibilities that a developing tidal power industry could provide near Campbell River. In addition, the video shown to respondents depicts a tug boat and barge lowering a tidal turbine into place, which may have predisposed respondents to the idea that local marine industry could also work in this capacity. Economic development ranked relatively high amongst the eco-tourism, marina and shipping stakeholder groups indicating that as these groups all have significant connections to the marine industry in Campbell River. The eco-tourism group often provides water taxi services and provided transportation support to local resource industries during the low tourism season, possibly explaining their support of economic development benefits of TE.

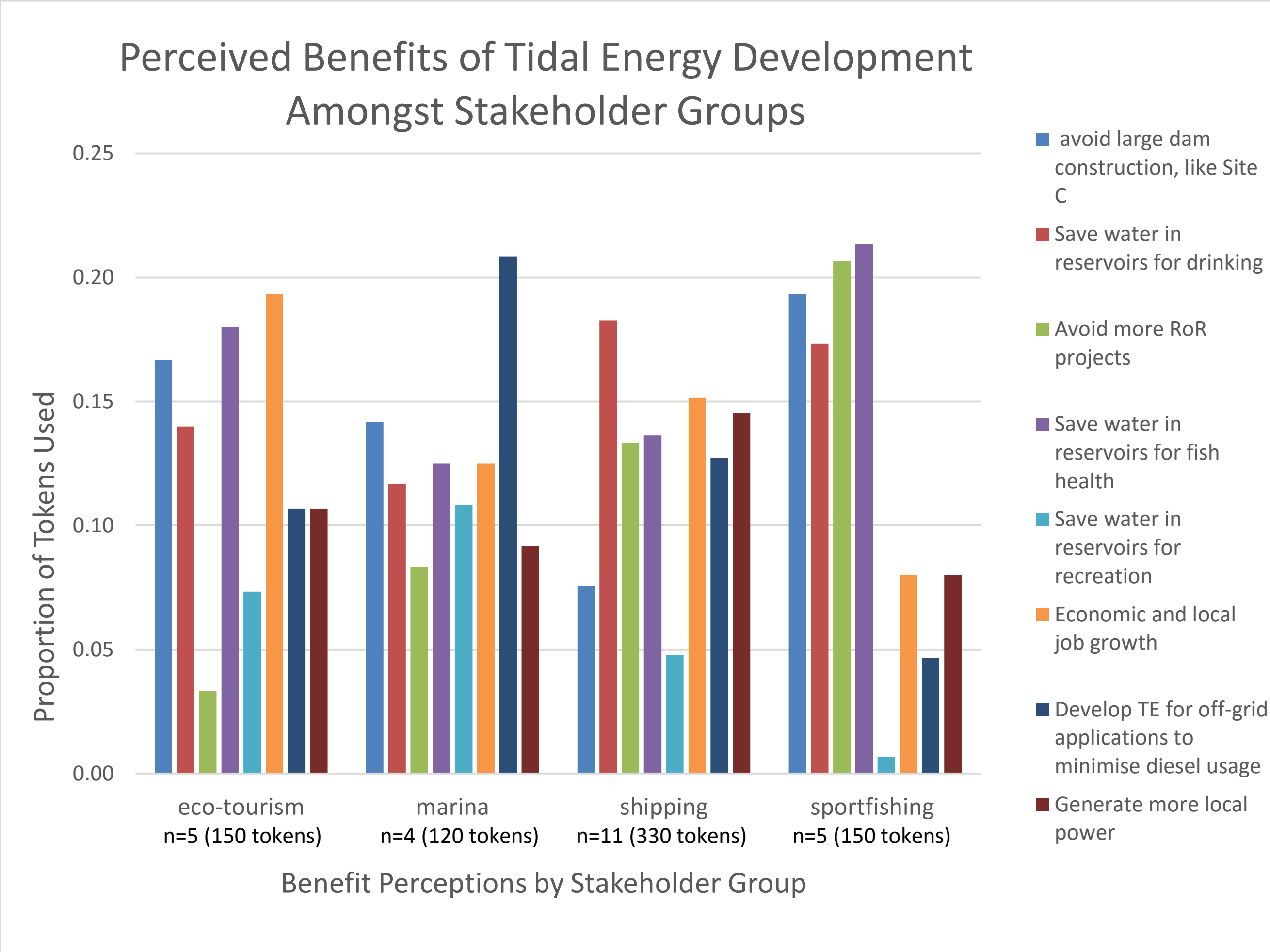


Figure 3-18b: Top perceived benefits of TE development amongst eco-tourism, marina, shipping and sportfishing stakeholders.

Off-grid and localised TE power development

First Nations in particular valued development of TE for off-grid applications as well as for supplying more local energy sources after the benefits of water conservation for fish health (see fig. 3-18a). In general, developing TE for off-grid as well as for generating more local power was deemed to be the 4th and 5th most important benefits across all groups. These findings are similar to the aspects valued in the general energy and energy attributes questions at the beginning of the interview which ranked energy reliability as the 3rd most important attribute when considering where respondents' energy came from, preceded only by environmental impacts and cost. As well, the perceived reliability of the local grid was ranked lowest by First Nations amongst all stakeholder groups at a mean score of 2.33 out of 5 (5 being highly reliable), possibility demonstrating why they later highly valued developing TE for off-grid applications and supporting more local power generation. Overall, the perceived mean reliability of the grid was only rated as a moderate 3.45 out of 5 (σ=0.92, n=38) across all stakeholders, while the support for more local power generation was rated high at 4.24 out of 5, with 5 being highly supportive, again correlating with the valued benefits at the end of the interview (see fig. 3-21).

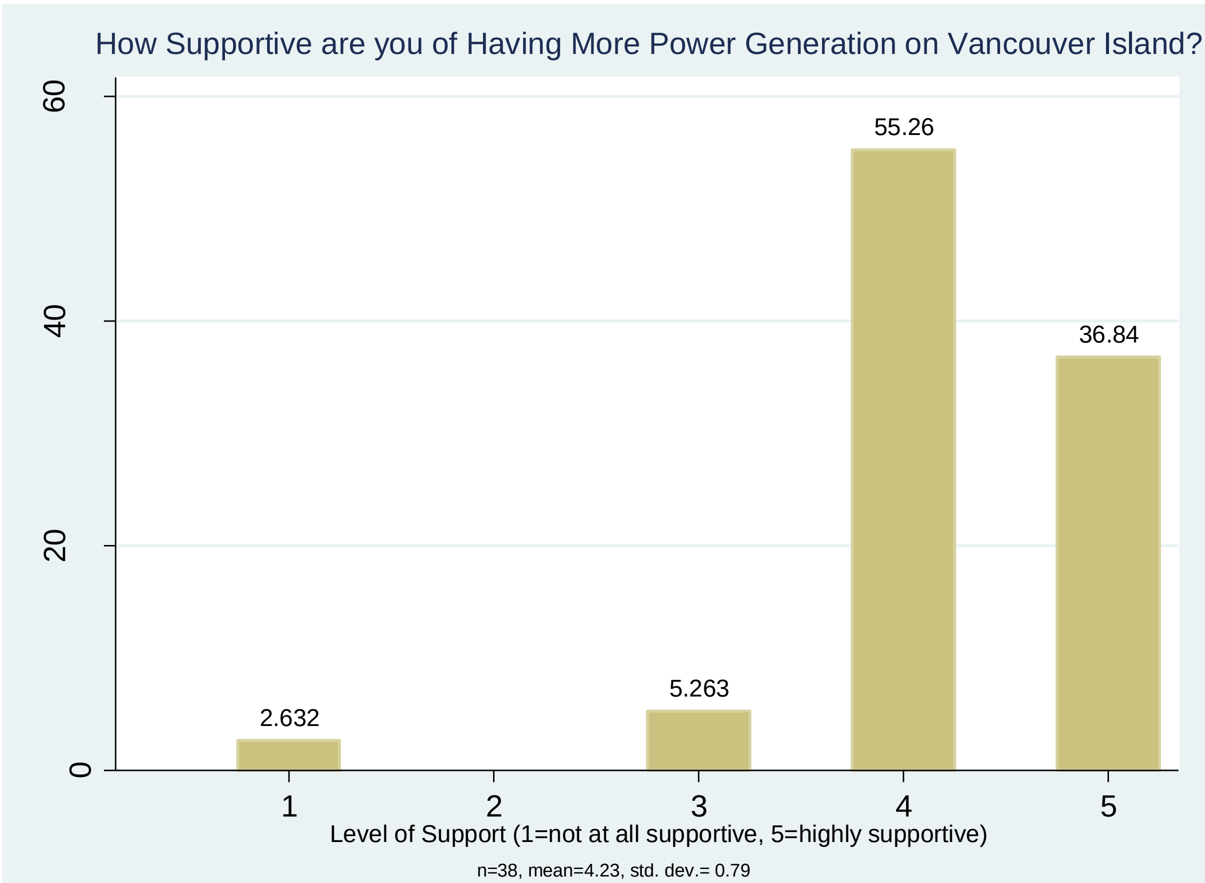


Figure 3-21: Respondents' mean level of support for having more localized power generation on or near Vancouver Island. 1 indicates being not at all supportive of more local generation, and 5 indicates being highly supportive.

Sportfishing Perceived Benefits

Except for the Sport fishing group, none of the interviewed stakeholder groups heavily favoured both the avoidance of the construction of both more large dams and more run of river projects (see fig. 3-18b). The Sport fishing group ranked avoidance of these two technologies very high. Avoiding run of river (RoR) projects was ranked 2nd only to preserving water for fish by the sport fishing group, while preventing further large dam construction was ranked as 3rd. Several sport fishing respondents opposed the construction of more RoR projects as they regarded such projects as detrimental to salmon spawning habits, given the significant levels of water being diverted from streams in order to generate power. While sport fishers' support of tidal energy at the end of the interview was tied for the highest amongst all stakeholder groups at 4.8 out of 5, once they saw the IL sites where the TE was proposed to be developed, their levels of perceived conflict with the sites was the highest amongst all groups as well at 3 out of 5. Their group in particular represented the largest shift from support for tidal to opposition to it as a result of seeing the IL sites.

3.4 Conclusion

Thirty-nine stakeholders and First Nations individuals were interviewed in relation to several tidal energy IL sites near Campbell River, BC. Overall, on the grounds of environmental impacts, economic benefits, cost to develop, technical feasibility and reliability, tidal ranked quite favourably in competition with 10 other energy technologies identified as possible for development in BC. The perceived risks of tidal energy development near Campbell River were localized and specific to the IL site locations provided, and to stakeholder groups' specific needs, while the perceived benefits were more uniform across all stakeholder groups and diffuse in their geographic applicability.

Local sport fishers' apparent spatial incompatibility with tidal energy and marine traffic operators' perceived spatial interference as a result of it were some of the highest rated risks related to tidal energy and were specific to the sport fishing and shipping industries surveyed. Again, sportfishers' conflicts were deemed to be spatially incompatible with tidal energy due to their very high levels of rated conflict, while shipping conflicts were deemed to be spatial interference due to their somewhat lower levels of conflict. This finding seems to be consistent with several other studies examining conflicts between ORE sites and various stakeholders (Alexander et al., 2012; Kim et al., 2012). The highest general conflict ratings were observed amongst sport fishers due to their concerns around downriggers. In particular, sport fishing guides exhibited the highest levels of spatial conflict with the IL sites, demonstrating that the two resource uses could likely not co-exist in the same marine space. Shipping stakeholders were concerned with having the channel being potentially blocked by a tidal energy installation or maintenance vessels. Tug and tow companies, in particular, were concerned with their tow cables being snagged on tidal turbines causing potentially dangerous marine accidents; however, areas and amounts of cable sag were generally outside of turbine areas and likely not low enough to cause snagging, based on operators' anecdotal evidence and experience. Nevertheless, these findings highlighted the challenges of implementing ORE sites in narrow, high use shipping channels. In terms of spatial conflict ratings in reaction to seeing the IL sites, risk to marine traffic accounted for 64% of all conflict types identified by respondents.

While stakeholders stated a high support for TE and a high willingness to pay for its development, they also saw its cost as being a high risk, rating it as the second greatest risk associated with TE development in BC. This finding is consistent with attributes that stakeholders identified as highly important at the start of the interview (cost was rated as the second most important attribute next to environmental impacts). Power reliability and locality of generation were deemed as important as well; respondents rated having more power generated on or near Vancouver Island as very important. While barrier effect was the top rated risk, its highly theoretical nature and the lack of empirical evidence surrounding it indicates a requirement for more research on the environmental impacts of multi-turbine array installations and means of mitigating the risks of high channel blockage ratios negatively affecting passage of marine life.

The top benefits associated with tidal power generation were water conservation in local reservoirs for fish health and drinking water purposes, although watershed flows during the study period were at near 23 year lows during the time of the survey. Campbell River and Vancouver Island area very dependent on the local Strathcona watershed for hydroelectric power, drinking water supplies and water for fish in the Campbell River. The notion that tidal power could help save some water used for hydropower in the local watershed was highly valued and could be theoretically achieved if commercial tidal energy were developed in the region and grid managers utilized this new generation resource to this effect. Following these choices, people viewed economic growth and job creation as another key benefit of tidal, followed by off-grid energy production as well as more localized energy generation.

Overall, respondents demonstrated a high willingness to pay for tidal energy and strongly supported the idea of its development in BC. However, when shown the IL sites near their city, only 60.5% said they did not have a conflict with the sites. Further, when given an opportunity to draw a conflict polygon on or near the IL sites on an IPAD map, some 72% of respondents did so, indicating high initial idealized support of a MRE but a typical U-shaped response to their actual development, as found in Wolsink's (2007) findings relating to land based wind energy. Many questions were also asked by stakeholders and First Nations, as to the nature of the IL sites and the associated technologies, offering the possibility that more definition of the exact parameters and effects of a proposed tidal energy array could help in lowering peoples' concerns about it. During the interviews, specific topics to be included in any further research were identified including where more information on the impacts of tidal energy would be beneficial to stakeholders. In addition, suggested mitigation measures to address some of the risks were discovered. These topics are discussed in Chapter 5 of this Thesis.

Chapter 4: Conflicts and Marine Spatial Planning Relating to Tidal Energy

4.1 Introduction

In-stream tidal energy (ISTE) is approaching commercialization, mostly in Europe and Nova Scotia, Canada, but also elsewhere in the world such as the United States and Asia, with several multi-turbine arrays scheduled for install in 2015 and 40 MW of capacity to be installed by 2018; similarly some 26 MW of wave energy are expected to be installed by the same time (Magagna & Uihlein, 2015). A significant amount of work has been put into ISTE resource characterization and tidal turbine engineering, as well as research on impacts of ISTE on marine life; however, one area lacking research is the cumulative environmental and other effects of arrays of multiple turbines, largely because there are no multi-turbine arrays yet installed in the world (Copping, A., 2013; Dalton et al., 2015; Polyage, Brian, 2010). Various researchers have explored concepts of optimal turbine placement in the water column in order to minimize inter-turbine wake interference (Blanchfield, Garrett, Wild, & Rowe, 2008; Boronowski, 2009; Garrett & Cummins, 2007, 2008; Hagerman & Polagye, 2006; Karsten, Greenberg, & Tarbotton, 2011). This effort also includes a three dimensional depth planning component which involves avoiding bottom shear (the lowest 10% of the water column where flows are reduced due to bottom surface friction) and placing installations at a sufficiently safe depth to remain clear of shipping and fishing traffic. However, little work has been put towards harmonizing the two fields of technical resource assessment and three-dimensional marine spatial planning for ISTE array optimization, in an effort to help minimize potential stakeholder conflict and environmental impacts, yet maximize resource extraction potential. For example, floating turbines may be ideal in some locations with minimal shipping traffic, however would likely cause conflicts with stakeholders in narrower, busier channels. In other instances, a mid-water floating turbine deployments may be well suited in applications where a bottom mounted turbine would be too deep to capture high energy currents and too deep for installation assistance from divers or remote operated submersible vehicles. Similarly, shallower water, narrow channel sites may do well to host a bottom-mounted turbine with sufficient surface clearance for safety of shipping.

This chapter will focus on the interactive marine spatial planning methodology used to examine spatial and temporal usage patterns associated with a narrow channel ISTE site at Campbell River, BC. Focus will be placed on how important spatial and temporal risks to the ISTE installation were elicited through this methodology and what those important risks were, accompanied with some brief discussion. As well, general findings regarding notions of loss of use and reaction to seeing the ISTE sites being revealed at the end of the interview will be analyzed.

4.1.1 Background

A more thorough review of the literature surrounding ORE development can be found in chapter 3, however, some of the more salient work will again be discussed here as it applies to this chapter. General marine spatial planning (MSP) and risk perceptions based work relating to ORE is slowly developing. Relating to fishing, several studies have been done on perceptions of commercial fishers towards ORE (includes offshore wind, wave, and tidal) indicating that the stakeholder group tends to be most affected by ORE projects yet don't always necessarily have high amounts of opposition towards them (Alexander et al., 2013; Reilly et al., 2015). There is an important distinction to be made between on trawl net or pelagic fishing where large gear is used to drag for fish and line or trap type fishing which generally has far less area impact in the ocean and can possibly co-exist with ORE (DP Energy, 2009). In fact, innovative MSP studies have shown that significant mixed zone usage of ORE and static gear fishing (traps) can be achieved with minimal costs to both sectors (Yates et al., 2015). Further, some new evidence of ORE arrays acting as *de facto* marine protected areas (MPAs) by offering colonization habitat for the benthic environment and refuge for fish now exists, thus adding a potentially very important aspect to the benefits of ORE technologies (Ashley et al., 2014; Inger et al., 2009; Yates et al., 2015).

Kim et al. (2012) also examined wave energy resources off the West Coast of Vancouver Island, contrasting them with existing fishing, shipping, tourism and ecological areas as defined in the British Columbia Marine Conservation Atlas (BCMCA). NPV values of wave energy were determined using typical development costs along with expected annualized power sales based on wave data. Results were that high density wave energy was found far offshore, yet the cost of submarine transmission cable rendered the more nearshore sites most viable, a common occurrence among ORE projects making their competition with other nearshore resources inevitable. When overlaying positive NPV sites with other ocean usage feature counts as described in BCMCA, it was found that shipping and transport, followed by commercial fishing had the highest median overlap with high NPV wave areas, rendering them as the most important resource uses to consider in relation to these ORE sites. Alexander et al. (2012) explored optimal tidal array siting utilizing interactive marine spatial planning techniques in the Mull of Kintyre, Scotland, examining the interests of commercial fishing, boating and ecotourism stakeholders with interesting results. Commercial fishing in that study area comprised mostly creel (traps) fishing as well as relatively less scallop dredging (essentially a type of trawling) and diving. The site was relatively unconstrained, in comparison to Campbell River, being situated in a roughly 20km wide channel. The site was also at the headlands of the Mull of Kintyre peninsula and bordered on established shipping lanes, which generally exclude large shipping traffic, reducing the number of shipping stakeholder considerations. Alexander et al. (2012) utilized spatial decision support systems and IMSP, engaging with stakeholders in order to assess levels of conflict in relation to several proposed scales of tidal energy arrays. The study results paralleled many results within this study including notions of loss of use, the vulnerabilities of fishers to tidal energy arrays and the likelihood that tidal energy arrays would require fisheries exclusion zones around them. Notions around loss of use in relation to renewable energy were similarly found in Wolsink (2007) where support for land-based wind power projects was found to be relatively high in the conceptual design phase, but then declined in the detailed project planning phase, with an eventual recovery of support once the turbines were actually built. This finding is important and has begun to be observed in the ORE sector (Reilly et al., 2015).

While existing literature on perceptions of stakeholders towards ORE and tidal energy is useful, as is the application of interactive marine spatial planning in conjunction with ORE site selection, applying the practice to narrower, higher use marine channels has apparently not yet been done, nor have any such studies been previously conducted in British Columbia. Discovery Passage and Seymour Narrows, near Campbell River, British Columbia, are representative of many potential narrow channel ORE sites in the world for which it is important to consider not only fishing, boating and tourism, but in some cases also heavy shipping, including tug boats, cruise ships and freighters. These heavy vessels are unable to be separated from ORE sites by use of shipping lanes, simply due to a lack of space and therefore must be additionally considered. There are 4,000 MW of assessed theoretical ISTE potential in British Columbia, the bulk of the 89 identified potential sites are in narrow channels less than 2 km wide (Cornett, 2006; Tarbotton & Larson, 2006). Many of these sites are in active fishing, ecotourism, First Nations and shipping areas representing a variety of potential conflicts with ISTE in confined waters. Several regional, coastal level marine planning efforts such as the Marine Planning Partnership for the North Pacific Coast (MAPP) have been undertaken in BC in a broad effort to map the coast's resources and their users, including mapping potential tidal and wave energy zones; however, the plans are generally at a strategic or regional level and do not account for site level considerations. These additional, localized and ISTE - specific geographic and stakeholder considerations will be discussed in this article.

Near Campbell River, BC, two 5-year investigative licenses (ILs) were issued to local renewable energy project management and development firm, SRM projects, by the BC Ministry of Forests Lands and Natural Resource Operations (BCFLNRO), in early 2014. The ILs occupy the vast majority of the width of the channels known as Discovery Passage and Seymour Narrows, and caused a low to moderate amount of perceived conflict amongst First Nations and stakeholders interviewed for the study (see fig. 4-1, 4-2). In particular, active towboat shipping and sportfishing downrigger communities presented unique challenges in the form of underwater obstructions which will undoubtedly require further study and possibly even special operational procedures and/or regulations in order for ISTE arrays to succeed in balance with these other resource users. Periods of slack water were found to be an important regional and even international economic resource due to the necessity for marine traffic to generally time their movements according to these short time periods.

4.1.2 Study Area

The study area is located in Discovery Passage from Separation Head to Cape Mudge, between Quadra Island and Vancouver Island (see fig. 4-1, 4-2). Discovery Passage is a relatively narrow (average channel width is 2km, narrowest point is 800m) marine waterway between Vancouver Island and a group of islands to the east and is part of the Inside Passage, connecting major ports from Puget Sound in Washington State to the Alaska Panhandle. The Passage has no defined shipping lanes or traffic separation schemes and vessels typically utilize the majority of the channel for navigation, with local knowledge being key in the selection of optimal routes when traversing on the ebb or flood tides. This study area was selected because it encompasses the ILs of SRM Projects and the surrounding areas where users may be affected by the installation or operation of tidal energy systems. The foreshore area was deemed part of the study area as proposed tidal energy installations would need subsea electrical cables to transmit the power to onshore locations. If any of these proposed projects are realized, their transmission cables would likely have to be underground where they cross intertidal and backshore areas.

Figure 4-1: Vancouver Island, British Columbia. The study area at Campbell River is indicated. Reprinted with permission of Open Street Maps, source: www.openstreetmaps.org.

In Richard Thomson's *Oceanography of the British Columbia Coast* (1981) detailed depictions of tidal and current flows as well as a brief marine history of the region are given. The tidal currents in the region are powerful and one of the main reasons why tidal energy development is being considered there. As the tide rises (or floods) it moves southwards through Seymour Narrows and past Campbell River and Cape Mudge (see fig. 4-2). When the tide ebbs it reverses direction and travels in a northbound direction. This cycle repeats itself twice daily producing two flood tides and two ebb tides per twenty-four hour period. The strength of the currents moving through Discovery Passage are considerable: in the wider portions of the passage, maximum currents will reach 7-8 knots (roughly 3.5-4 metres per second), while in the Seymour Narrows (narrowest point in the passage of 800m) currents will reach up to 15-16 knots (roughly 8 metres per second) on full moon/new moon cycle. Due to the large amount of tidal flushing through the area, the water is highly oxygenated, mixed and nutrient rich contributing to a rich marine ecosystem.

The bottom topography of south Discovery Passage is relatively uniform with a deep, level channel running throughout, resulting in fast but relatively laminar water flows compared to Seymour Narrows. By contrast, the undersea floor around Seymour Narrows is populated by large rock formations, rising upwards of 30-40m from the sea bottom. The pre-eminent of these formations, Ripple Rock, sits right in the middle of Seymour Narrows at a depth of 13.7m at lowest low water. However, it was once only 3m below the surface causing numerous shipwrecks (estimated at roughly 100) and was partially destroyed by explosives in the late 1950s in order to ease shipping (Rogers, 1984). Due largely to the bottom topography, the flows of the tidal stream here are turbulent, producing upwelling, whirlpools, overfalls and large eddies (Thomson, 1981). These eddies are important as local mariners know and use them frequently to help them move against the main currents if necessary. It is not uncommon to see a large fishing trawler traveling northwards against a strong southerly flood tide, hugging the shoreline some 30ft. from the beach. See sections 3.2.1 and 3.2.2 for greater description of the study area, including socio-economic composition.

4.2 Methods

Interviewees for this study spanned a variety of sectors and were selected based on their commercial, recreational or cultural usage, or regulatory jurisdiction over, Discovery Passage and its foreshores. Interviewed groups included: First Nations, museums, sport fishing guides and lodges, water taxis, BC ferries, marinas and harbour authorities, eco-tourism operators including whale and wildlife viewers and SCUBA diving operators, various city planners and government officials, including Department of Fisheries and Oceans (DFO) and the Canadian Coast Guard (CCG), the region’s large aquaculture industry, and numerous tug and tow operators, both locally and regionally based, as well as regional heavy vessel navigation specialists (see fig. 3-5). Given that the area was a major coastal shipping route, a large number of shipping stakeholders were interviewed. In interviewing the DFO representative, it was determined that commercial fisheries did not occur within the study area. Thus, only one commercial fisher was interviewed, whose opinions were categorized into the shipping group, as his usage data reflected routing of commercial fishing vessels through the study area (and to the fish packing plant located within it) for transit purposes only. A large portion of the interviewees were considered experts on the local or regional marine sector including ship captains and company operations managers. A total of 39 interviews were conducted, 36 in Campbell River, 2 in Vancouver and 1 via telephone to Seattle, Washington.

Spatial GIS data and survey type risk perceptions data were gathered in a semi-structured interview process for the purposes of the study. The spatial data was used to inform location, intensity, and seasonality of marine usage by stakeholder and First Nations groups, as well as levels and areas of conflict in relation to the proposed IL sites. Interview subjects were informed in advance via a letter of recruitment that the study was in relation to some proposed tidal energy developments in South Discovery Passage between Separation Head and Cape Mudge, which became known as the “study area.” Subjects were also sent an information briefing on tidal energy and energy in BC in general in advance of the interview, which included a 2 min 40 second live and animated video showing an Open Hydro commercial scale tidal turbine being lowered into the water from a barge and a view of it underwater from an ROV at depths up to 30m indicated in the ROV’s display footage. The video also showed an animation of the turbine’s blades slowly rotating at roughly 15 rpm and reversing with the direction of the tidal stream over time. This speed of rotation is common amongst most commercial scale tidal turbines.

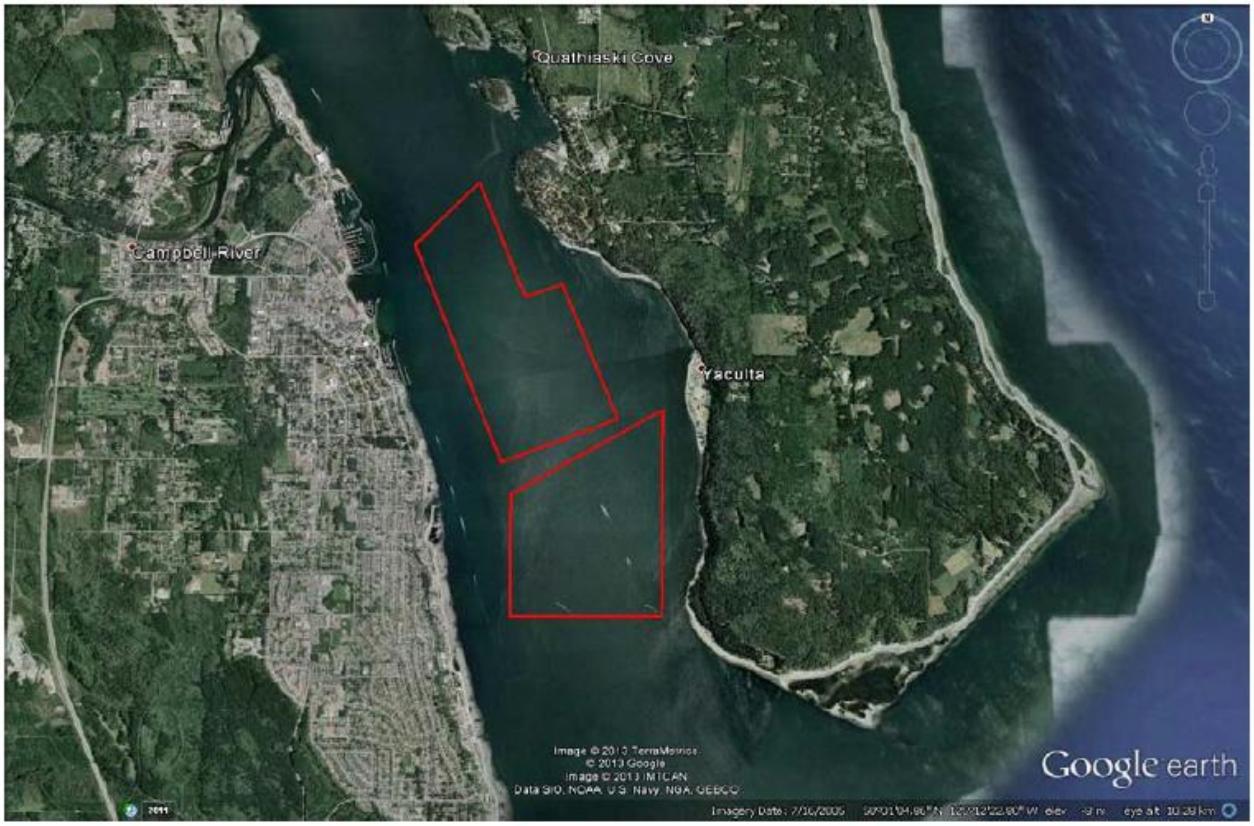
The interviews were conducted on location, mostly in Campbell River during the summer of 2014. The researcher brought a paper marine chart showing the study area (CHS chart 3539: “Discovery Passage”), as well as an IPAD with a Google Earth map showing the IL sites for later in the interview. The interview protocol itself was conducted in five parts. The first part comprised marine spatial planning (MSP) questions which asked the subject to identify their organization’s top three areas of usage, or predominant shipping routes at different points of the tidal cycle. The subjects were asked to assign a level of value to each of these sites. The iGIS application was used in conjunction with an IPAD to map out subjects’ spatial interests and perceived conflicts. A Google Earth base map was used and could be zoomed in and out to high degrees of detail on the IPAD.

The GIS format enabled users to either input polygons indicating their areas, or lines indicating their routing if they were a shipping user. IMSP methods on the IPAD used iGIS, a GIS application, and ARC GIS in order to gather large amounts of spatial data and then sort and display them on maps produced in ARC GIS. Data forms were created in ARC GIS in advance of the study and then loaded onto the IPAD for interview use. The forms were designed to enable additional data collection and other comments to be easily recorded each time a spatial feature was created. For the initial spatial usage question, subjects were asked: “if you were hypothetically given $100 how you would apportion the money in order of importance between your sites or routes?" For the non-shipping respondents up to three polygons were generally identified and valued. Along with value ($100 to be distributed amongst the top three or four sites), seasonality, frequency and type of usage were gathered for each polygon area. For certain common usage types such as sport fishing, usage intensity was defined as zero to twenty-five being low, greater than twenty-five to fifty being moderate and greater than fifty being high. This value delineation allowed for usage density maps to later be created in ARC GIS showing low, medium and high usage density by stakeholder type.

4.2.1 Conflict Areas in Relation to IL Sites

At the end of the interview, subjects were then shown the IL areas (Figures 4-2 and 4-3) and provided details about the tidal energy projects which are being investigated there. Subjects were asked to draw polygons where they saw potential conflict with their organization's operations or interests, as well as to explain the cause and nature of the conflict they foresaw and the predominant season of the conflict, if any. They then rated the severity of conflict on a scale of 1-5, with 5 being the highest level of severity. Subjects were asked to limit their conflict areas to the most important 3 or 4 areas. Conflict rankings of less than two were classed as low severity conflicts; rankings from two to four were classed as moderate severity conflicts and rankings of greater than four were classed as high severity conflicts.

Investigative Area Photos

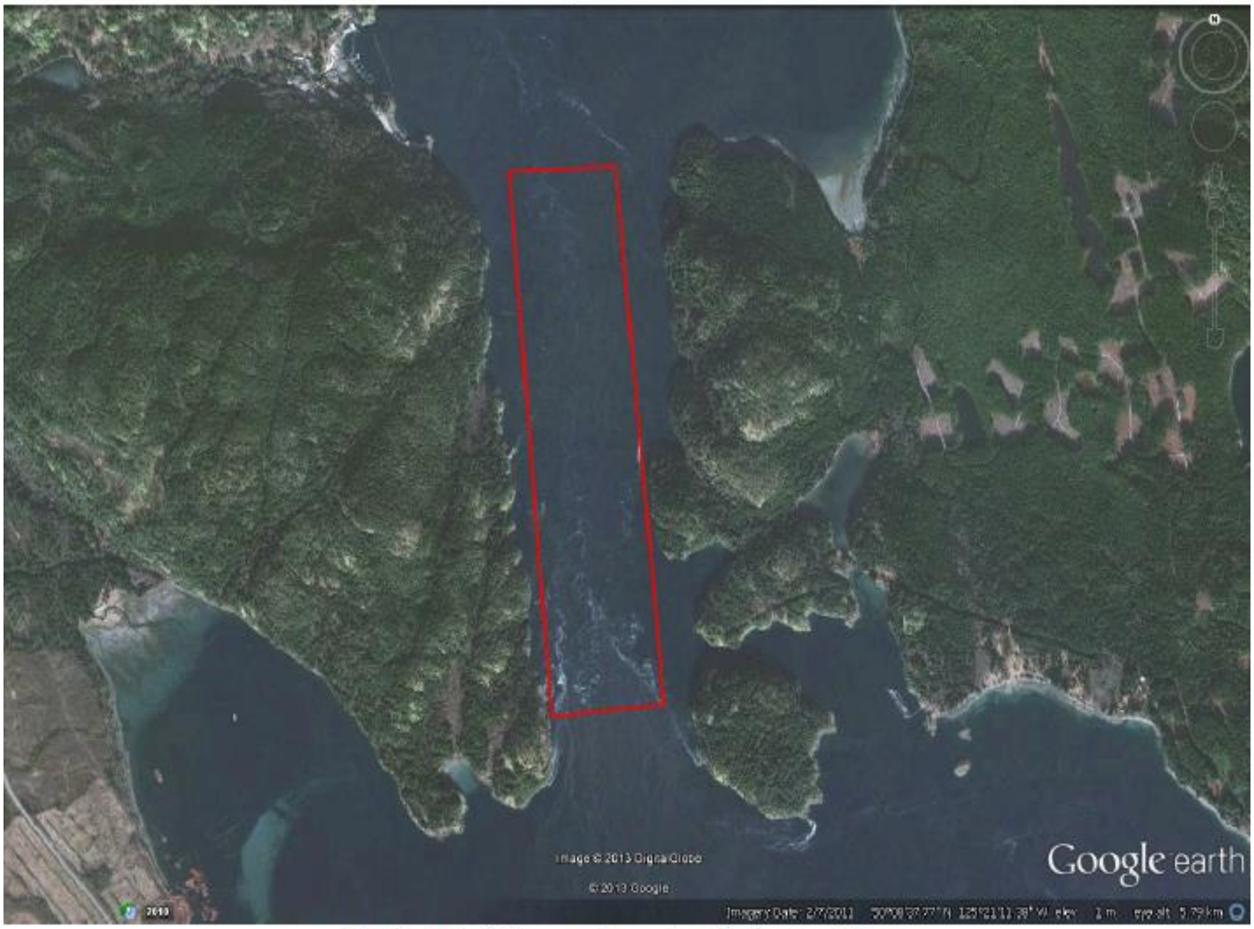


Satellite Photo 1: Discovery Passage South Investigative Areas – Polygons South 1 and South 2

Figure 4-2: Southern IL areas shown to interview participant just before the final conflict questions. Two polygons compose the southern IL as shown here. Reprinted with permission of SRM Projects.

Conflict polygon maps were overlaid on each other in order to determine overall conflict potential. Polygons were first grouped according to their severity scores onto low, moderate and high conflict maps. If a stakeholder indicated various polygons with differing severity scores, the polygons were separated out and placed on their respective severity maps. Further, conflict polygons of similar severity and conflict type were combined together to indicate areas of concern on each of the low, moderate and high conflict maps related to specific stakeholder uses. For example, moderate levels of concern regarding impacts of the IL sites on sportfishing were detailed on a moderate conflict map under the legend heading “sportfishing concerns.” A total of eleven maps were created: five depicting recreational, commercial, and cultural usage areas, two depicting vessel routing (for light and heavy traffic), three depicting conflict areas (low, moderate, high), and one additional map depicting a bio-physical area. While bio-physical or marine ecosystem mapping was not the purpose of this study, some data were elicited responses from stakeholders and described important rearing areas for salmon smolts near the mouth of the Campbell River. This represents an example of how this IMSP method could be employed for bio-physical mapping in relation to ISTE or ORE sites as well.

Investigative Area Photo



Satellite Photo 1: Seymour Narrows Investigative Area Polygon

Fig. 4-3: Satellite photo of northern IL, Seymour Narrows. The photo depicts a northerly, ebb tide, as currents can be seen streaming through the Narrows. Reprinted with permission of SRM Projects.

4.2.2 Shipping Routes

Those identifying shipping routes were initially asked for three route lines. However, three route lines were generally insufficient for those identifying shipping routes. Smaller vessels (ships) often used back eddies and nearshore currents in the area to their advantage when transiting Discovery Passage. Given the ebb and flood tidal cycle and strong currents in the area, operators could have upwards of six to eight different routes depending on their direction of travel and the state of the tides at the time of travel. In addition, vessel operators often had weather routes depending on different times of year, adding to the complexity of the analysis. Thus, the subjects' exact routing in relation to the tidal cycle were elicited and subjects were permitted to add in as many route lines as they wished. Each route line was recorded as to which tidal cycle and direction of travel it related to: for example, “northbound on a flood tide, southbound on an ebb tide.” The weather routing factor was in relation to Cape Mudge at the southern extent of the study area, which is widely regarded amongst shipping experts interviewed as being one of the most dangerous pieces of water on the British Columbia coast. This statement is primarily due to the long southerly fetch area in Georgia Strait to the south of it, which allows large southerly gales sufficient sea room to build large waves. These wind driven waves also become even steeper and closer together when they oppose the direction of the tide flooding south against them out of Discovery Passage. According to the interviews conducted, local Coast Guard staff stated that 90% of their distress calls came from Cape Mudge while only 10% came from the turbulent, yet relatively sheltered waters of Seymour Narrows.

Vessels were categorized as “light” and “heavy”. Light traffic included water taxi operators, wildlife and whale watchers, sportfishing guide boats and any vessel which transited the study area with high speed and maneuverability. Heavy vessels included tug boats and their tows, ferries, freighters, cruise ships, commercial fishing boats and aquaculture resupply boats; all such vessels transited the study area at a lower speed and had less maneuverability. In retrospect, due to greater vessel maneuverability and expert knowledge of the waters, including local tug operators as a light vessel traffic would have been more accurate and applicable. More discussion of this will be undertaken in chapter 5 of this Thesis.

4.3 Summary of Results and Discussion

General MSP study findings are discussed here, along with the ongoing discussion of the effectiveness of the IMSP methods employed. Seymour Narrows at its narrowest and shallowest points is roughly only 800m wide and 13m deep at lowest low water. SRM Projects stipulated for its ILs that tidal turbines would be submerged at a depth that would be safe for shipping, as approved by the national regulatory authority, Transport Canada. However, marine expert respondents cited marine traffic interference and hazards to shipping as the overwhelming top spatially related conflict concern. The information briefing given to subjects prior to the interview included showing a video depicting a large tug and barge lowering a tidal turbine to the sea floor; offering the impression that this was the determined method for deploying the devices. The experience level of shipping stakeholders interviewed was also generally high and many of them saw a high potential for marine traffic interference and danger within Seymour Narrows, possibly due to the turbine deployment measures displayed to them. The history of shipping hazards in Seymour may have contributed to the high degree of perceived conflict related to installing turbines there. Numerous ships were wrecked prior to the destruction of Ripple Rock which was a submerged rock near the surface, and even after the explosion, ships have been occasionally sunk or overturned by the strong currents and whirlpools present in the narrows (Rogers, 1984; Thomson, 1981). As well, the importance of slack water at the Narrows could not be understated as many mariners perceived that tidal energy installation and maintenance operations would have to take place at slack water, thus possibly impeding their passage through the Narrows at this important, safe period.

The distribution of perceived conflicts between the north and south sites is also useful to examine because marine traffic was more the concern for Seymour Narrows, while fishing, foreshore usage and disturbance of cultural areas of importance were more the concern for the southern sites. These findings appear to support the general hypothesis that narrower channel, higher flow ISTE sites garner more shipping safety related concerns whilst wider channel sites, opening onto even wider straights are generally important fishing areas and thus garner conflicts related to fishing. Potential ISTE sites in areas such as the headlands of the Mull of Kintyre, or the Meygen tidal energy site near the Orkney Islands, Scotland, represent more water space and possibly less shipping and fishing activity than is the case for Discovery Passage. A topic for further research would be whether marine spatial planning would be more or less challenging for areas with more space than is the case for Discovery Passage.

Specificity of Conflict Perceptions

In general, the elicitation process for asking subjects their levels of perceived conflict in relation to the ILs clearly had an effect, as subjects' stated conflict ratings went higher as more specific questions were asked. Following the introduction of the sites on the IPAD and a brief description of them, subjects were then asked whether they had a potential conflict between the installation of tidal turbines in the ILs and their organization's operations as a "yes" or "no" question. Some 60.5% of respondents said "no" to this question. However, when asked to specify on a scale of 1 to 5 (1 being no conflict and 5 being large amounts of conflict) how severe the conflict was some 67% of respondents indicated a score of 2 or higher that indeed a conflict did exist. Further, when given the chance to draw on conflict polygons in relation to the ILs displayed on the IPAD, 72% of respondents did so. Thus, when given a binary choice respondents expressed less conflict than when given the option to express a range of conflict severities or spatially draw and rank their conflict area.

4.3.1 Tow Cable Risks

Snagging tugboat tow cables was also a moderately rated conflict amongst shipping stakeholders. The vessels' tow cables were typically heavy braided steel wire which were reported to sag beneath the surface of the water and provide a dynamic system enabling the barge to surge and move in response to sea conditions without putting shock loads on the tow cable fittings and the tug (see fig. 3-13). It was also determined that areas of "towline surge" risk exist and are generally at corners in a channel and areas where significant eddies, turbulence and tidelines occur, causing different bodies of water to move at differing speeds and the tug and towed vessels to correspondingly shift positions and cause towline surge with concomitant potential risk of snagging (see fig. 3-14). Tugboat operators generally defined large areas of potential conflict (rated anywhere from low to high depending on the interviewee) in the study area relating to the risk of snagging a tow cable on a tidal turbine. However, based on interviews with the 4 towboat operators surveyed for the study, 2 of them believed, based on their many years of experience and some empirical monitoring via a ship mounted echo sounder, that their tow cables descended no more than 10m below the water surface at their lowest point. If such claims are true then the actual risk of tow cables snagging onto turbines deployed more than 20m below the surface would be low. As such, it is recommended that this risk be further considered in relation to ISTE or ORE installations where tug boats may operate, particularly in turbulent waters where corners in tidal channels will likely produce large eddies and the possibility for towline surge and sagging.[20]

4.3.2 Sportfishers

While commercial net fishing did not occur in the study area due to regulatory restrictions and high flows, sport fishing was a very common activity, particularly in the late spring, summer and early fall months. Sport fishing density maps were created based on fisher's top 3 or 4 self-described usage areas, which they were asked to apportion a value to (out of a total of $100). Fishing intensity areas were then classed as low ($0-25), moderate ($26-50), or high (greater than $50) value and inputted into ARC GIS, creating a fishing value density map. While low value fishing areas spanned much of the study area, moderate and high value areas were mostly to the north and south of the ILs at the terminuses of the main tidal channel where it expands into open, slower moving water. This finding suggests that narrow, fast moving tidal channels are generally not high activity fishing areas (except perhaps in back eddies where

[20] Subsequent to the study work completed for this Thesis, SRM Projects and Others initiated a research project to better quantify the risk of interactions between ISTE/ORE installations and marine traffic caused by tow cable drooping. Results are expected to be published by the end of 2016.

slower water is present, or at slack water); however, where channel cross-sections open into larger passages or straits, the water slows down, which likely gives rise to locations of high activity fishing. This method of creating a stakeholder value usage map can be applied to any sector from eco-tourism to recreational boating.

When shown the ILs at the end of the interview process, however, another trend was observed whereby fishers created broad scope conflict polygons spanning the entirety of the south ILs and beyond, much larger than their original self-described fishing usage areas. An example map of this is portrayed as figure 4-4, showing the actual southern ILs and hypothetical usage areas and then the resulting conflict area created by a stakeholder in reaction to seeing the ILs. This trend, discussed in general at the beginning of section 4.3, was most strongly witnessed amongst the sport fisher stakeholder group. These findings in relation to usage and conflict areas introduce notions of loss of use and reflect Alexander's (2012) findings at the Mull of Kintyre peninsula where stakeholders reacted strongly to seeing the actual proposed project areas. This trend was also seen for land based wind farms as summarized with Wolsink's (2007) U-shaped support levels curve for projects going through various design, implementation and development phases.

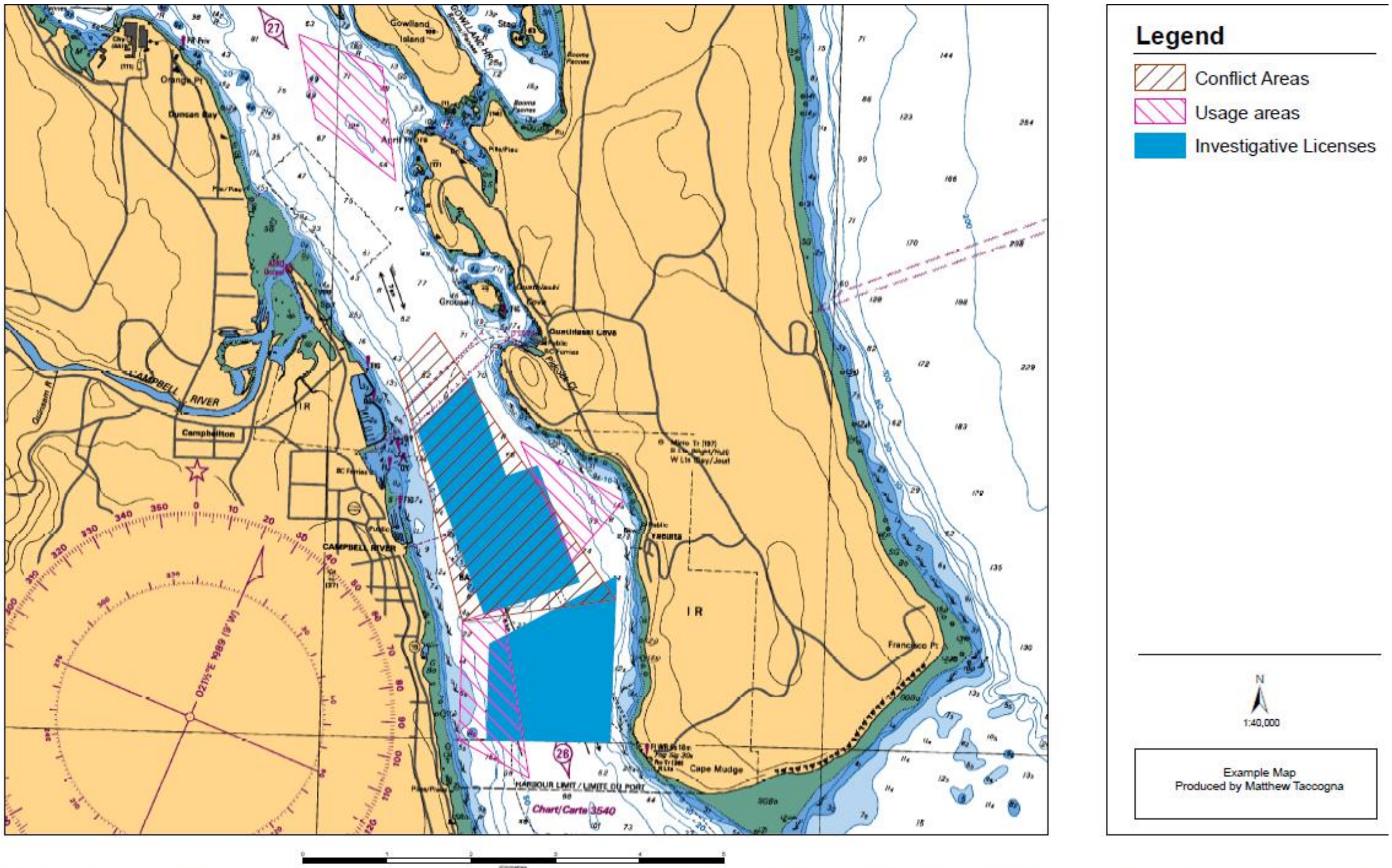


Figure 4-4: An example ARC GIS map showing the southern ILs in blue, initially stated usage areas in magenta and a later stated conflict area in brown. This map is an example of how some stakeholders would place conflict polygons after seeing the ILs at the end of the interview, which were completely different from their originally described usage areas, drawn at the beginning of the interview before the IL sites were introduced. These usage and conflict areas shown here are hypothetical and for demonstration purposes only; however, the IL sites are real and accurate. Source: author.

The conflicts between fishers and the IL sites were also mainly to do with the type of fishing they engaged in, known as downrigger fishing. Downrigger fishing uses up to 2kg lead weight balls on the end of steel wires attached to fishing boats in order to place their fishing line in upwards of 80m of water (see fig. 3-10). Thus, similar to tow cables, downrigger cables were stated to pose both a real and perceived risk to stakeholders in relation to ISTE arrays. The potential for a downrigger ball from a small boat to snag on the bottom in high currents was described by stakeholders as very dangerous. Subsequent verification of downrigger manuals also revealed that snagging a downrigger from a small boat in high currents could cause injury to the fisher and possibly serious damage to their boat as well (Scotty Fishing and Marine Products, 2015). Interestingly enough, however, given the apparent potential spatial conflict between downrigger fishing and tidal turbines, inclination towards spatial usage trade-offs was also mentioned amongst the sportfishing guides. The fishing regulatory body, Department of Fisheries and

Ocean Canada (DFO), employs several spot closure areas for sport fishing within the study area. This involves closing certain geographic areas for prescribed amounts of time in order to aid in salmon migration and conservation measures. One spot closure area in particular, known as the “lighthouse” was identified by one fishing stakeholder (out of 5 interviewed) as a potential trade-off area. The idea was that, in exchange for the creation of a non-fishing exclusionary zone around the southern IL tidal array, the fishers would want the “lighthouse” area open to them for fishing (see fig. 4-5). In the case of downrigger fishing where shared zoning between tidal arrays and fishing could possibly be unachievable due to safety concerns, trade-off is recommended as a feasible mitigation measure, especially if tidal arrays are found to act as fish aggregation, refuge areas or *de facto* marine protected areas (Ashley et al., 2014; Boehlert, George and Gill, 2010; Inger et al., 2009). In particular, Inger et al. (2009) suggests that, “if properly applied, [ORE] arrays can have the capacity to act as both artificial reefs and fish aggregation devices, which have been previously used to facilitate restoration of damaged ecosystems, and *de facto* marine-protected areas, which have proven successful in enhancing both biodiversity and fisheries.” In regard to the efficacy of MPAs in increasing marine biodiversity, Halpern (2003) synthesized the results of 89 previous studies and discovered that, generally, MPAs succeeded in increasing density, biomass, organism size and diversity within the reserves, compared to surrounding areas. Some other fisheries mitigation measures in relation to tidal energy are discussed in chapter 5 of this Thesis.

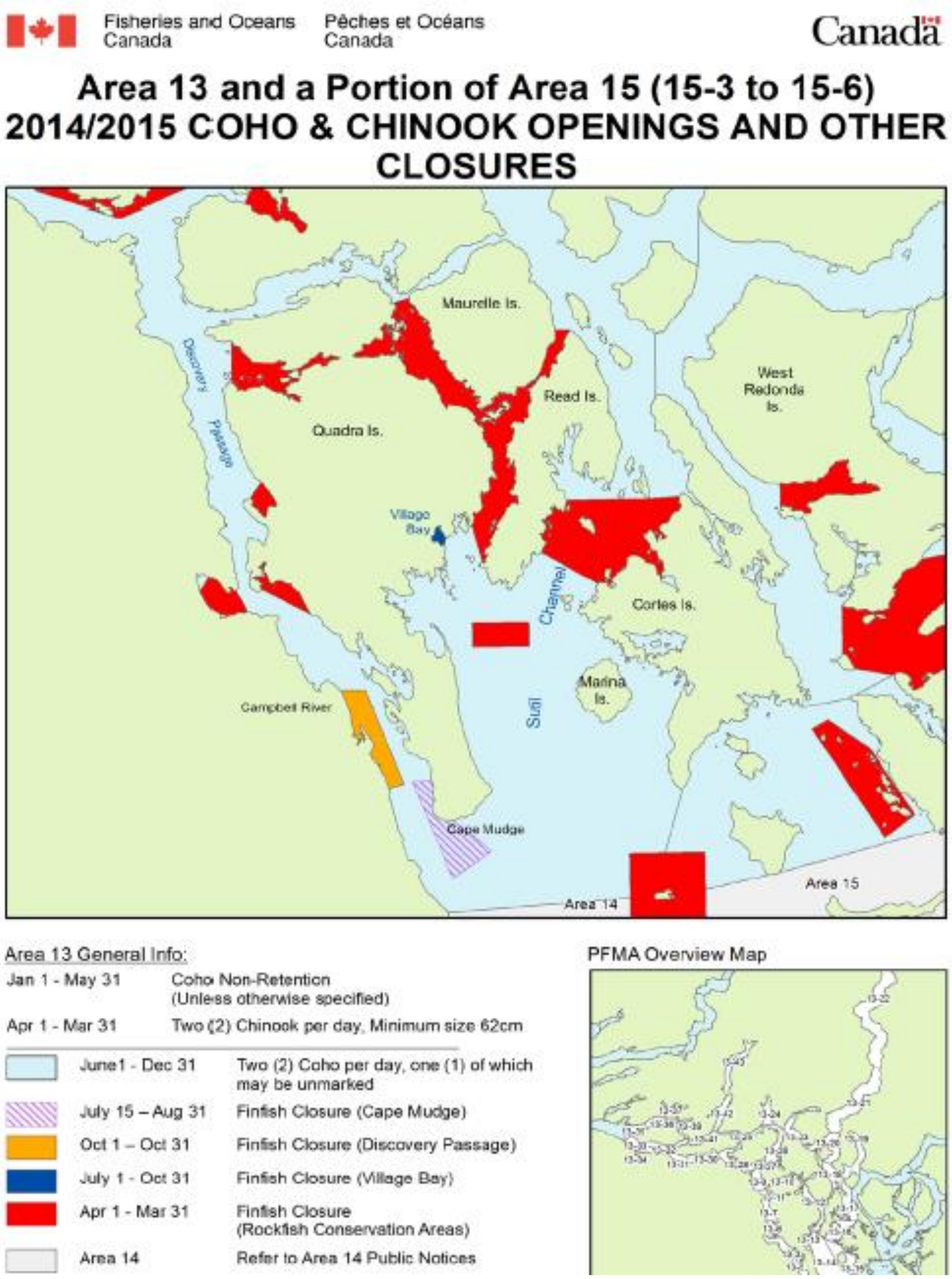


Figure 4-5: Department of Fisheries and Oceans 2014 spot closure areas for management area 13, encompassing the study area. The "lighthouse" closure area is indicated by the purple hatched area. Reprinted with permission from Department of Fisheries and Oceans Canada, map is a copy, original map can be found here: http://www.pac.dfo-mpo.gc.ca/fm-gp/rec/tidal-maree/a-s13-eng.html

4.3.3 Timing - Specific Activity

Conflict was also largely determined by the stakeholder group's particular timings of usage, which all contributed to higher or lower levels of perceived conflict in different areas at differing times of the year for different users. Especially in narrow, high velocity tidal channels, slack water, or the period when the tide is turning and is mostly still, is a very important resource to local and non-local shippers alike and the possibility of losing a slack water window was very important to stakeholders. As ISTE surveying, installation and maintenance windows would also likely have to occur at or near slack water, it is clear avoiding parts of the year where shipping and boating activity occurs would likely benefit the ISTE industry. As well, higher amounts of route variation were observed for smaller vessels traveling with the tide, than those traveling against it. This trend was because smaller vessels traveling against the tide would use specific nearshore back currents or eddies which moved backwards against the predominant tidal flow, while vessels traveling with the dominant tidal flow could use the majority of the channel width freely. Route variation in accordance with direction of the tide was not observed to the same extent amongst larger classes of vessels, as they generally adhered to the middle of the channel, particularly in the narrower sections.

Strong seasonalities were observed in the study area in relation to cruise ship traffic, sport fishing, tourism and recreational boating. Both primary and secondary data were gathered in relation to this seasonality of shipping and boating usage. Secondary, publically available data exists on DFO’s website recording the estimated (based on aerial and point of access surveys) number of boat trips related to sport fishing which occurred within the fisheries management area encompassing the study area. The month to month data clearly show a summer season spike in sport fishing boating activity from 2007-2009 (see table 4-1).

	Number of Boat Trips in Area 13		
Year/ Month	2009	2008	2007
APR	0	57	313
MAY	1053	572	796
JUN	2989	1814	1826
JUL	5665	5784	5621
AUG	7277	5685	6732
SEP	2560	2526	3487
OCT	0	2139	1237
total annual trips	**19544**	**18577**	**20012**

Table 4-1: DFO creel survey of sport fishing pressure in Management Area 13 from the years 2007-2009. No reported boat traffic occurred outside of the months cited here according to the study. Highest pressure months are highlighted in yellow. Data compiled using DFO historical recreational catch data, source: http://www.pac.dfo-mpo.gc.ca/stats/rec/gs/index-eng.html

Similarly, boat fuel sales volumes at a major local marina were examined month to month over a 4 year period, again showing higher volumes of fuel sold in the summer months, particularly July and August, indicating higher amounts of recreational and commercial boating traffic (see fig. 4-6). The marina serviced a large number of recreational yachts and sportfishing boats as well as commercial tugboats fishing vessels, and government vessels, both based out of Campbell River and transiting through the area.

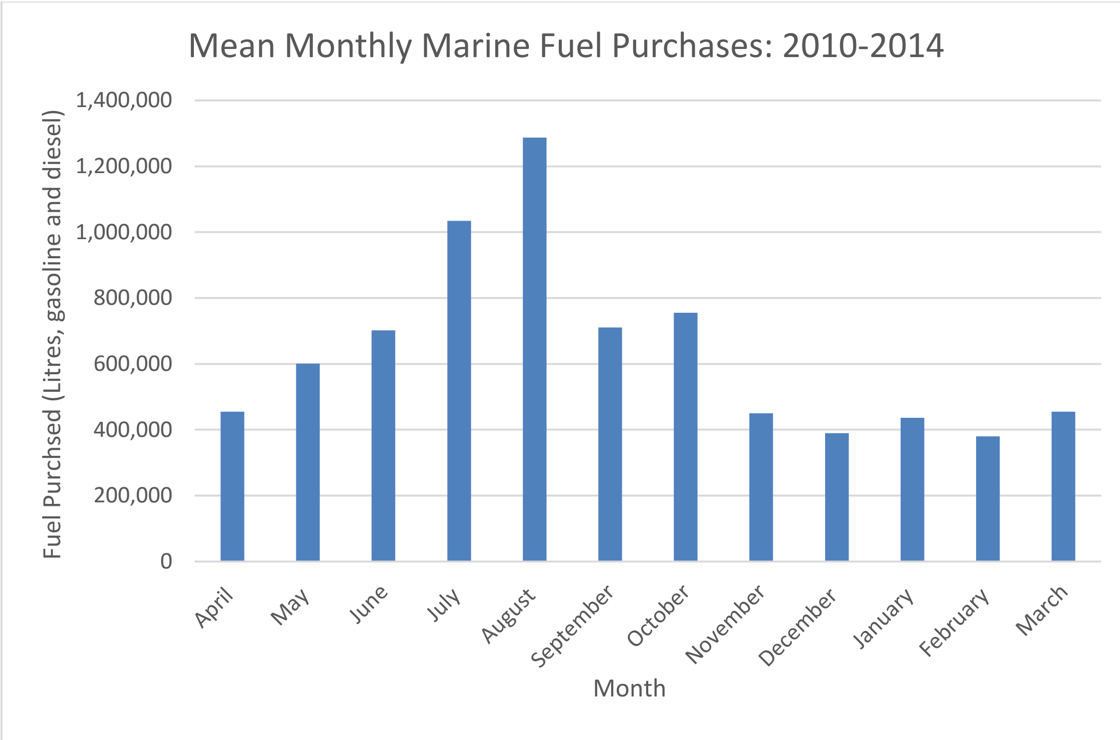


Figure 4-6: Mean monthly fuel purchases from 2010-2014 in litres from a prominent fuel dock at the Campbell River waterfront. Quantities include both diesel and gasoline fuel sold to recreational and commercial customers.

Regional shipping regulations mandate that any foreign flagged vessel over 350 tons must carry a marine pilot onboard (Ministry of Justice, 2015). A marine pilot is a heavy vessel navigation expert with strong knowledge of local coastal waters. Accordingly, the marine pilotage regulating authority records all voyages they undertake including cruise ship transits through Seymour Narrows. 2013 data show a prominence of cruise ship activity through the summer timeframe (see fig. 4-7).

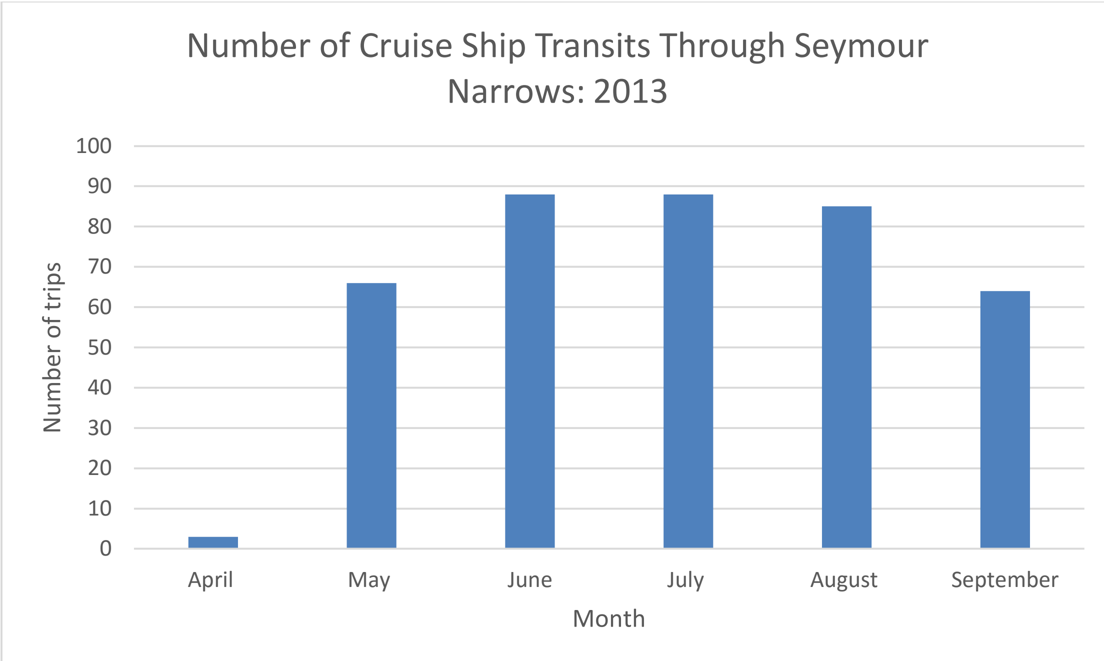


Figure 4-7: Number of cruise ship transits north and south through Seymour Narrows in 2013. Source: Pacific Pilotage Authority, 2014.

It is not clear from this research whether a great deal of the perceived conflict related to marine traffic, could have been due to the lack of information surrounding the surveying, development, and maintenance schedules for the sites as well as the turbines' height off the bottom and subsequent surface clearance. This would be a good topic for further perception research. Numerous stakeholders and First Nations asked questions related to:

- what the turbines might look like;
- how deep they would be deployed;
- what size of barges and tugs would be used to deploy them;
- would the turbines harm marine life;
- how high off the bottom they would stand; and
- how many would there be.

Given the number of unknown factors perceived by the stakeholders related to the ILs, it is recommended that Project Development Plans include as much technical definition as possible, particularly related to size and surface clearance of the turbines, in order to reduce stakeholder and First Nations concerns. This practice may also lead to more accurate IMSP results as respondents will have more information at their disposal.

4.4 Conclusion

This chapter examined some of the conflicts and usage characteristics surrounding two narrow-channel proposed tidal energy sites as well as highlighting the methodologies used to do so. The main conflicts and findings of the study were not foreseen by the researcher or project team; however, the methods and research questions used managed to successfully elicit these results and are worth considering further. Clear issues, both real and perceived, were identified relating to the development of the IL sites, namely shipping and fishing conflicts, and the IMSP methods helped to identify spatial and temporal specifics surrounding these issues. The notions of slack water windows and high summer cruise ship activity were important, as was the risk of towline sag occurring around corners and bends in the channel. High value fishing areas occurring at the terminuses of the channel as well as the trends of fishers and shippers to identify conflict areas related to the IL sites which weren't previously identified as usage areas were also important findings and correspond with work already conducted in the field of risk perceptions surrounding renewable and offshore renewable energy (Alexander et al., 2013; Devine-Wright, 2011; Wolsink, 2007; Wüstenhagen et al., 2007). One limitation of the study methods used was that the offering of theoretical money to the interviewees versus tokens (as in several of the other interview questions) may have had the effect of making subjects more protectionist or concerned about their identified sites. Utilizing money as a valuation method is clearly more associated with economic livelihood and income rather than aesthetic value or personal satisfaction derived from said sites, and thus may have biased the subjects slightly towards the prior consideration rather than the latter. Finally, some weaknesses regarding mapping shipping routes were also identified with this IMSP process. The inherent inaccuracy of lines representing exact shipping routes and polygons representing usage and conflict areas over time cannot be easily overcome, as usage parameters can often be more contiguous rather than delineated specifically. Nevertheless, the method overall sufficiently documented both the stakeholder and First Nations engagement process, as well as an effort at defining the considered water space usage characteristics both in general, and in relation to the proposed tidal energy sites. Further discussion of this methodology as well as some recommendations for a prescriptive site assessment and engagement methodology and some associated conflict mitigation measures are discussed further in the conclusion of this Thesis.

Chapter 5: Conclusion: Prescriptive Engagement Policies and Methods for ORE Site Assessment

5.1 Introduction

This conclusion section will begin by summarizing the Thesis and looking at some potential limitations of the study. Secondly, it will discuss some mitigation measures designed around how to minimize possible risk between offshore renewable energy (ORE) equipment and the fishing and shipping stakeholders identified in this study as having high levels of conflict with the proposed in-stream tidal energy (ISTE) sites. Thirdly, the chapter will suggest how to assess a proposed offshore renewable energy ORE site from a regulatory, stakeholder and First Nations engagement and shipping standpoint, ending with a prescriptive matrix on how this effort can effectively be accomplished. Finally, the chapter will conclude with some broader policy and regulatory recommendations regarding the implementation of ORE, and suggest some of the academic implications and recommendations for further study.

5.2 Summary of Thesis

This Thesis first provided the necessary background to understand tidal energy and the role it could potentially play in meeting BC energy needs. Then, it looked specifically at a narrow channel BC tidal energy site and examined perceptions of local key informants (stakeholders and First Nations) of tidal energy within the BC context. Where, when and how various First Nations and stakeholders' day-to-day activities might conflict with these proposed sites were then elicited. Finally, in this chapter, the Thesis will propose some means to try and mitigate these conflicts and methods for conducting ORE site assessment and associated stakeholder and First Nations consultations.

In chapter 2, the Thesis first began by introducing the concept and need for renewable energy (RE) and how it can fit into our existing electrical grids, both in centralized and distributed fashions. Various RE technologies were discussed with emphasis on the applicability of different REs for different, more suitable regions of the world. Ocean energy and, in particular, tidal energy were then introduced with a gradual focus onto ISTE in a BC context. BC's overreliance on hydroelectric in the face of climate change, the highly centralized nature of its power grid, and the large number of populations on its coastline, both on and off-grid, all were presented as reasons of demand for ORE and ISTE in particular within its coastal zone. Subsequently, the presence of a substantial ISTE energy supply on the coast was also presented. Finally, in this chapter, some of the methods and reasons for conducting marine spatial planning around ORE sites were introduced and context was given as to how this might occur in BC.

The field portion of this study comprised chapters 3 and 4 and examined proposed tidal energy projects at Campbell River, BC, a narrow channel high use marine area known as Discovery Passage. The study interviewed members of the shipping and boating, sportfishing, regulatory, First Nations, eco-tourism, marina operator, environmental and aquaculture communities in Campbell River, BC. Methods used included interactive marine spatial planning (IMSP) and semi-structured interview techniques in order to identify stakeholder usage of Discovery Passage in a spatial and temporal context. The interview process then introduced participants to the basic concepts of ISTE, measured their perceived risks and benefits of it, and finally, examined their reactions to being introduced to the ISTE sites in geographic and technical detail in close proximity to their community.

Perceptions of risk were generally stakeholder specific and localized within the study area, particularly around the ISTE sites. Meanwhile, benefits were perceived more uniformly across all groups and more regional in their applicability. Interviewees were introduced to the hydroelectric nature of their current energy supplies and the possible impacts climate change may very likely have on these supplies in the future. This notion had a strong resonance with people, possibly due to Campbell River being home to the sizable Strathcona watershed which hosts 3 hydroelectric dams, feeds a river home to 5 species of Pacific salmon and supports a substantial commercial and recreational fishing industry in the region. Further, 2014, the summer in which the surveys were conducted was one of the driest on record with dam discharge levels (and subsequent river flows) at 23 year lows. Subjects were told that significant ISTE development in the Discovery Passage adjacent to their town and the Campbell River itself could possibly help displace local hydroelectric generation, thereby enabling dam down ramping and subsequent reservoir conservation. Tidal power enabling local reservoir conservation for drinking water and fish health were thus the top 2 perceived benefits of the proposed developments across all stakeholder groups, followed by providing more local power generation for Vancouver Island, enabling local economic development and displacing regional off-grid diesel power generation.

Perceived risks were far more specific to stakeholder groups and their particular technical concerns. Namely, while commercial fishing did not occur in the study are, sport fishers were among the most opposed to the developments citing the highest general levels of conflict with the ISTE sites and spatially specific conflict directly where the turbines were to be installed. Their reasons were that their predominant method of fishing, the downrigger, would possibly snag on a turbine and create a dangerous marine accident situation. From these discussions and data, it was apparent that downrigger sport fishers believed that this activity could not occur within a tidal turbine array area. Although one possible mitigation measure was conceived by the Author to possibly mitigate this risk and is discussed in section 5.3.1.

Shippers and boaters in particular were overwhelmingly concerned with marine traffic interference. In particular, tug boat operators were worried that their tow cables might sag down and snag a turbine. Specific spatial analysis of the tow cable risk with stakeholders revealed that it would likely only occur around turbulent bends or corners in the channel where tug and barge velocities would differ causing a droop in their connecting cable and a subsequent risk. In general, marine operators were concerned that tidal turbine installation and maintenance operations would restrict their passage through the narrow Discovery Passage, which is a major regional shipping route, even though respondents were told that the turbines were to be installed at depths deemed safe for shipping as approved by the shipping regulatory authority Transport Canada.

A “barrier effect” or the theoretical idea that a number of tidal turbines comprising an array installed in a channel could possibly scare marine life away from passing through the channel also received the highest overall risk valuation amongst all stakeholders. This risk was immediately followed by “cumulative impacts of many tidal turbines” clearly showing that interviewees were most concerned for the safe passage of marine life as well as their own ships and boats. Cost was also a highly ranked concern around tidal energy although, interviewees also stated a high willingness to pay for tidal energy development as part of BC Hydro’s already implemented rate hike schedule. These values around energy development correlated strongly with an initial interview question asking respondents to rank attributes around where their energy came from in order of importance. Here, localized environmental impacts and cost were the highest ranked items of importance.

Finally, notions of loss of use became apparent, paralleling other work done in the field of risk perceptions surrounding renewable energy installations (Alexander et al., 2012, 2013; Wolsink, 2007). Namely, after hearing all of the information on tidal energy and knowing the general area where it was proposed to be installed, some 88% of respondents demonstrated strong levels of support for its development in BC and a strong willingness to pay small amounts to support said development. However, when the specific ISTE site areas were shown to the respondents on a map, some 72% indicated an area of conflict in relation to the sites. Yet, prior to being given the option to draw a conflict area, respondents were asked “yes or no” whether they had a conflict with the ISTE sites and some 60% said “no”, representing a near flip of opposition in relation to the spatial conflict question.

5.2.1 Limitations of this Study

Having outlined these methods in this paper, it would be remiss to not identify their weaknesses. Perhaps most broadly, the questions of scale and scope, or breadth versus depth, are clearly apparent. It is a challenge to interview and engage with a statistically representative sample of each stakeholder group (i.e. fishers, shippers, etc.) while still cross sampling all applicable groups sufficiently within a reasonable time frame and project budget. In this study, it was decided that more emphasis should be placed on shipping stakeholders due to the very busy nature of the site from a marine traffic perspective. Many other groups were also sampled, but not to the same extent. The sampling methods chosen were in-depth stakeholder interviews with an interactive marine spatial planning (IMSP) mapping exercise component. While it could be argued that broader scale in-person or online surveys, measuring levels of support and conflict with the tidal energy projects, would have gathered a larger sampling of the community, the depth of information on specific types of marine conflicts would likely not have been achieved through this method. For example, the findings around tow and down rigger cables specifically may not have been uncovered through an online survey as the conflicts were partially elicited through interaction and discussion between the researcher and the interviewees. These particular subjects did not necessarily think of these two specific risks, often until they were asked follow on questions by the researcher. Further, the dynamic and complex notions of locations and occurrences of tow cable sag could not have been understood or communicated through a survey: it required an in-person interviewer with knowledge and experience with shipping, marine navigation and tidal currents.

In addition, the level of complexity of shipping patterns could likely not have been captured through surveys. In particular, interviews with vessel traffic management authorities and the local Coast Guard station took over four hours and illustrated the ever-changing and busy nature of marine traffic through the Discovery Passage. This level of detail could simply not have been achieved through a closed form survey questionnaire. The interview subjects in these cases outlined vessel traffic patterns by vessel class, size and season, and were invariably further elicited by the researcher's own questions on the topic, which arguably helped to better define the patterns. Again, the researcher's own marine navigation and shipping background helped him to relate to the shipping community more, thus enabling him garner a more in-depth understanding of how shipping and boating activity occurred throughout the year. While likely not effective for IMSP, online or survey type questionnaires aimed simply at measuring broad types and levels of support and conflict for marine energy could be used to gain a larger sample size within a community, and identify which groups or resource users within community might need to be focused on for further engagement and more in-depth study. However, given the often small budget for initial community engagement on marine energy projects, it may be more efficient to simply focus on the key stakeholders who use the water extensively.

A second challenge with the methods chosen is to accurately map identified and valued usage areas across many different stakeholder groups. For example, fishing areas are one type of use, while eco-tourism areas are another, and the two groups' impacts and potential conflicts with an ORE site can be quite different. If an active industrial port area is defined as being very high value by one shipping stakeholder, but is low value to a First Nations respondent; the effort to reconcile the difference is neither clear nor simple. In other words, is it appropriate or possible to determine whose values are more important? Given this heterogeneity of views, it may not be desirable to try to create one metric or model to encompass all users of a site, but rather to consider them all separately. From this, similarities can be observed within the results and aggregation of these results can be considered for the sake of efficiency. See an example map in figure 5-1 with some hypothetical usage areas and shipping route added.

In retrospect, identifying key marine stakeholders and their concerns is the ultimate goal of any IMSP study. Upfront use of secondary data sources and delineation of pre-study resource usage maps as done in Alexander et al. (2012) can possibly yield more accurate or in-depth results in advance, and aid researchers in focusing their engagement. Certainly, once accurate resource usage maps are defined within a study, it would be useful to conduct a negotiation workshop as done in Alexander et al. (2012), in order to attempt to mitigate conflicts between stakeholder and First Nations groups and ISTE/ORE developers. This negotiation phase could be considered a second phase of any IMSP study. Again, however, sufficient project staff and budget would be required in order to conduct such a level of engagement.

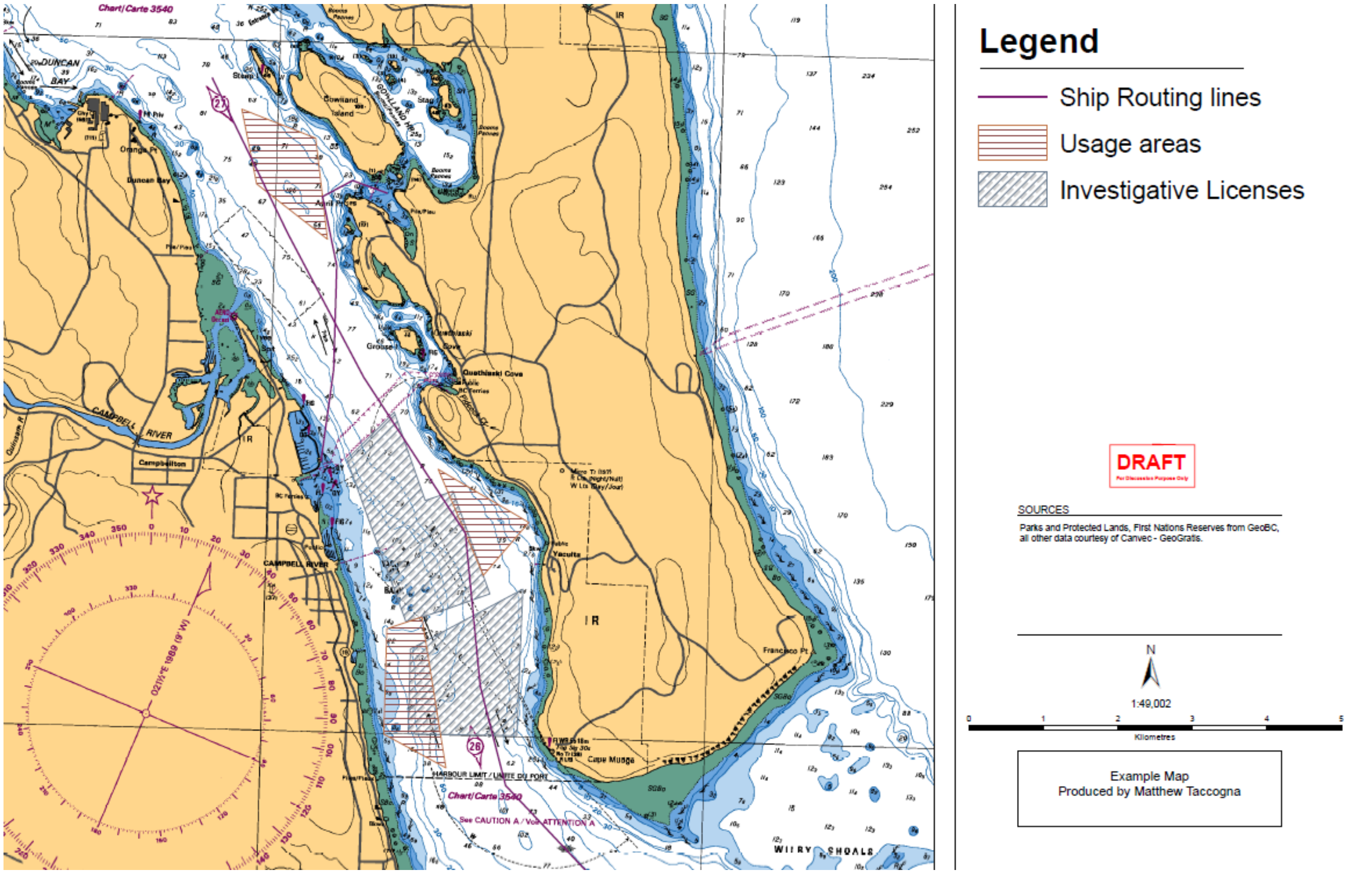


Figure 5-1: An example IMSP map showing example, hypothetical ship routing lines, and various stakeholder usage areas in relation to the IL sites (not real data). Aggregation or combing of similar usage areas can help simplify usage maps. The same practice can be employed for conflict maps as well. Shipping routing maps can be separated and similarly grouped according to tidal cycle or other criteria. Source: author.

5.3 Depth Specific IMSP and Risk Mitigation Measures

Vertical marine spatial planning offers one potential mitigation measure for spatial conflicts within narrow channels (or possibly for ORE sites in general) as well as being of importance when considering aspects of a possible bio-physical “barrier effect” as discussed in Chapter 3. The notion of safe surface clearance for tidal turbines must be considered, which is the ocean depth at lowest low water, minus the overall height of the turbine being used (or in the case of a neutrally buoyant mid-water floating turbine, its depth below the surface). Typical bottom situated commercial scale turbines can currently measure upwards of 25m high from their foundation base to the top of their turbine housing (see fig. 5-2). Thus, in depths of water of 75m, which are typical in south Discovery Passage, a 25m turbine will sit 50m below the surface offering substantial sea room for vessels, fishing gear, marine life and even tow cables to pass over unimpeded. The BC Pacific Pilotage Authority identified a vessel maximum permissible draught of 12m for any vessel transiting Seymour Narrows. Consultation with a heavy vessel navigation specialist concluded that an additional margin of safety of 20% should be added on top of that giving a minimum safe surface clearance (from the water surface) of 14.4m at lowest low water. The depths of water in the area and required clearances could provide means to mitigate some of the perceived risks of tidal energy in the study site.

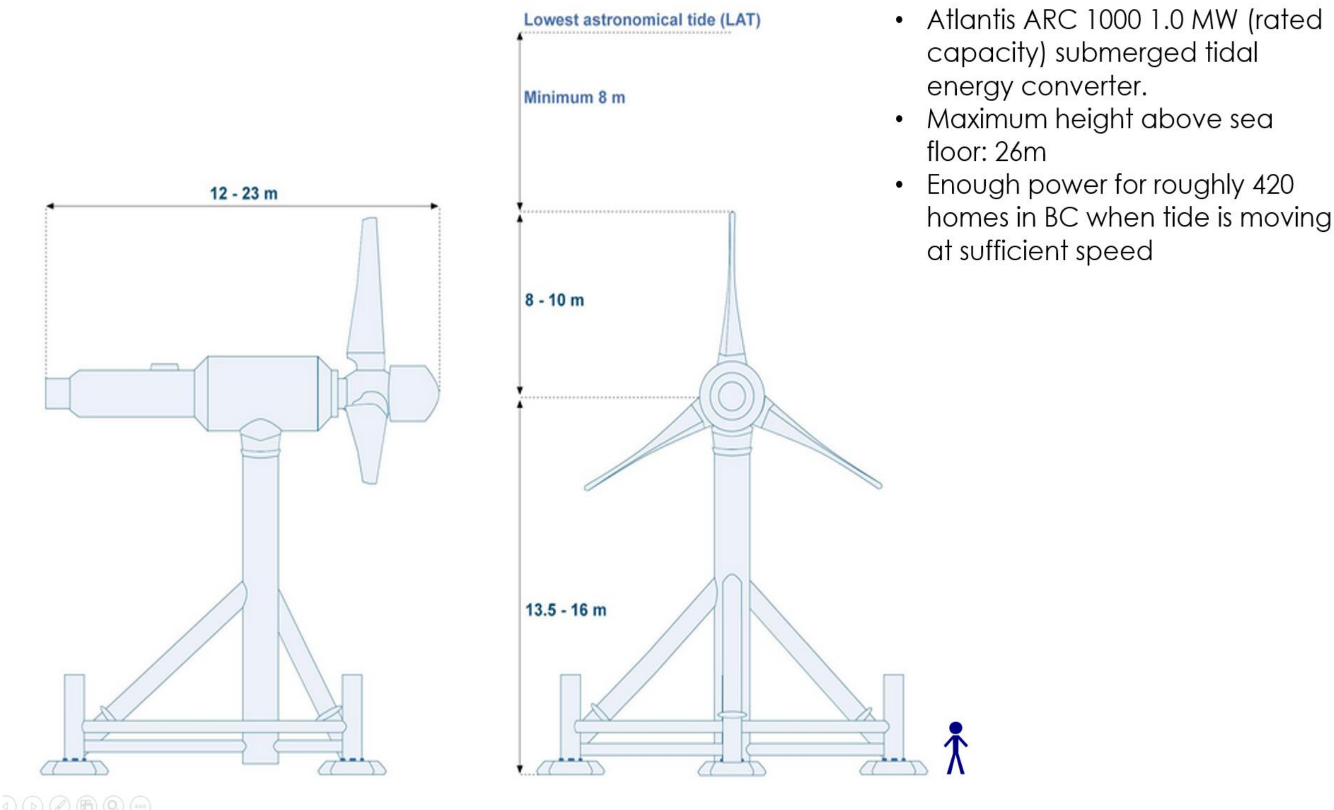


Figure 5-2: An Atlantis ARC 1000 1.0 MW tidal energy converter standing 26m high on the seafloor. A typical 2m tall human is seen standing next to it. Reprinted with permission from Atlantis Resources Limited, source: www.meygen.com

5.3.1 Downrigger Fishing Mitigation Measures

The more common current option for dealing with fishing conflicts around ocean energy sites is to simply establish a geographic boundary or exclusionary zones around the ORE array, or perhaps simply around each turbine (Alexander et al., 2012; Huckerby, J. and Brito e Melo, 2012). This discussion has been underway in 2015 at the Fundy Ocean Research Centre for Energy (FORCE) where authorities were reportedly considering establishing 500m wide safety corridors around their four 15 MW undersea power cables, each leading to a respective turbine test site, where lobster fishermen could not lay their traps (Beswick, 2015). Exclusionary or sometimes mixed use marine planning zones are often situated around offshore wind farms in Europe and this practice will likely continue to evolve into zoning around wave and tidal energy arrays as the technologies develop there as well (Huckerby, J. and Brito e Melo, 2012). Further, notions of mixed used marine spatial planning and ORE arrays possibly acting as *de facto* marine protected areas, as mentioned in section 3.1.1 of this Thesis, offers further interesting areas of study, as MSP co-zoning methods could help benefit both bio-physical health of the oceans and ORE projects (Yates et al., 2015). Finally, the possibility that trap fisheries, such the lobster fishery at FORCE in Nova Scotia, can be co-zoned with certain types of ORE (such as off-shore wind where there are no underwater turbines or machinery to snag fishing gear) is important to consider.

However, based on interviews conducted for this Thesis, one possible problem with geographic exclusionary zones is that sport fishers do not always have up to date charts which would show these areas. Or, in the instance of smaller sport fishers, they may not even carry charts or navigation systems whatsoever. Based on interviews and anecdotal accounts with professional sport fishing guides, most fishers would not want to pay to update their charts in accordance with exclusionary zones regularly and may not always be watching their chart plotter, even if they have one.

A possible solution to this conflict for downrigger fishery is the creation of "fishing floor." Essentially, a fishing floor would be a maximum depth to which downrigger fishermen would be allowed to put their cannon ball weight. Typical downrigger systems display the depth of the cannon ball to the nearest linear foot, therefore making it reasonably easy for a fisherman to abide by a depth restriction. If the top of the turbine is 50m below the surface, then a downrigger fishing floor of 40m could be established allowing 10m of safety separation and permitting the two water space users to co-exist via a depth separation stratum (see fig. 5-3). A possible problem with this approach is that high energy levels are usually not found in deeper water and the best energy content is generally located near the surface of the channel. Nevertheless, depth associated MSP is a possible planning option to consider in order to identify suitable sites which provide high enough energy densities at operating depths compatible with this approach to downrigger fishing. While not effective with trap fisheries, establishing a fishing floor, whereby a downrigger fisher could easily watch their depth counter and ensure that their gear remained safely above a tidal turbine vertical safety separation zone would likely ensure better compliance and less interference in high use fishing zones such as Campbell River and the Discovery Passage area. Turbine areas and depths would still be indicated on marine charts but the establishment of a fishing floor would perhaps add an additional, simpler and more "user-friendly" measure of safety.

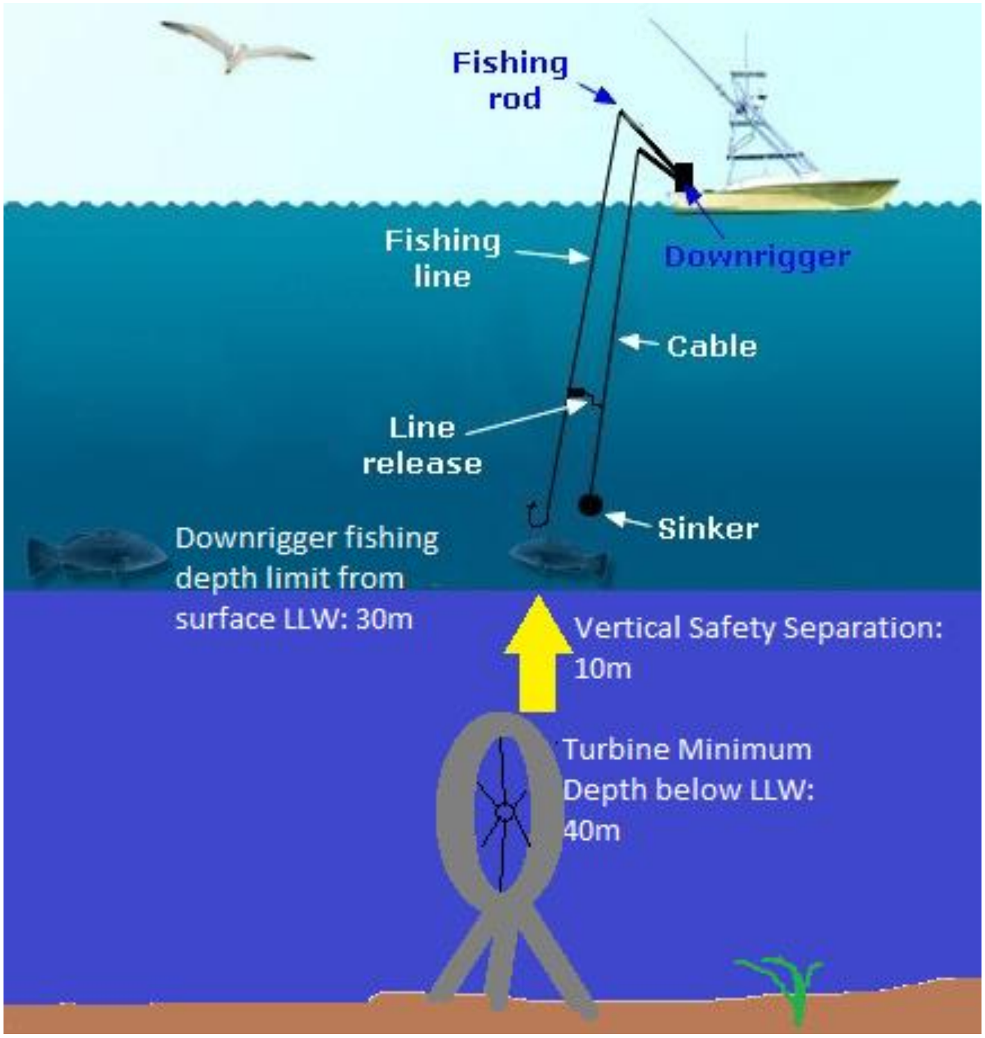


Figure 5-3: Drawing depicting an ISTE vertical safety separation zone allowing for 10m separation between the turbine zone and the downrigger fishing zone. Similar measures are applied by submarine Navies in order to safely separate submarines operating in close proximity to one another. Downrigger image reprinted with permission from Hookline, source: http://www.hookline-fishing.com/

5.3.2 Tow Cable Mitigation Measures

As mentioned in Chapters 3 and 4 of this Thesis, snagging tow cables from tugboats onto tidal turbines was seen by tugboat operators/stakeholders as being a moderate risk (based on mean conflict polygon severity score of 3.7 out of 5 amongst tugboat tow cable operators). 2 of 4 towboat operators interviewed stated based on their expert experience and some empirical measurements that their cables seldom would droop more than 10m below the surface. However, anecdotal evidence of turbulent corner areas in tidal channels producing conditions of towline sag due to varying velocity vectors between the tug and its tow, led to the conclusion that corner areas in channels are at higher risk of experiencing towline sag. However, turbulent corner areas of tidal channels are also generally not desirable areas for ISTE turbine placement due poor energy conversion efficiency in non-laminar water flows, thus perhaps rendering negating this risk somewhat. A separate marine spatial planning report, produced by this author for SRM Projects in early 2015, detailed and mapped these conditions of towline sag and surge in more detail and recommended further analysis. Subsequently, SRM Projects has embarked in a 6 month study specifically conducting risk analysis of tow cable sag in relation to the tidal energy development in Discovery Passage. Results of this study are expected in mid-2016.

5.4 ORE Site Assessment and IMSP Matrix

Given the results of the thesis regarding general support for tidal energy by key informants but with a number of perceived risks and perceived conflicts (that increase with greater specificity on sites), appropriate policies and planning methods would have to be in place to guide development of this industry. This section will briefly examine BC's ocean energy policy and then follow on with guidance for engaging with and consulting with stakeholders and First Nations for ORE projects. Then, MSP for shipping in relation to ORE projects will be looked at in detail. Finally, a general guideline for ORE site development from a developer and regulator standpoint will be outlined, based on experience gained from this study.

5.4.1 BC Crown Land Use Operational Policy for Ocean Energy Projects

The BC Crown Land Use Operational Policy for Ocean Energy Projects stipulates that various site assessment studies can be initiated to demonstrate "diligent use" of an investigative ocean energy permit site, a requirement for any holder of an ocean energy investigative license (BC Government-MFLNRO, 2011). Diligent Use refers to utilization of the land for its designated purpose within an appropriate timeframe (i.e. tenure holders cannot reserve Crown land for future use). Demonstrations of diligent use defined in the policy include ongoing surveys of the site and assessment of the following characteristics:

- Oceanographic
- Geophysical
- Biophysical
- Archaeological
- Road Access and Land Use
- First Nations Considerations
- Public Consultation

From the above list, this Thesis essentially encompassed public consultation, First Nations considerations and some archaeological data research (from secondary sources only). However, what is noticeably absent from this list of criteria are a definition of what, if any, kinds of marine spatial planning efforts should be undertaken as a possible means of mitigating multiple marine resource use conflicts which may arise in the assessment process. Based on the results of this thesis, a site-specific IMSP approach is recommended as a means to assess these conflicts as it provides a tool to engage stakeholders and First Nations and elicit specific concerns. The scale and scope of such a required IMSP study must be tailored, however, to the development stage of the ORE project. Initial, investigative license applications in BC for example should require less in-depth study than an application for a semi-permanent lease tenure or license of occupation. Further evolution of this policy and its standards would possibly enable developers and regulators to more efficiently assess each ORE site prior to major expenditures, and enable the location of sites where long term tenures are more likely to be approved.

5.4.2 First Nations and Stakeholder Consideration

IMSP, as used in this study, employs a value based conflict assessment approach and can help to identify areas of importance both on and under the water and the foreshore, which may hinder or impede an ORE development. Engagement with the people whose livelihoods would be most impacted by an ORE development is the general premise used in this study. The remainder of this section offers guidelines on which potential marine resource users may need to be considered when conducting IMSP for an ORE site as well as the validity of some of the IMSP methods used. In addition, this section includes discussion of methods of depth-specific or three dimensional MSP which could be employed to mitigate some of the stakeholder conflicts cited in this study.

Defining the users present at or near an ORE site, who need to be consulted is not always readily apparent. Shipping stakeholders, for example, often are not present at the sites, in offices or at docks, and may simply pass through at infrequent intervals; yet they will derive considerable value from that particular ocean passage and will raise serious concerns about it being impeded, as seen in this study. Similarly, First Nations may have claims at a site, and heritage resources such as burial, archaeological sites or shipwrecks may be present on the ocean floor of foreshore areas, and may be protected or of strong importance for First Nations or academic research, or both. In addition, FN jurisdiction or claims may be overlapping between various bands, or may not be readily apparent.

Commercial and recreational fishers present at the ORE site are also very important to consider as lines and nets can easily become snagged on ORE equipment, particularly wave or tidal turbines. Engaging with the fisheries regulator in the region can verify whether the area is open to both commercial and recreational fisheries, an important delineation as seen in this study. In addition, First Nations' fisheries which generally encompass food, social and ceremonial (FSC) as well as commercial fisheries and are often co-managed by First Nations and DFO, must be additionally considered. For ISTE sites in particular, high tidal flow environments may not be conducive to net fisheries, such as seining or gillnetting, due to difficulty in setting and retrieving nets; however, trap or line fishing may be readily practiced and could represent a source of conflict (for example, the concerns of lobster fishers and the proposed fishery exclusion zones occurring around the Fundy Ocean Research Centre for Energy (FORCE) tidal energy test beds in the Bay of Fundy) (Beswick, 2015). More discussion on potential fisheries mitigation measures are discussed later in this section.

Inevitably, the best way to determine the users of the waterway site in question is to engage and speak with the local marine operators and experts. Local mariners have often lived in the region for long periods and are habituated to shipping, various resource use patterns, as well and the general oceanographic and meteorological conditions present at a site. In addition, if there is any local vessel traffic management system, harbour authority or other marine regulatory or safety authority such as the Coast Guard, they will also have a strong knowledge of the area.

As witnessed in Campbell River, where many users have a clear high and low season period, seasonal temporal usage patterns should also be analyzed. Vessel and mariner activity proxies such as local marine fuel sales, pilotage records, slip rental rates, industrial port loading activity records or any other regulatory historical shipping records related to the area are good potential sources of secondary data for the development of an IMSP study. In addition, choke points or tidal narrows along major shipping routes will very likely represent a concentration of large shipping traffic near or during slack water periods and will almost certainly be regulated by a vessel traffic management authority. Methods and scheduling for surveying, installation and maintenance activities related to ORE sites must be considered in order to mitigate conflicts between shipping stakeholders and tidal energy developers based on these seasonal temporal traffic variations.

5.4.3 MSP for Shipping Traffic

The utility of mapping shipping routing is important, yet it may not always provide useful information, particularly in narrow channels. While this study mapped ship routing as was self-described by operators in relation to the tidal cycle by drawing lines on a digital map, in practice, expert mariners will seldom follow such exact, predicted routing. This practice can be due to any number of unforeseen and stochastic issues which mariners face such as avoiding other vessel traffic, vessels in distress, weather, mechanical failure, or prevailing currents, to name just a few. While large vessels will generally stay within a traffic separation scheme (TSS, also known as shipping lanes) in larger straits and passages, these lanes may not always be present, particularly in narrower channels or more remote areas (see fig. 5-5). In the absence of a TSS, it is general practice for larger vessels to adhere to the middle of the channel in order to maximize their area to maneuver, although the international regulations governing conduct of vessels in proximity to one another stipulates that "two power driven vessels meeting each other from opposite directions so as to involve a risk of collision should stay, as far as practicable, on the outer extent of a narrow channel on the starboard side of it" (Minister of Justice, 2015). In addition, in Canadian waters, in channels or waterways where there is a current, the vessel proceeding against the current must give way to the vessel proceeding with it (Minister of Justice, 2015). This latter rule affects passage in tidal narrows as vessels literally wait in line to pass through at slack water, and vessels with the following tide proceed first.

Interviewed regional heavy vessel navigation specialists (The Pacific Pilotage Authority) identified corridors of safe water which they utilized in the study area as opposed to route lines (see fig. 5-4). These experts, who navigate the largest vessels through the study area such as freighters and cruise ships identified the vast majority of the channel which was deep enough for these class of vessels as their "preferred navigation area." This statement clearly reflects the requirement for a large ships' pilots to have "room to maneuver" given the potential risks which they might face in their transit, and their very likely seldom adherence to consistent route lines within such a narrow channel.

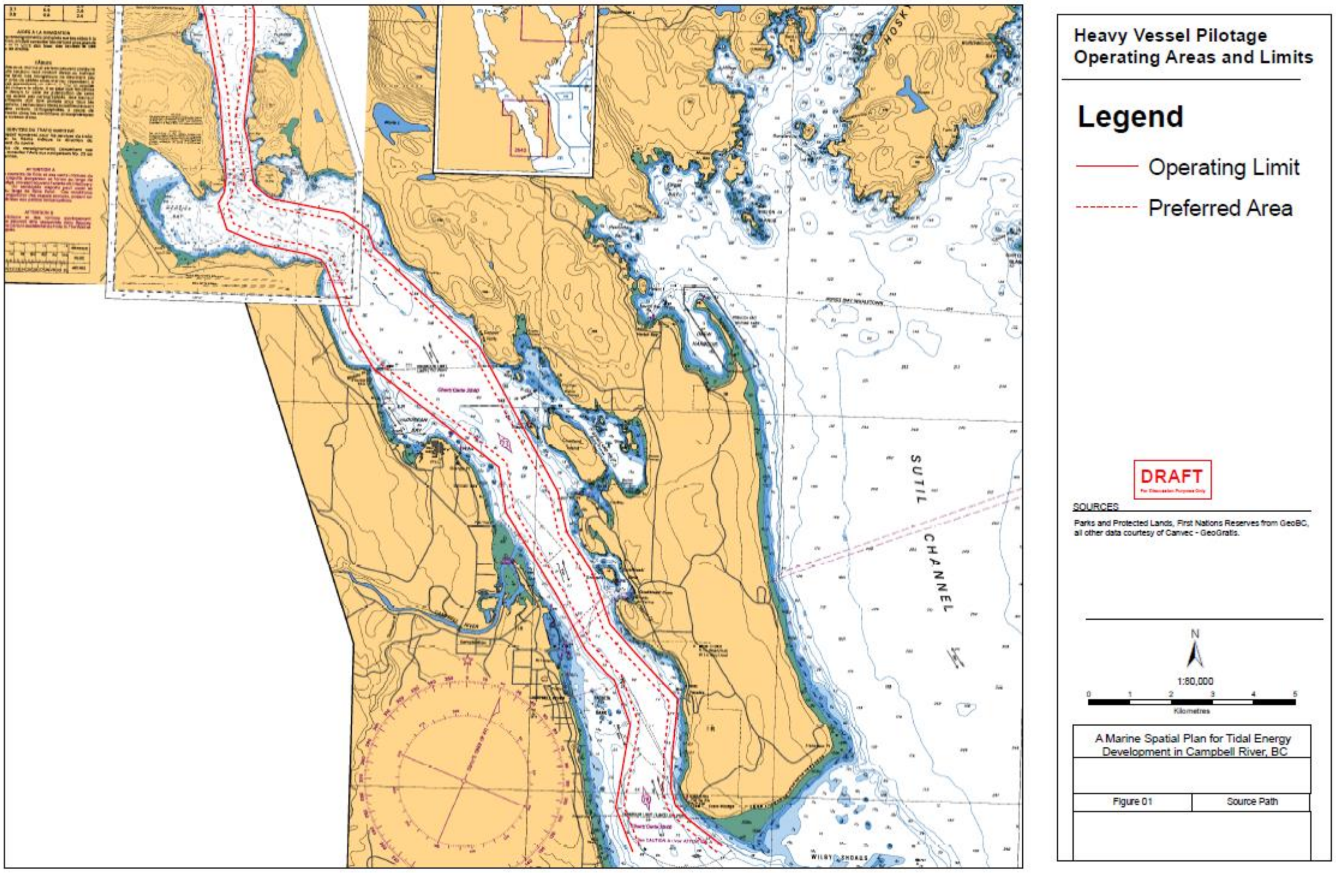


Figure 5-4: Pacific Pilotage Authority's typical corridors of usage for the study area. Corridor shipping data supplied by Pacific Pilotage Authority, 2014. Map constructed by author.

While the presence of a TSS can greatly reduce shipping conflict with an ORE site by keeping the majority of the large shipping within the lanes, narrow channels without a TSS pose greater complexity and methods of mitigation must be considered. In essence, mapping the routes of light and local vessels operators who may use the tides and eddies to their advantage to oppose the tidal current was found to be useful and consistent, possibly offering an ISTE regulator or developer reasonably consistent data with which to approve or situate tidal turbines, respectively. On the other hand, for larger, deeper draught vessels, defining corridors of usage would likely be more accurate and the chances of identifying areas where vessels "won't go" is simply not realistic, except in shallower areas where deeper draught vessels cannot safely transit, found in this study to generally be in waters shallower than 20m at lowest low water (low tide).

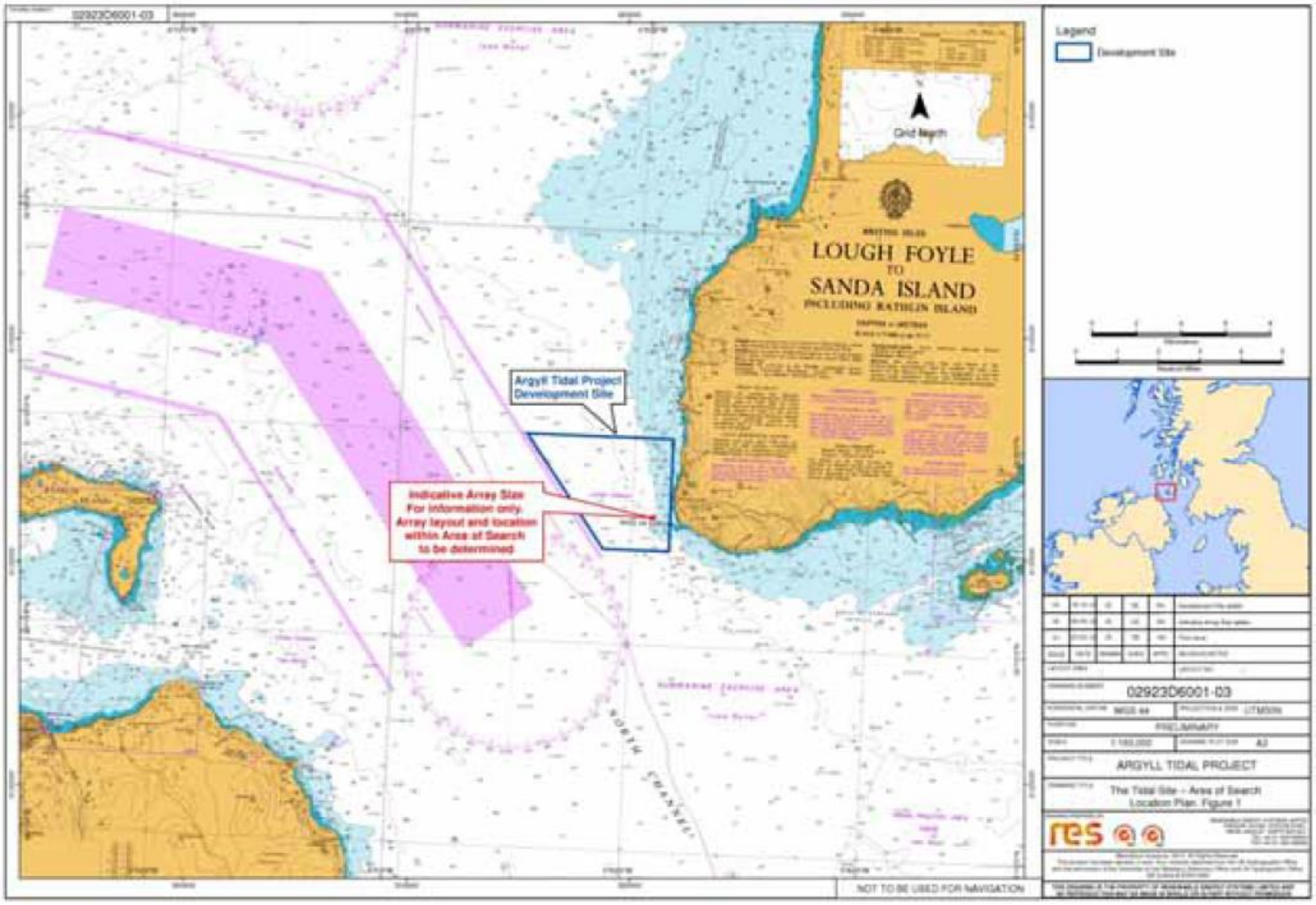


Figure 5-5: A proposed tidal energy site, outlined in blue, at the Mull of Kintyre Peninsula in Scotland. Shipping lanes are defined by the purple lines with the solid purple area being the traffic separation scheme. Reprinted with the permission of Argyll Tidal Limited, source: http://www.nautricity.com/docs/014_036__argylltidal_environmentalappraisal_dec13_lores3_1392661149.pdf

While vessel routing data are available from commercial marine traffic data companies and some Coast Guard Authorities and can be processed in order to create vessel routing density maps, the likelihood of identifying areas within a narrow channel that are free of or experience less traffic is unlikely within a narrow, high traffic channel. In addition, publicly available data in Canada are currently spatially coarse, incomplete and unsuitable for use in confined coastal waters for the purposes of ORE site identification. Data used in the BC Marine Conservations Atlas' (BCMCA) shipping density maps were resolved to 5km^2 grid cells in open ocean and 3km^2 cells (for some maps only) in coastal waters and were based on tracking data provided by Marine Communications and Traffic Services (MCTS). In addition, the data are based on vessels of only 20m length or greater, which are required to call into the MCTS, and thus do not account for the numerous other smaller vessels which transit the area. Vessel traffic density maps can thus be more concretely employed in open ocean applications where general shipping routes can be identified such as in the BCMCA's shipping density maps; however, their utility in confined waters ORE sites is limited unless more accurate tracking data such as automatic identification systems (AIS) are used, and even using these systems cannot guarantee that vessels will adhere to these routes of probability (see fig. 5-6).

Commercial vessel traffic density maps are available at some cost, based on AIS ship tracking data; however, again, vessels without AIS are not accounted for and the possibility of “no”, or “low” shipping zones existing in confined and busy waters is unlikely. In addition, financing the construction of such maps would place additional burdens on the developer while possibly contributing little within a narrow channel situation. Even if low traffic shipping areas were identified, they may not correspond to viable project development parameters for any number of other stakeholder-related or energy availability parameters, thus leading the developer to spend considerable money on developing a vessel traffic density map possibly without much application for it.

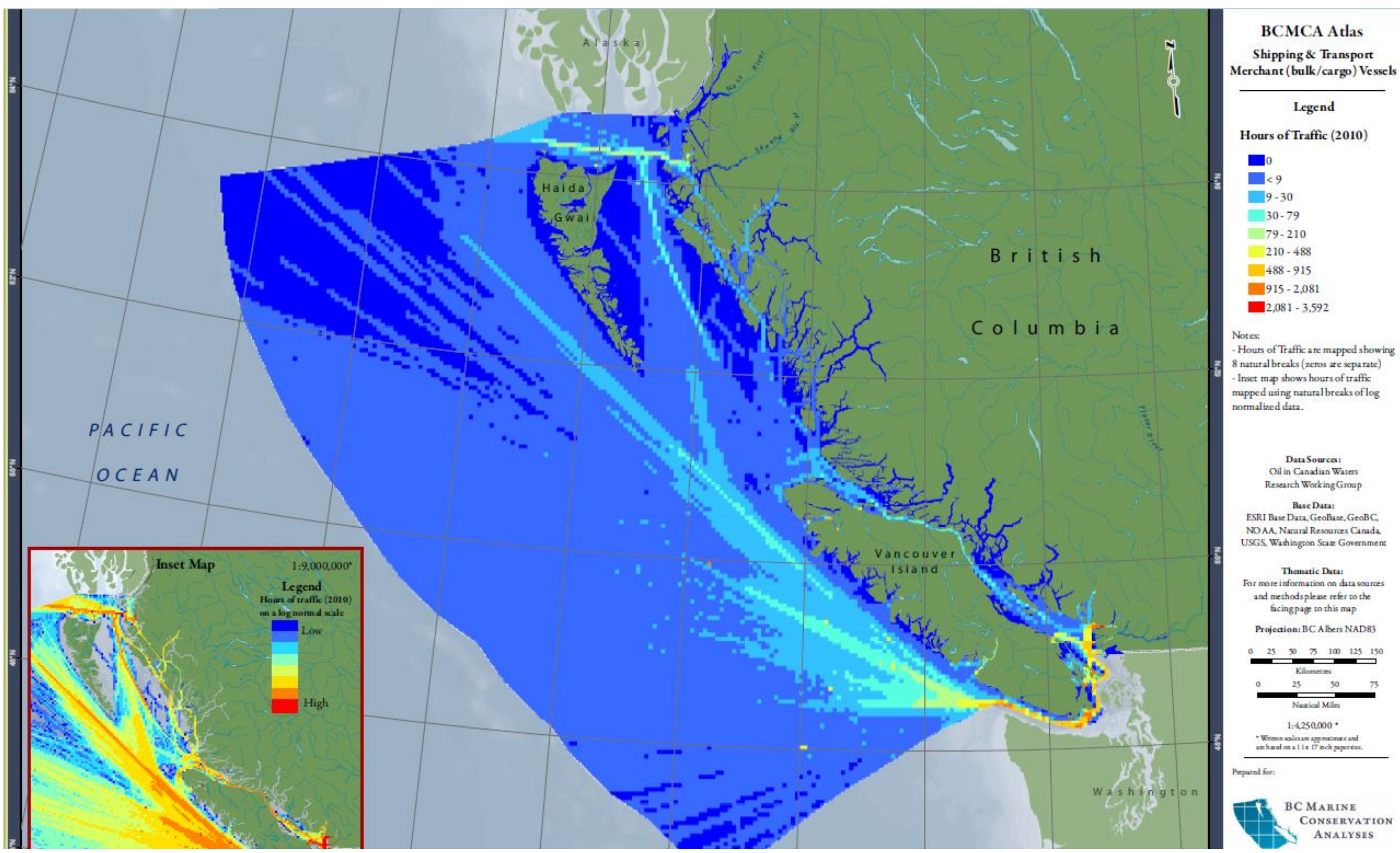


Figure 5-6: A vessel traffic density map for bulk and cargo vessels, constructed using Canadian Coast Guard MCTS data. Reprinted with permission from British Columbia Marine Conservation Atlas, source: British Columbia Marine Conservation Analysis Project Team (2011).

To summarize, stakeholder engagement and IMSP must be locally and regionally focused on people who use the site waterway and surrounding areas in question with emphasis placed on expert mariner engagement (including shipping, fishing, First Nations and otherwise). A defined engagement framework of speaking with and interviewing people with commercial, recreational and cultural/heritage interests in or around the ORE site and its foreshores will hopefully help assure that no groups are missed in the initial consultation process. Further, an IMSP mapping framework similar to the one used in this study will help delineate both spatial and temporal distributions of marine usage as well as possible stakeholder conflicts with the ORE sites in question.

5.4.4 Prescriptive ORE Site Assessment Framework

Several tidal energy site applications in BC have revealed that a comprehensive approach to site assessment and development would be of benefit to both developers and regulators (Lavoie, 2013). Given the substantial risk perceptions surrounding the impacts of ORE technologies on marine life (see chapter 2 of this Thesis), it is highly recommended that early in the site assessment process a check of existing coastal environmental planning resources (such as MaPP for the North coast of BC) be done to ensure that a site is not infringing on any important regulated or sensitive marine habitat. Initially, as well, significant amounts of desk study analyzing existing resource assessment documents and identifying good potential sites based on marine charts and similar nautical documents can be done. Communities adjacent to these sites can then be studied remotely and contacted to develop an initial stakeholder list, areas of interest and general marine traffic related information in order to start formulating an engagement plan.

Stakeholder engagement and marine spatial planning studies for ORE sites should generally consider the geography of the sites, the turbines and equipment envisioned for deployment there, the types of human usage which occur and any already existing regulatory framework outlining how such a process should be undertaken. IMSP studies will need to be staged and scoped depending on the level of ORE site investigation and development being undertaken at a site. Initial explorations could be cursory and low cost, looking for major possible barriers to development, or “tripwires.” If these initial investigations indicate positive possibilities for development, then further, more in-depth and costly engagement practices need to be undertaken, geared towards long-term development preparations. In addition to these considerations, while not fully examined within the scope of this thesis, the bio-physical aspects of an ORE site must be carefully considered as Chapter 3 of this study has also clearly demonstrated stakeholder concern around impacts of ORE on marine life.

In screening an ORE site in general, energy levels, socio-economic and biophysical aspects must be considered. Searching existing web-based marine and coastal planning initiatives such as the Marine Planning Partnership (MAPP) and the BC Marine Conservation Atlas (BCMCA) in British Columbia, can help indicate important marine ecological or socio-economic zones of importance when considering application for an ocean energy site tenure. This practice was successfully utilized in Alexander et al. (2012), offering baseline resource usage map data for stakeholders to consider when formulating their responses; the process used also allowed for stakeholder negotiation forums, another method which could be considered for more in-depth interactive marine spatial planning (IMSP) processes.

In general, the team conducting the IMSP and stakeholder related research about the sites in question must have a strong local and regional marine knowledge of the area, either from a shipping and transportation, or natural resources management background. It is assumed that ORE site assessment and adjudication procedures would follow existing government regulations and relevant policies; however, given the nascent nature of the field, if adequate policies do not fully exist or lack definition, it is recommended that relevant regulatory agencies work to develop appropriate policy and regulations to fill any gaps. It should be noted that, in BC, different levels of screening are required for Investigative License applications vice longer term Licenses of Occupation or Lease tenures. The former requires examples of diligent use investigating the potential ORE site, while the latter two generally involve development of the site and thus require adherence to a proposed, and more in depth, development plan (BC Government-MFLNRO, 2011).

A significant number of questions were asked by stakeholders as to the layout of the ISTE arrays at Campbell River. As discussed earlier, it is possible that the sparse amount of information given to study participants may have contributed to their elevated conflict perceptions related to the sites. While it is difficult, given the nascent and constantly evolving stage of ORE technologies, it would likely be an advantage to be able to provide as much up-to-date technical information as possible to study participants about the layout of the ISTE or ORE sites and the associated installation methods and maintenance intervals, particularly if knowledgeable stakeholders are involved. ISMP studies in relation to ORE sites would substantially benefit from defining the size of energy technology, how much marine traffic interference will have to take place to install and maintain it, and the planned locations of the technology within the water column. This practice would give shipping and fishing stakeholders in particular a better sense of the depth that turbines would be at and how this might impact their lines or equipment and normal operating and business routines. Having this information at least roughly defined would help provide a more complete picture to stakeholders and would likely garner more accurate and useful results. Once the engagement study has been conducted with said accurate information, results can be processed utilizing spatial mapping, temporal scheduling and risk and benefits perceptions of the First Nations and stakeholders interviewed. From this point, further project refinement plans can be put in place in response, including adaptive or mitigating measures such as negotiation workshops, and a clearer understanding of the project requirements can be realized. One of the challenges of this idealized approach, however, is that the efforts at ascertaining exact ISTE or ORE equipment specifications and positions early in the project planning phase is often too expensive and unfeasible given the lack of other important stakeholder concerns, a detailed resource assessment or other extraneous factors.

A recent best practices document produced by the Nova Scotia department of Energy Marine Renewables Section has also defined a holistic approach to ISTE site development including aspects of (Nova Scotia Department of Energy and Marine Renewables, 2014):

- initial and pre-planning processes (which include many of the elements of a desk study identified above),
- First Nations and stakeholder consultation,
- resource assessment (energy estimate),
- baseline and environmental impact screening and assessments,
- ongoing monitoring programs,
- regulatory assessment and oversight,
- construction of the site,
- on-going operations and maintenance,
- and finally site decommissioning

While this plan incorporates the whole lifespan of an ISTE project our model looks more at the initial screening of a site, with emphasis on the IMSP and stakeholder engagement aspects and project planning. Our resulting framework is more of an initial "tripwire" or "showstopper" approach whereby the project planner endeavours to quickly and economically parse out any environmental, economic, regulatory, stakeholder, or energy resource related concerns which may completely negate the possibility of a project occurring. Once these initial criteria are met, then a more detailed (and more costly) set of assessment procedures can be conducted in order to better define and refine the project plan and, if need be, adapt it in response to more in–depth feedback based on more information given to respondents. Thus, the process becomes more iterative, with several “loops” of assessment, incorporating more information gathered to further refine project plans and then gather further information once again, and so on (see fig.5-7).

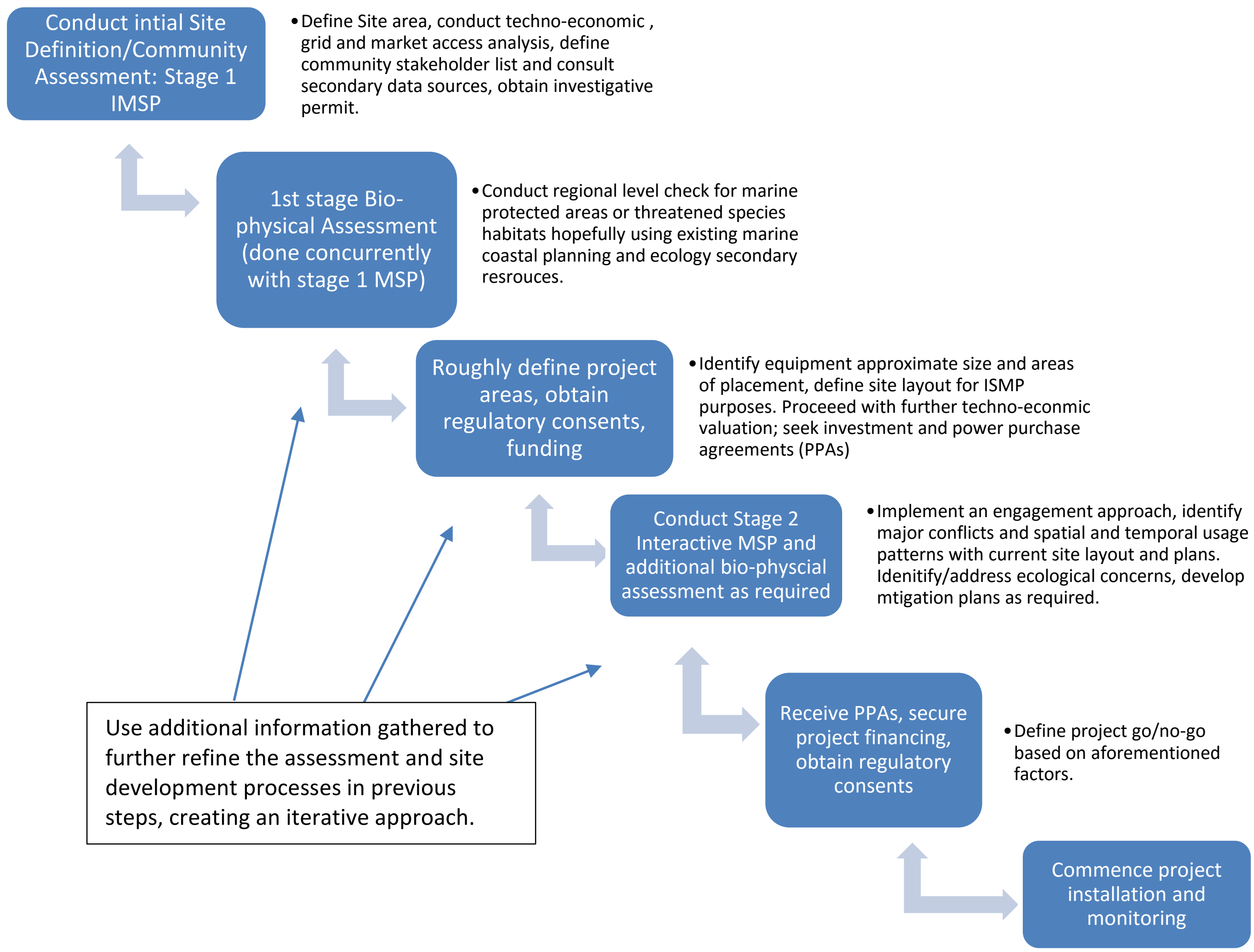


Figure 5-7: A model for ORE initial site assessment and development. This matrix is not meant to be an exhaustive list for ORE or ISTE developers or regulators; it is simply a model of suggested possible steps. Source: Author.

5.5 Regulatory Recommendations and Areas for Further Study

High energy ISTE sites in BC (and elsewhere in the world) usually occur in narrow channels where flows are forced by topography into achieving high velocities and thus high energy and economic value for ISTE developers and utility companies. However, these narrow channels are also often subject to significant human and ecological uses, creating potentially high conflict areas between ISTE and human and ecological values. This statement must also be tempered with the notion that adaptive marine spatial planning can temper conflicts, human and ecological, through implementing sustainable channel blockage ratios and depth specific marine spatial planning, whereby only ecologically sustainable numbers of turbines are installed in a channel, and done so at depths safe for shipping and other human uses. Thus, reasonably economic levels of ISTE development in narrow channels may be achievable while still incorporating human and ecological usage patterns and planning ISTE operations around these uses. Of course, in order to achieve these marine resource usage balances, concerted levels of ISTE (or ORE sites in general) site assessment from energy level and location, socio-economic and bio-physical standpoints must be undertaken prior to development, and the questions of who will pay for these up-front assessments prior to any energy being generated and sold remains to be determined.

Currently, in BC, the onus is on the project proponent to conduct these assessments, yet the present high costs of ISTE and ORE mean that such projects are difficult if not impossible to develop without additional government support or subsidy. Thus, while barriers and conflicts with ISTE or ORE sites will certainly exist on localized, site scales, the broader regulatory and institutional barriers must also be considered. The lack of development incentives (such as grants and Feed In Tariffs) offered by the provincial government and BC Hydro (BC's predominant utility provider) for proposed ORE projects in BC means that, given the high levels of unknown impacts of ORE, both from public and scientific perspectives, and the likely high amounts of regulatory and public scrutiny of them, the high upfront study and site assessment costs will very likely discourage development of grid-connected projects.[21] Conversely, high energy costs for remote and off-grid communities present a more economically friendly option for ORE project developers and represent cases where ORE can likely very reasonably displace more costly fossil fuel generation options.

[21] As of the publication date of this Thesis there are currently no grid connected wave or tidal energy installations in BC and only one (funded by federal research program) expected in the near future.

ISTE in BC in particular is quite remarkable given that the largest and arguably best site (Seymour Narrows and Discovery Passage analyzed in this Thesis) is also one of the busiest marine passages for shipping and tourism, as well as a massive salmon migration route and local sport fishing capital. The impacts on the interruption of any of these sources of livelihood would have to be very carefully weighed and studied prior to permitting ISTE development of significant scale. This inherent resource use conflict was remarked at by several scholars as being interesting and clearly posing the question of whether high energy ISTE sites were necessarily always going to be high conflict sites due to the bio-physical and human traffic bottleneck which occurs in the same location as high velocity (and hence high energy) tidal flows. It is of the opinion of this author that South Discovery Passage is in fact very unique with its large tidal energy density on the shores of a City and also comprising a major shipping and ecological route. There are numerous other high tidal energy sites on the BC coast which are not subject to such activity levels and in fact very few if any could be argued to possess the level of resource use complexity. Masset Inlet for example offers considerable energy with not even close to the level of human activity. Yet, no other ISTE sites in BC possess nearly the level of energy which Seymour Narrows and South Discovery Passage do, nor the level of human activity

The Campbell River area is particularly unique in that the energy is right at the shores of small city, complete with electrical grid and road access, significant marine industrial support and a suitably level bottom trough area for turbine placement (although also being quite deep). Most other sites in BC do not have this confluence of positive attributes. The high energy high conflict scenario may not exist in all ISTE sites, however, further study is required both in BC and worldwide. For example, could Active Pass be developed as an ISTE site given that it is a busy ferry route? Similarly, could Dodd’s narrows be developed given its very narrow cross-section and frequency of Orca whale transits through it? Large energy sites in the UK such as at the Mull of Kintyre Peninsula or perhaps more importantly now the Meygen site near the Orkney Islands in northern Scotland, should be studied in comparison with other sites around the world. Locations such as Nova Scotia, Alaska and British Columbia, should be analyzed in order to try and determine what factors lead to both feasible, economic ISTE development as well as being acceptable projects from socio-economic and environmental factors. Surely a combination of regulatory, economic and institutional factors either promoting or inhibiting ORE development at various locations on Earth would be interesting to consider as well. For example, how much does the incumbent regional energy supply dictate the level of ORE development? Is Nova Scotia, with its largely fossil fuel driven electrical grid more likely to develop ORE before BC's hydroelectric dominated grid and, if so, at what scales? And what of off-grid communities, how feasible is ORE development for displacing fossil fuel generation in these remote locations? Where are the locations of off-grid consumer demand for relatively cheaper renewable energy (compared with fossil fuel energy) and how do these locations correspond with potential ORE resource locations?

From a governance perspective, ORE, and ISTE in BC in particular, exists at a regulatory nexus between safety and freedom of marine navigation as mandated under Transport Canada's Navigational Waters Protection Program (NWPP), marine life impacts and considerations as regulated by the federal Department of Fisheries and Oceans (DFO), provincial lands and waters jurisdiction considerations governed by the BC Ministry of Forests Lands and Natural Resource Operations (MFLNRO), and First Nations considerations. Additionally, BC Hydro has perhaps the largest influence as they control the electrical transmission and distribution system, interconnection requirements and costs, and perhaps most importantly, rates paid for renewable grid connected power from emerging technologies, which is a major barrier to ORE development as its costs are currently very high. Thus, the regulatory and economic barriers to ORE (as well as other forms or RE) development in BC are numerous.

Any region in the world which has seen effective ORE development has had concerted regulatory guidance, government support in the form of test centres and funding, as well as defined economic subsidies or markets to promote development of what is currently a costly and uncertain technology. Clear examples of these measures are the European Marine Energy Centre in Europe and the Renewable Obligation Certificates (ROCs) in the UK offering large scale test centres and repayable grants to UK ORE developers. Further, Nova Scotia's recent Marine Renewable Energy Act (passed in 2015), commercial feed-in tariff, and Fundy Ocean Research Centre for Energy (FORCE) also provide very clear and similar examples and have thus attracted significant levels of industry investment from major companies such as Schottel, JDF Suez, Lockheed Martin, Atlantis and many others. While ORE development rates in these regions remain slow and costs remain high, one must always consider the exponential cost reduction versus installation curves of land based wind power in the United States since 1985 and the now similar curves seen in solar PV (see fig. 3-9). New technologies are difficult and expensive to develop, but proper, concerted measures combining all of the sectors and factors mentioned above can help ensure their eventual success, cost recovery and substantial returns on investment.

From a strict power supply perspective, BC may not need ORE nearly as much as these other regions due to its large amounts of hydroelectric power. However, evidence presented in this Thesis on the highly centralized nature of the BC electrical grid, with its major generation assets being positioned very far from its major load centres, its heavy reliance on hydroelectric power, which has been shown to already be susceptible to climate change, and the overreliance of Vancouver Island on the mainland for its energy, lead one to hypothesize at least somewhat to the contrary. Perhaps BC should at least consider some concerted program for ORE development given that some 80% of its population lives on the coast, quite close to this substantial energy resource. In addition, what about developing the technology and capability for export to regions of the worlds where clean energy is in far greater demand, such as China, India or south east Asia? But what form would such a program take, and what would be needed to facilitate a modest or even small amount of sustainable ORE development? BC's current political priorities are focused on liquefied natural gas development for the province as well as the construction of the Site C dam, yet both of these agendas have attracted considerable public opposition.

As mentioned above, numerous regulatory approvals from various agencies are needed in order for an ORE project to proceed. While BC does have a formalized Crown Land Use Operational Policy for Ocean Energy, it is largely uncoupled from the NWPP, DFO, BC Hydro, as well as other First Nations and municipal or regional government agencies. This arguable creates an application process that is somewhat repetitive, cumbersome and inefficient, requiring the applicant to seek and receive regulatory clearance from numerous different agencies. These hurdles are also in conjunction with a lack of enabling price signals (e.g. Feed-In-Tariffs or competitive standing offer power purchase prices from BC Hydro) for ORE projects. Instead, ORE and RE developers in BC are reliant on specialized clean energy grant funding schemes which do not create a defined market subsidy for renewable energy, but instead simply provide limited startup funding for the company to develop its technology and hopefully find the right combination of factors in order to commercialize it. The end result has been that ORE has achieved little, if any, commercial success in British Columbia, as have any other RE with the exception of hydroelectric. While the arguments of BC Hydro and politicians have been that BC is simply blessed with hydroelectric potential and should fully develop it, it would seem obvious that total reliance on one energy source for a whole province is risky, especially given some of the evidence of what climate change is already doing to the Pacific Northwest region's watersheds. In addition, hydropower has been shown to have particular and significant social, economic and environmental impacts, making the incentive for diversification even more serious.

While the exact definition of an ORE development policy would take considerable work and would need to result from academic research, industry development and corresponding regulatory consultation with all stakeholders, much of these steps have already taken place in Nova Scotia. The socio-economic, regulatory, environmental and energy infrastructure are all different between the east and west coasts, yet BC could learn some valuable lessons from its fellow ORE developing province. With the recent renewal of the MOU between the two provinces on sharing information and effort within the ORE sector, it would seem an opportune time to embark on such a venture. Developing ORE in BC could help bring more energy generation assets to the coast, build more resiliency in the electrical grid in the form of distributed generation, create a new high tech sector promoting jobs and economic growth and would help make BC a world leading location for ORE technology development and expertise. All this type of effort would take is political leadership and the will to succeed beyond the energy status quo, for all British Columbians.

5.6 Conclusion

This thesis attempted to answer the research questions of whether real and perceived marine resource use conflicts existed in relation to proposed tidal energy developments on Discovery Passage at Campbell River, BC. In addition, it attempted to answer whether there were any perceived or real benefits to these installations. Semi-structured interviews incorporating IMSP and risk and benefit as well as general energy perception choice prioritization questions were conducted with a wide sampling of marine stakeholders and First Nations peoples present in the area. Prominent conclusions revealed that perceived risks were quite localized within the channel while benefits were more regional in nature. Marine traffic interference, the hypothetical "barrier effect" of many turbines potentially blocking a channel and the likely high cost of tidal energy were all highly ranked perceived conflicts. Tugboat tow cables and fishers' downrigger cables snagging on turbines were identified as specific risks by some stakeholders, also possibly resulting in very high consequences, and were consequently analyzed further. Top rated benefits included reservoir water conservation (achieved through tidal power penetration enabling displacement of water used for hydropower in the area), followed closely by local job creation and displacement of off-grid diesel generation in the area. In addition, trends were noticed whereby severity of perceived conflict amongst stakeholders in relation to the tidal energy sites increased the more detailed the questions were asked in regards to it. Further, usage areas defined by subjects early in the interview often differed in relation to the conflict areas defined after seeing the sites at the end of the interview. Both of these trends correspond with Wolsink's (2008) findings in relation to wind farms, showing that increasing opposition to proposed projects occurs after more details and project plans are revealed to local citizens. Once projects were constructed and commissioned, however, sites typically regain their support. In addition, reflections on of loss of use can be seen in this study, similar to ISTE sites in the Mull of Kintyre in Alexander et al. (2012).

The results of this study above all highlight the importance of stakeholder (especially subject matter expert marine stakeholders) engagement and marine spatial planning early on in any ORE project planning. "Red flags" can often be identified early in the planning process through use of these methods and can thus inform the developer or the regulator whether it is feasible for the project to proceed further, or how such problems may in fact be mitigated. It can be argued that much ORE research has focused in a monodisciplinary fashion on resource assessment and modelling, turbine technology development, or environmental impacts, while the broader comprehensive thought process on how to plan and situate an ORE array within a complex human and ecological ocean water space has been addressed to a lesser degree. For example, concepts such as channel blockage ratios have been seen to augment energy output in models, but what density of turbines can be sustainably deployed in combination with marine life passage, so as not to induce some type of barrier effect and also perhaps allow for a co-zoned trap fishery to take place in the same area? Further, what may be the economic and ecological utility of such a spacing endeavor? Clearly, many different factors must be considered when situating an ORE or ISTE array so as to induce economical rates of energy extraction, but also to mitigate ecological and socio-economic impacts in the surrounding area. Therefore, an interdisciplinary approach to ORE site planning with reasonable consideration of socio-ecological and economic impacts can hopefully help both mitigate potential conflicts and impacts, and ensure economic and sustainable and renewable energy extraction at the same time.

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