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From Scotland to New Scotland: Constructing a sectoral marine plan for tidal energy for Nova Scotia

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ABSTRACT

Competing usage of marine space has prompted several coastal nations to implement marine spatial planning (MSP). While progressive governments promote the deployment of renewable energy technologies (RETs) in order to meet renewable energy capacity and greenhouse gas emissions reductions targets, offshore RETs become another player operating within a finite and already stressed marine environment. This paper applies the sectoral MSP process employed by Scotland to the Nova Scotia context in order to draft a MSP for the province's tidal energy sector. Applicable legislation is reviewed in order to establish the regulatory authorities with powers to plan for both the marine development and ecosystem protection agendas. The scoping process identifies suitable resource areas based on the operational parameters of commercially viable tidal current turbines (TCTs), while the sustainability appraisal identifies areas of cultural, industry, ecological, and socioeconomic constraint and exclusion. Plan option areas emanating from the applied methodology demonstrated a 238.345 km^2 (98.1%) increase in suitable TCT deployment area than the marine renewable energy areas identified in Nova Scotia's Marine Renewable Energy Act which did not undertake such a methodology.

1. Introduction

The marine environment has historically played a significant role in sustaining coastal economies, as can be witnessed through the evolution of global super powers from Ancient Greece to the USA. This relationship of societies strategically positioning themselves close to water bodies, thereby proliferating access to the marine environment and its natural resources, continues into modern times, with 44% of the global population living within 150 km of the coast [1]. In 2012, Europe's Blue Economy supported 5.4 million jobs, producing €500 billion [2] through such traditional marine industries such as fishing, shipping, and tourism. Running in unison with this congregation of marine-based economic activity are future projections of global population growth, the majority of which is expected in the 82.3% of coastal mega cities [3], with an increase in living standards expected to accompany such projections [4]. It therefore follows suit that economic activity linked to the marine environment will grow exponentially, providing an increase in spatial usage in finite marine space, which ultimately provides for an increase in the potential for spatial conflict. This dilemma is referred to as user – user conflict [5]. The intensification of various industries operating in marine space, and the subsequent concentration of the extraction of natural resources for purposes of economic exploitation, places stress on the ecological functions of the marine environment, resulting in the declination of the health of the overall ecosystem [6]. This dilemma is referred to as user – environment conflict [5]. Such dilemmas have triggered political support for the application of marine spatial planning (MSP) in order to effectively manage activity in areas experiencing multiple uses. Comprehensive MSPs are being implemented in nations including Germany, Belgium, and Scotland. However, the construction of a comprehensive MSP alone will not suffice as a measure to stabilize marine-based economies. Increases in global warming of 0.65–1.06° from 1880 to 2012 have had substantial implications on the ecological functions of the Earth's oceans at a greater pace than any other in human history [7]. This climate change dilemma has prompted support from all levels of government globally to curtail the release of greenhouse gas (GHG) emissions via the

Abbreviations: **MSP**, Marine Spatial Planning; **TCT**, Tidal Current Turbine; **GHG**, Greenhouse Gas; **RET**, Renewable Energy Technology; **Vmsp**, Mean Spring Peak Tidal Flow Velocity; **SMPTE**, Sectoral Marine Plan For Tidal Energy; **NMP**, National Marine Plan; **LAT**, Lowest Astronomical Tide; **HAT**, Highest Astronomical Tide; **POA**, Plan Option Areas; **MREA**, Marne Renewable Energy Areas; **MRE Act**, Marne Renewable Energy Act; **RLG**, Regional Locational Guidance; **SEA**, Strategic Environmental Assessment; **MEKS**, Mi'kmaq Ecological Knowledge Study; **TZ**, Territorial Zone; **CA**, Competent Authority; **DNR**, Department of Natural Resources Nova Scotia; **DoE**, Department of Energy Nova Scotia; **NSE**, Nova Scotia Department of Environment;; **EA**, Environmental Assessment; **UKC**, Under Keel Clearance; **CVD**, Charted Vertical Depth; **MuZC**, Multiple-Use Zoning Compatibility; **COMFIT**, Community Feed-in Tariff

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promotion of renewable energy technologies (RETs). Given competing uses for terrestrial space in an ever-densifying civilization [3], the deployment of offshore RETs is gaining momentum in the public policy agendas of progressive governments with suitable resources [8].

One such offshore RET that is showing promise with regards to the transition from pre-commercial to commercial status are tidal current turbines (TCTs). TCTs operate to produce electricity by harnessing the kinetic energy from the lateral movement of tidal flows where current speeds reach a mean spring peak velocity (Vmsp) of 1.5 m/s [9]. By harnessing this energy, TCTs become advantageous in comparison to other RETs due to their predictability, reliability, high capacity factors, and ability to easily accommodate energy storage [10], as tidal flows are nearly constant and can be modeled for centuries in advance [11]. Scotland is one such nation that possesses economically viable Vmsps, with available resource estimates demonstrating 32 TW h/yr [12], 25% of Europe's tidal energy resource [13]. Therefore, Scotland has heavily invested in the deployment of TCTs within Scottish waters in order to meet GHG emissions mitigation targets of 42% below 1990 levels by 2020 and 80% below 1990 levels by 2050, while providing 100% of it's electricity demand from renewables by 2020 [14]. However, in attempting to mitigate this climate change dilemma, Scotland recognizes that TCTs essentially become another industry within their national economy that demands usage of marine space. Therefore, anticipating user – user and user – environment conflicts, Scotland has become the first and only nation to construct and implement a sectoral marine plan for tidal energy (SMPTE) to strategically identify suitable sites for TCT deployment, thereby assisting their national marine plan (NMP) in effectively managing industry conflict and ecosystem health while meeting GHG emissions reduction and renewable energy deployment targets [15].

Across the Atlantic Ocean resides another geographical region with substantial tidal current resource potential. The Canadian province of Nova Scotia is home to the highest tidal range fluctuations in the world, measuring in at a maximum of 16 m between lowest (LAT) and highest astronomical tide (HAT) [16], subsequently forcing 160 billion tonnes of water through the Bay of Fundy with every flow of the current, approximately four times more volume that every fresh water river in the world combined [17]. This extreme flow of the tides has been estimated to produce approximately 7.4 GW of power in the Bay of Fundy alone [18]. However, despite substantial provincial and federal investments into the Nova Scotia tidal energy sector, only one TCT is currently deployed in Nova Scotia waters. While industry, government, and R & D organizations have worked in tandem to produce numerous insightful resource, economic, and social studies, the commercial development of the TCT industry remains uncertain. A commonality that the vast majority of European nations who have successfully deployed offshore RETs is the construction and implementation of MSP, although Nova Scotia, moreover Canada, has yet to implement such a plan. This paper constructs a SMPTE for Nova Scotia loosely based on Scotland's SMPTE process. The objective of the paper is to utilize the Scottish methodology and apply it to the Nova Scotia context in order to generate a glimpse into what a SMPTE may look for the province.

The remainder of this paper constructs a SMPTE for the province of Nova Scotia. Nova Scotia's tidal energy industry and the Scottish SMPTE process are discussed in Section 2. The panning process is detailed specific to the Nova Scotia context in Section 3, with outputs generated for each phase of the process. In Section 4, final plan option areas (POAs) are compared to the marine renewable-energy areas (MREAs) legislated in the MRE Act which didn't not undergo a formally structured planning framework. Recommendations are made on gaps in the Nova Scotia context in relation to the TCT development framework currently in place in Section 5. Finally, Section 6 concludes by overviewing the methodology, results, and objectives of the paper.

2. MSP for TCTs

With 7,579kms of coastline [19], Nova Scotia's economy holds strong ties to the marine environment, touting the largest conglomeration of ocean R & D firms in all of North America at approximately 300 [17]. With marine industries accounting for 1/3 of all R & D business in Nova Scotia, the approximately 60 innovator technological organizations generated an estimated over $500,000,000 in revenue in 2009, with projections suggesting an increase in the decades to follow [19]. Nova Scotia is also home to the world's highest tides, the range fluctuations of which result in comparative impressive Vsmps when forced through narrow passages [16]. Such velocities of sites in the Bay of Fundy and the Cape Breton Region have been estimated to produce 7435.8 MW of power, 2096.7 MW of which is deemed sustainably extractable [18]. In order to capitalize upon this vast resource, the Nova Scotia and Canadian governments partly funded the development of a large-scale TCT test center in the Minas Passage called FORCE, which became operational in 2009 [20]. From FORCE's early conception, it hosted an Open Hydro TCT that underwent environmental effects monitoring, although the rotors blew out a few weeks after deployment [21]. Five years later, the installation of four 24.5 kV subsea power cables have made FORCE [22] capable of accommodating four 16 MW TCT arrays, reaching an aggregate installed capacity of 64 MW [17], with projections of 110 MW of electricity becoming online by 2020, accounting for 5% of the current installed electrical capacity, and creating 340 person-years of employment during installation and 550 person-years over the 25-year lifespan of TCTs [23]. An economic assessment undertaken by Pinfold [24] suggests that the tidal energy industry can provide $1.7 billion in GDP [19].

With such a vast resource potential, political backing from the provincial and federal governments, financial support of over $100 million [20], capacity building via the 450 ocean related PhDs [19], supply chain industries amounting in $5 billion in GDP, a world class test facility, regulatory legislation in the Marine Renewable-energy (MRE) Act, and 30,000 direct employment opportunities, Nova Scotia could play an integral role in the emerging tidal energy industry as a global industry cluster, providing physical, technical, and scientific resources to other nations with similar tidal energy potential [25]. Despite such a favourable climate, in 2017, there is only one TCT in provincial waters, the implementation of which was met by intense lobbying by other marine industries over environmental, social, and cultural concerns [26]. However, support for the industry overall does continue in the province. Examining best practices from the international leader in the tidal energy industry in Scotland, the one component that is absent in Nova Scotia is the construction and implementation of a comprehensive SMPTE.

Scotland's SMPTE is subsumed within the offshore wind and marine RET sector identified within the NMP, with all policies and regulations set out in the SMPTE in conformity with the strategic objectives designated within the NMP [14]. The primary output of Scotland's SMPTE is the identification of 10 POAs, based on the prime suitability of commercial-scale TCT deployment at a capacity of = > 30 MW, resulting in a streamlined licensing and consenting regime. Scotland's SMPTE process, (Fig. 1) is comprised of three phases.

The first phase includes scoping for areas with appropriate resource potential and industry, environmental, and social constraint, while regional locational guidance (RLG) from subject matter experts as well pre-statutory consultation with key stakeholders further informs the scoping exercise [14]. The second phase undertakes a sustainability appraisal inclusive of a habitats and regulations appraisal, strategic environmental assessment (SEA), and socio-economic assessment to further inform suitable POAs, which then undergo another round of RLG as well as statutory consultation in order to produce a draft plan. For the final phase, the plan is put forward to Scottish Ministers for adoption, resulting in the provision of licensing for adopted POAs. Given the scope of this paper to construct a SMPTE for Nova Scotia, the

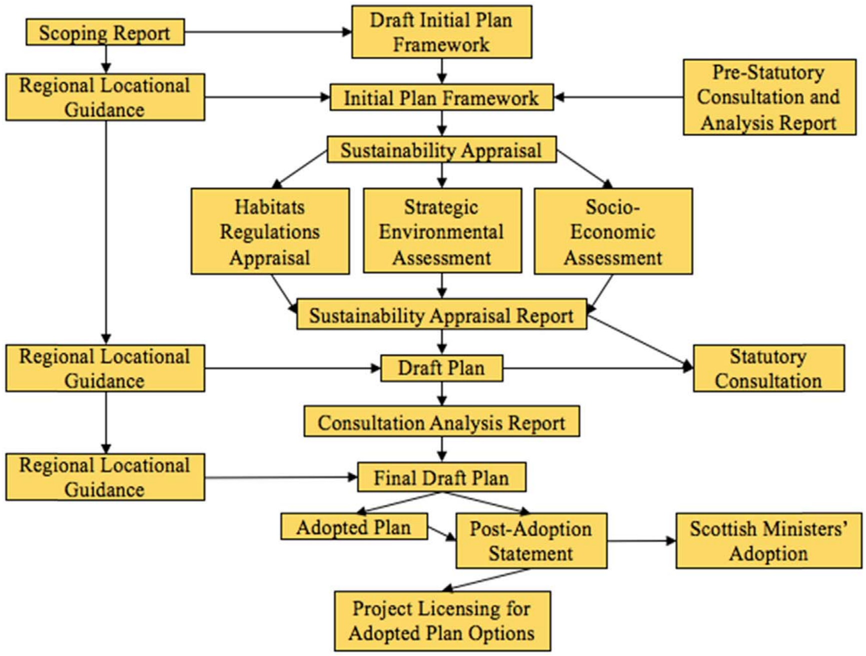

Fig. 1. Flow chart depicting the process for Scottish Sectoral Marine Plan for Tidal Energy.

scoping portion of the Scottish methodology will be employed without RLG or pre-statutory consultation, while the sustainability appraisal was employed using the two Mi'kmaq Ecological Knowledge Study (MEKSs) reports [27,28], socioeconomic assessment [29], and the three SEAs [30–32]. No Ministerial consultation was utilized as the objective of the Nova Scotia SMPTE presented in this paper is to conceptualize what a plan may look for the province as opposed to a definitive plan to be implemented by the province.

3. Methods

3.1. Public policy agenda

3.1.1. Jurisdictional boundaries

Establishing Jurisdictional boundaries for Nova Scotia is essential for the MSP process and, due to the lack of federal and provincial governance regarding marine planning [33], there exists no current legislated boundaries [34]. Drawing from precedent within the Scottish marine plan, as well as best practices from European North Sea nations [35], a 12-nautical mile limit territorial zone (TZ) from LAT is proposed. Where any overlap exists between the nautical limits of Nova Scotia and its neighbouring provinces of New Brunswick and Prince Edward Island, an even partitioning of the territory was implemented (Fig. 2).

Additionally, the designated tidal development schedules set forth within the MRE Act were geo-referenced (Fig. 3), the extents of which would provide a valuable comparison between the recommendations of this MSP and current adopted legislation.

3.1.2. Political and economic purpose

To create the SMPTE in unison with the Scottish approach, it was necessary to determine vision, key drivers, and strategic aims by undertaking an analysis of reoccurring themes emanating from keystone industry documents including *Marine Renewable Energy Legislation: A Consultative Process* [33], the MRE Act, the Environmental Goals and Sustainable Prosperity Act, Nova Scotia's Electricity Plan [36], and the *Marine Renewable Energy Strategy* [17]. The analysis suggests that Nova Scotia's vision for their tidal industry is to become a global leader in the development of technology and systems that produce environmentally sustainable, competitively priced electricity from the ocean. The key drivers that influence the construction of the SMPTE to realize the stated vision include:

- marine planning – to assist with the development of a comprehensive policy framework for future decisions made at the project level [33,34];
- reduction of GHG emissions – contribute to federal targets of 30% in GHG emissions by 2030 over a 2005 baseline, contribute to provincial targets of 80% GHG emissions reductions by 2050 over a 2009 baseline, and contribute to G7 commitments of a carbon-free economy by 2100 [36];
- price stability - to reduce provincial reliance on coal and it's inherent volatile prices and exchange it for indigenous resources, with TCTs contributing to a 40% renewable energy generation portfolio by 2020 [17,33,36], and;
- marine licensing - to streamline the licensing and consenting process of TCT testing and development.

The strategic aims influenced by key drivers to realize the stated vision are reducing imported electricity to increase the wealth within the province, creating a skilled labour force with industry expertise to be exportable internationally, and maximizing the installed capacity of tidal energy in Nova Scotia, contributing to a more sustainable Nova Scotia [17,33,36].

3.1.3. Legislative regulatory authorities

Following the establishment of the SMPTE's jurisdictional boundaries and purpose, a competent authority (CA) accountable for decision making procedures pertaining to the construction and implementation of the SMPTE must be established. In order to decipher what governing body would act as the CA for the SMPTEs marine development and ecosystem protection agendas an overview of current legislation was undertaken. Under the Navigable Waters Protection Act, Transport Canada is the only authority who can issue permits regarding a development that may impede or obstruct marine transport both within and outside provincial boundaries [33]. The Fisheries Act provides similar powers to the Department of Fisheries & Oceans Canada with regards to the issuance of development permits that may disrupt the public right to fish both within and outside provincial boundaries. However, the Nova Scotia Department of Natural Resources (DNR) has proprietary rights over the seabed within provincial jurisdictional boundaries as delegated by the Crown Lands Act [37], thereby authorizing the

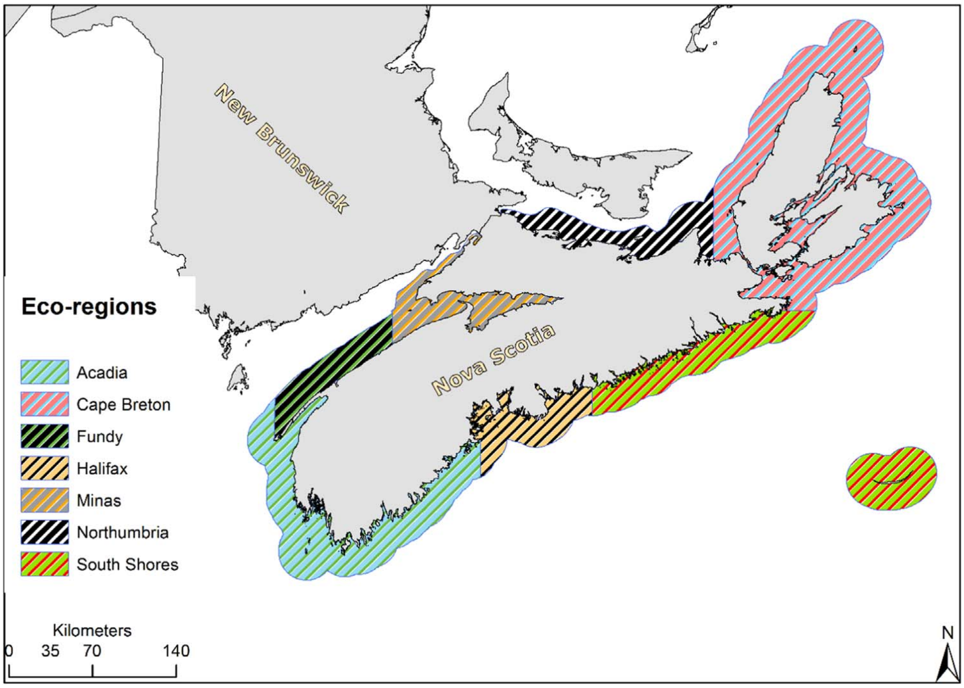

Fig. 2. 12 nm limits and enclosed ecoregions Geographic depiction of the 12-nautical mile jurisdictional limits created for Nova Scotia. This figure also depicts the seven unique ecoregions derived on the basis of environmental sensitivity and geo-political boundaries.

province the right to issue seabed leases for the development, conservation, and management of sites and facilities within provincial jurisdiction for the generation and production of electrical energy as mirrored by Section 92A (1)(c) of the Constitution Act [34].

When taking all the legislation above into consideration, the current regulatory regime of the SMPTE public policy agenda would permit the issuance of leases for TCT implementation under provincial authority, while all regulatory and legislative authority would remain in the realm of the federal government. While this system is technically feasible, a complex regulatory framework often deters developers who believe that such complexity can slow the licensing of projects, thereby increasing financial risk [33]. Therefore, in order to avoid deterring TCT project proponents, as few regulatory authorities as possible should be delegated powers to plan. Therefore, it is recommended that the federal government delegate administrative authority with regards to TCT projects within the TZ to the province via the establishment of prescribed regulations under the Oceans Act [34]. This would provide for a single figurehead provincial authority, thereby reducing regulatory complexity within the governance structure while allotting statutory weight via federal legislation to provincial administration.

It terms of which provincial body would be designated the CA for Nova Scotia's SMPTE, the MRE Act clearly delegates administrative authority to the Minister of Energy, with the general management and supervision duties of the Minister provided by Section 5(1), (2) (a)-(g). However, the Minister does not have the right to issue a lease of the seabed to a project proponent as submerged Crown Land within

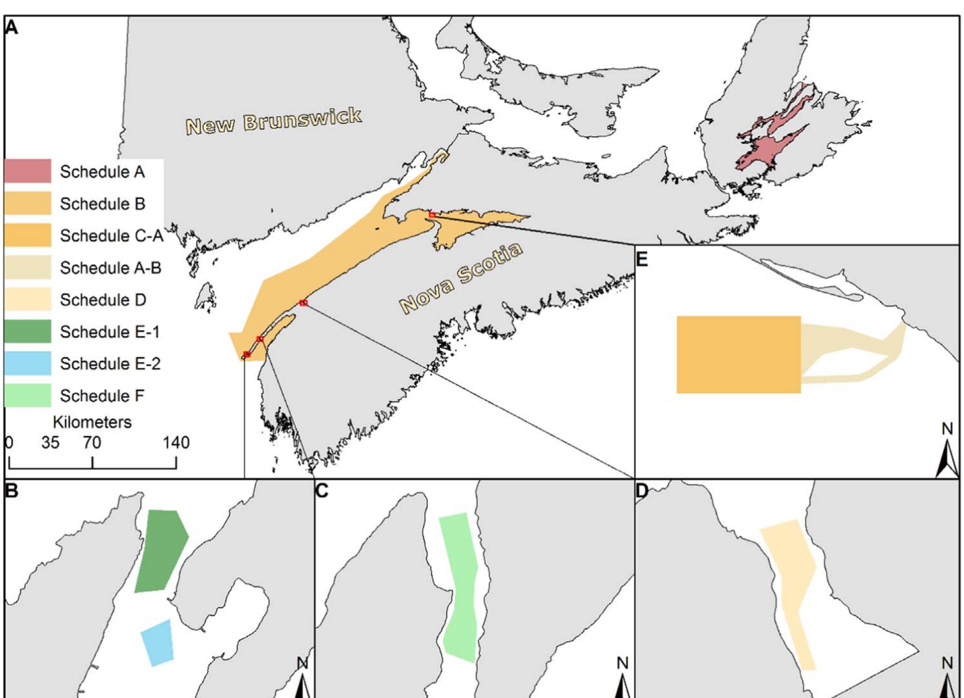

Fig. 3. Marine Renewable Energy Areas. Geographic extents of the designated tidal schedules described within the MREA act. **Panel A:** Represents the regional overview of the schedules. **Panel B:** Represents Schedule E-1 and E-2 within the Grand passage. **Panel C:** Represents Schedule F within the Petit passage. **Panel D:** Represents Schedule D within the Digby Gut. **Panel E:** Represents Schedule C-A and C-B for the Force Marine Testing site.

provincial waters is within the jurisdictional realm the DNR, and therefore, while Section 5(d) of the MRE Act provides for the Minister to consult and co-ordinate activities with other government bodies, full administrative authority over TCT implementation regulations in relation to the SMPTE process is not explicitly legislated to the provincial Department of Energy (DoE). Thus, the role of CA for the construction and oversight of the planning process of the marine development agenda for the SMPTE is enshrined upon the DoE, with the stipulation of mandatory consultation for site selection with the DNR, acting as an *other* CA.

Nova Scotia's SMPTE ecosystem protection agenda is shared jointly both between the DoE and the Nova Scotia Department of Environment (NSE) and Canadian Environmental Assessment Agency [34]. While Section 5(2)(g) explicitly provides that the Minister may measure and analyse the environmental effects of marine renewable-energy activities and develop programs to enhance any benefits and mitigate any concerns associated with these activities, and Section 58(1)(a) explicitly providing that the Minister may issue an order to cease work, the Nova Scotia Environment Act deems that tidal energy projects over 2 MW must undergo an environmental assessment (EA), with the NSE delegated with the legislative authority to grant approval of the completion of said EA [33]. Furthermore, tidal energy projects > 50 MW require joint federal and provincial review by the CEEA and the NSE under the Canadian Environmental Assessment Act. Therefore, the title of CA for the ecosystem protection agenda of the SMPTE is solely attributed to the DoE with projects up to 2 MW, split with the DoE and NSE in projects > 2 MW- < 50 MW, and split with the DoE, NSE, and CEEA in projects > 50 MW.

3.2. Nova Scotia SMPTE process

3.2.1. Scoping

Unlike the Scottish SMPTE, initial scoping plans began by geographically quantifying suitable tidal resource in Nova Scotia's provincial waters, with due consideration given to the technological components of modern day TCT's. Previous resource assessments, accounting for reduction in tidal flow, demonstrated that an estimated 2 GW of power is available within the Minas Basin, 180 MW within the Digby Gut, 19 MW within the Petit Passage and 16 MW within the Grand Passage [18]. However, these estimates do not take into account several primary parameters with relation to TCT implementation (such as bathymetry) as well the constraint arising from industrial and socio-economic activity or ecosystem sensitivity. Moreover, is important to note that Karsten's resource assessment indicated that Cape Breton and its enclosed Bras dO'r Lake lacked suitable resource for sustainable TCT implementation [18]; this, coupled with power density data deficiencies, have resulted in the region being excluded from formal analysis. To create an updated tidal resource assessment that is consistent with the key aims of this MSP, power density (Kw/m^2 on a 150 m·150 m resolution) data was sourced from Arcadia Tidal Energy Institute [38] and converted into Vmsp using a correlative model. The 2012 SEA for the Cape Breton region recommended that Vmsps measure > 1 m/s for small-scale TCTs and > 1.2 m/s for large-scale TCTs [39]. However, the slow pace of development in accordance to public expectations have led to frustrations amongst community stakeholders [40], and therefore, it is suggested that the province utilize parameters of current industry leading TCTs that are ready for deployment. In light of this, and in conformity to the parameters employed by Scotland [9], a Vmsp of 1.5 m/s will be the minimum velocity required to avoid exclusion in the scoping models. Thus, tidal suitability for the region around Nova Scotia was calculated where values less than 1.5 Vmsp were assigned suitability of 0 and values above this threshold were assigned suitability that increased on a positive gradient up to 0.99 — where any values above 2.5 Vmsp units would be considered entirely suitable. Another two technical parameters included in the suitability model were depth of deployment and distance from coast. Taking into consideration TCT technologies from different manufacturers (such as the small-scale KHPS TCT [41] and the large-scale Atlantis Resources AR1500 TCT [42]), this paper utilizes a 20–80 m depth of deployment for TCTs. Additionally, AECOMs maximum distance of TCT deployment from the coast (based on distance of AC export cables of 5 km for small-scale TCTs and 100 km for large-scale TCTs) will be utilized [40].

3.2.2. Sustainability appraisal

Following the resource assessment, and mimicking the sustainability appraisal undertaken for the Scottish SMPTE process, an extensive compilation of data was acquired from the two MEKSs produced by Membertou Geomatics Consultants [27,28] in accordance with Section 35 of the Constitution Act's duty to consult aboriginals which extends to marine RET developments [33], Howell and Drake's [29] socio-economic assessment, undertaken for the DoE and the OEERA, and the three SEA reports produced for the DoE with regards to tidal energy development, two of which were for the Bay of Fundy [30,31] and one for the Cape Breton Region [32], as well as their accompanying backgrounder reports [44,45]. This data was selected on its relevance to stakeholders and the key aims of the MSP as well as its conformity to the data utilized within the Scottish SMPTE. As per the Scottish plan, the intention of this MSP is to produce models of geographic constraint to determine the most suitable areas for TCT implementation. However, unlike the Scottish plan, which utilized simple overlay analysis to determine constraint, this paper employs a suitability gradient approach (0–99%), allowing quantitative justification of the determined POAs.

The geographic extents of each data layer emanating from the comprehensive list of all the data, categorised with relevance to associated stakeholders, as well their corresponding constraint weights are depicted (Fig. 4).

These parameters, were used to calculate to the total constraint at any given point in space for entire study area. A region that is completely absent from a data layer would incur a constraint value of 0, whilst areas where one or more layers overlapped would result in a cumulative constraint value based on the corresponding parameter weightings. As an example, regarding the environmental data, if a particular marine space was intersected by cetacean habitat and important bird habitat the value of constraint would equate to 0.11 units (0.07 units for cetacean habitat summed with 0.04 units for important bird habitat). Additional parameters were also included within the industry constraint model to account for Nova-Scotia shipping activity in shallow waters. A UK government policy paper published in 2014 offers guidance for TCT developers on assessing the minimum depth required for safe under keel clearance (UKC) of transport vessels [46]. The paper suggested that a minimum vertical distance above a TCT (M) be established, and a charted vertical depth (CVD) consisting of M, UKC, and a safe vessel clearance depth (D_c) be determined to allow for multiple-use zoning compatibility ($MuZC$). Advocating for a suggested operating clearance of 8 additional meters from LAT [43], the AR1500 (as an example) has a maximum devise design height (D_h) of 36.8 m. Furthermore, The Saint John, New Brunswick Harbor Master has confirmed that the largest tanker vessels operating in the Bay of Fundy can have a draft of up to 21 m — the value of which will be utilized as the full D_c inclusive of dynamic draft (Dd) plus an additional 30% safety clearance. Given that no standard UKC measurements are in place in Nova Scotia this paper will attribute a calculation of $M\bullet 2 + D_c$ to account for standard UKC. Final zoning compatibility was calculated using the following equations:

$$D_h = R_d + (0.6\bullet R_d) + M \quad (1)$$

Where D_h represents device design height, R_d is the rotor diameter and M is the minimum suggested distance above an operational TCT.

$$CVD = D_c + (M\bullet 2) \quad (2)$$

Where CVD represents the charted vertical depth and D_c is the safe vessel clearance depth

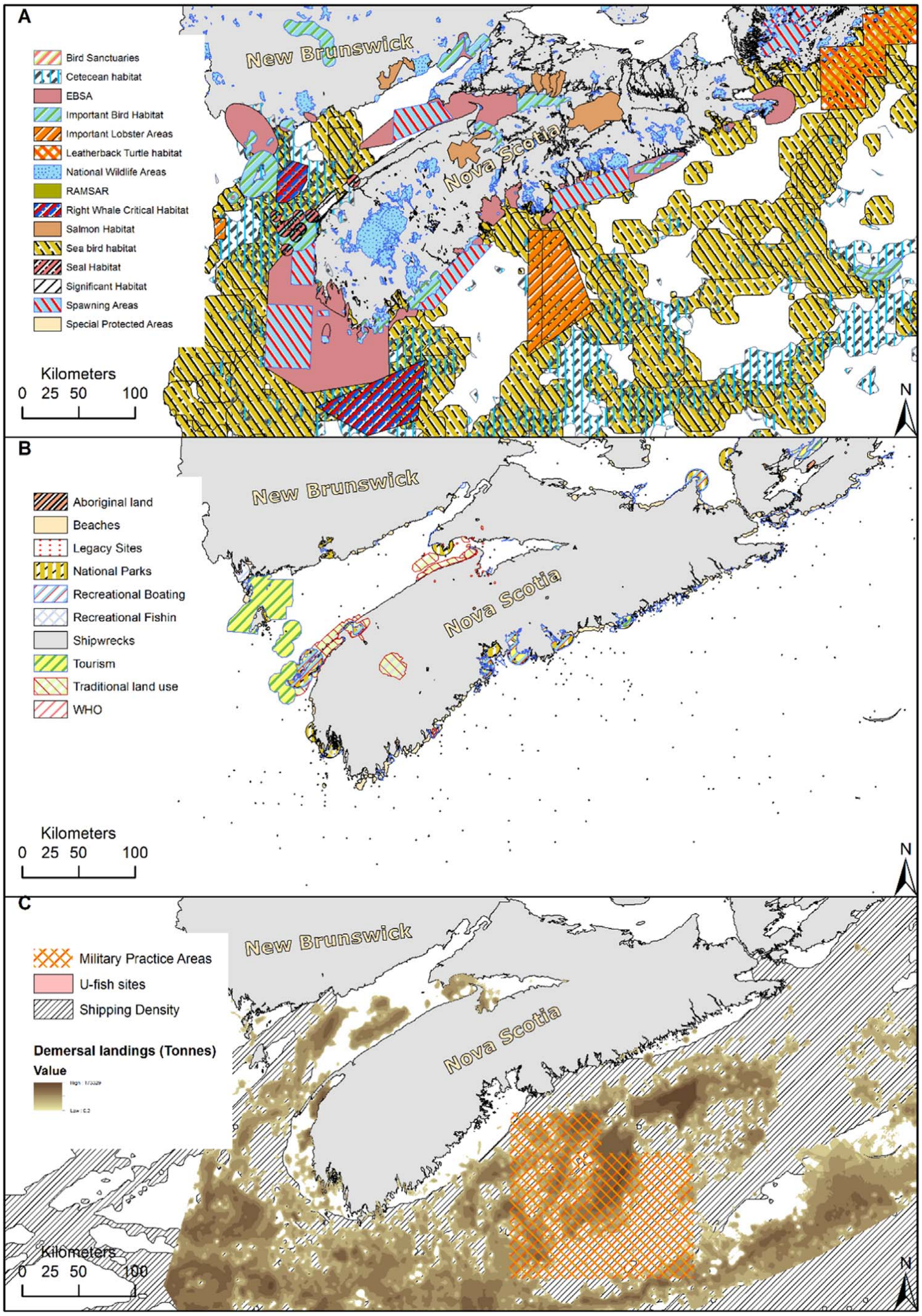

Fig. 4. Stakeholder Data. Geographic extents of the data layers used to determine constraint in TCT implementation. **Panel A:** Represents the data layers pertaining to the environment and eco-systems. **Panel B:** Represents the data layers pertaining to socio-cultural activity. **Panel C:** Represents the data layers pertaining to industrial activity. Though only demersal landings have been illustrated for the purpose of this visualisation, Pelagic and Benthic landings were incorporated into the quantitative modeling process.

$$MuZC = D_h + CVD - M \tag{3}$$

Where *MuZC* is multiple-use zoning compatibility.

Results indicate a minimum measurement of 65.8 m of depth to allow for *MuZC* between fully submerged TCTs and overhead vessel traffic. In summation, areas where shipping density exists at depth of less than the 65 m threshold were categorized as exclusion areas, while areas experiences shipping density at depths greater than the threshold were attributed a constraint weighting, reducing on a normalized gradient as depth increased. Two additional layers were created and incorporated in the modeling process; one being an opportunity elements layer, which comprised of the data listed. Any space in the study area within the vicinity of 100 km from any of these described elements was assigned the corresponding positive weight in the models. The second layer comprised data extents where TCT implementation would be unfeasible (due to already existing developments or underwater features) and are effectively exclusion zones for purpose of this analysis. The three constraint models for the environmental, socio-cultural and industry data, as well as the opportunity elements model, were combined using an equal weighting formula, resulting in a geographic measure of constraint for the entire study area. The final constraint layer was overlaid with the exclusion data regions, and was subsequently analyzed together with the tidal suitability layer. Essentially, at any point in space, one unit of constraint would subtract one unit of suitability for that site, allowing inference unto the most ideal location to implement future TCT developments. From these outcomes POA's (based on a suitability cut-off greater or equal to 0.40) were established and formed the basis of the key recommendation associated with this study. Finally, the creation of unique, delineated ecoregions for the jurisdictional boundaries of Nova Scotia was the last step in the

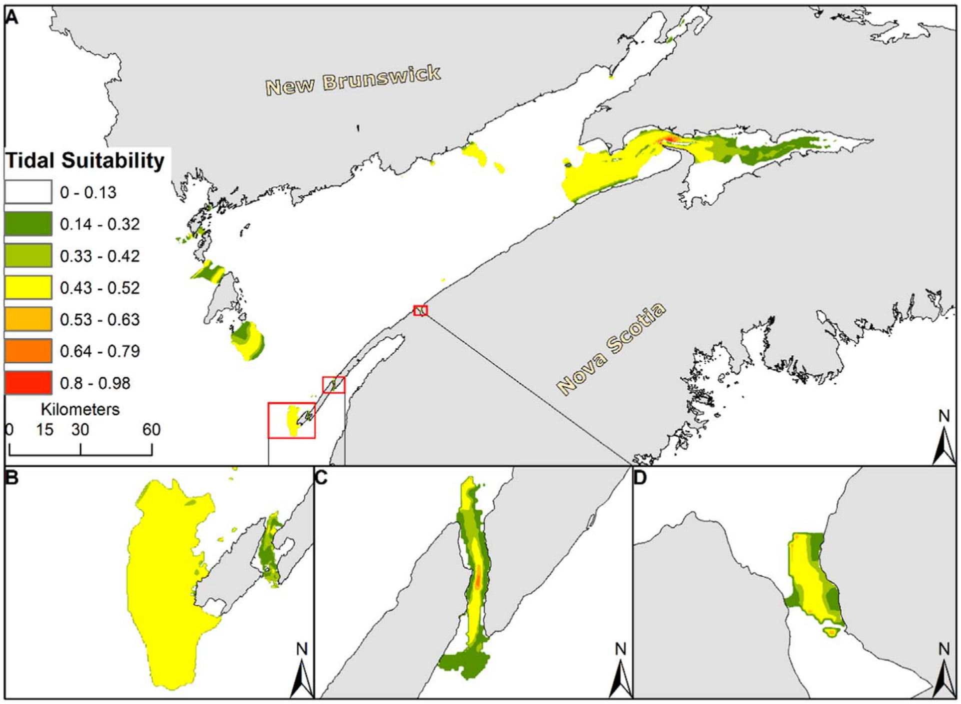

Fig. 5. Tidal Suitability Model. Geographic representation of the calculated tidal suitability for TCT implementation. Results were determined by assessing suitable Vmsp, depth and distance to the coast. **Panel A:** Represents the regional overview of tidal suitability. **Panel B:** Represents tidal suitability within the Grand passage. **Panel C:** Represents tidal suitability within the Petit passage. **Panel D:** Represents tidal suitability within the Digby Gut.

completion of this MSP. By applying the ecosystem approach to MSP [5,35], this paper set out to establish ecosystem boundaries by aggregating the data layers comprised within the environmental constraint model into a density map, thereby highlighted areas of outstanding occurrence rates of flora, fauna, and oceanographic processes. Combining these results with the established provincial TZ allowed for the creation of distinct eco-regions, which should be utilized for sectoral planning and management initiatives for the province.

4. Results

The creation of ecoregions can be observed (Fig. 2), where territories were established within the extents of the 12 nm jurisdictional boundaries and distinguished on the basis on eco-system sensitivity. Seven unique regions were produced, those being the Acadia, Cape Breton, Fundy, Halifax, Minas, Northumbria, South Shores ecoregions. Results from the Tidal resource assessment are depicted (Fig. 5), where areas of red indicate the highest relative resources in Nova-Scotian waters.

It can be observed that the most substantial regions of tidal resource exist within the Grand passage, Petit passage, Digby gut as well as the Minas Basin. Initial assessment also indicated small scale TCT's (such as the KHPS) would not be sustainable within the region, as suitable resource did not exist at operational depths between 10 m and 30 m, thus all recommendations arising from this study will primarily regard large scale TCT deployment. The constraint models for the environmental, socio-cultural and industry data have been geographically illustrated (Fig. 6).

These outputs illustrate regions in space where multiple geographic data occurrences may overlap, resulting in a cumulative constraint (red) relative to areas with little or no data overlap (blue). Results for the combined, equally weighted constraint model are also depicted (Fig. 6), this output also includes the geographic extents of the exclusion data regions. Final suitability analysis resulted in the creation of several draft POA's which have been depicted (Fig. 7).

In total, five separate POAs have been produced based on a suitability ranking of greater than 0.40, one in the Minas Basin, inclusive of the Minas Channel in the established Minas ecoregion, one in Petit Passage in the established Fundy ecoregion, and three in Grand Passage in the established Acadia ecoregion, with a combined total area of 242.966 km^2. When analysing the resulting POAs against the marine renewable-energy priority areas and MREAs identified in the MRE Act which did not undergo a strategic siting methodology, a number of inconsistencies emerge. Firstly, the marine renewable-energy priority area of Cape Breton prescribed in schedule A has been eliminated due to insufficient Vmsps. Secondly, the POA encompassed by the Minas ecoregion measures 242 km^2, a much larger area than the allocated FORCE schedule legislated within the MREA. This is primarily due to the extraordinary Vmsps characteristics and minimal spatial conflicts in the Minas ecoregion, with commercial fishing posing the only potential conflict just south of the Minas Passage. Unlike the proposals set forth in the MREA, this study has eliminated the Digby Gut as a POA due to an insufficient Vmsp and heavy constraint emanating from marine mammal habitat, commercial shipping, and indigenous cultural use. The Petit Passage POA measured 0.210 km^2, 0.609 km^2 less than the area set forth within the MREA. This was due to moderate constraint associated with shipping, commercial fishing, tourism and recreational use, and indigenous cultural use. Finally, the thee Grand Passage POA's measure a total of 0.608 km^2, 132 km^2 smaller than the schedules set forth within the MREA. This is primarily due to the existence of important bird habitat, national scenic areas, tourism and recreational use, and indigenous cultural use within the Grand Passage.

In summation, the six MREAs have an aggregate area of 4.621 km^2, which is 238.345 km^2 (98.1%) less than the five POAs area of 242.966 km^2, where most of the area lies within the Minas ecoregion, accounting for 99.6% of the POA aggregate areas. Since the primary suitability analysis demonstrated that no small-scale TCTs can be deployed in Nova Scotia, the largest Rd of the AR1500 1.5 MW TCT of 18 m has been utilized as a conservative buffer. Utilizing the layout optimization methodology suggested by AECOM [47], each individual TCT within an array would require an area of 8.1 km^2, while utilizing the methodology suggested by Myers and Bahaj [48], each individual TCT within an array would require an area of 1.458 km^2. Based on the necessity to employ an array of TCTs in order to maximize economically viable returns, Myers and Bahajs layout optimization methodology will be employed to determine installed deployment capacity for each MREA and POA. The methodology suggests that the Minas Basin POA could accommodate an installed capacity of 250 MW, and the Petit and

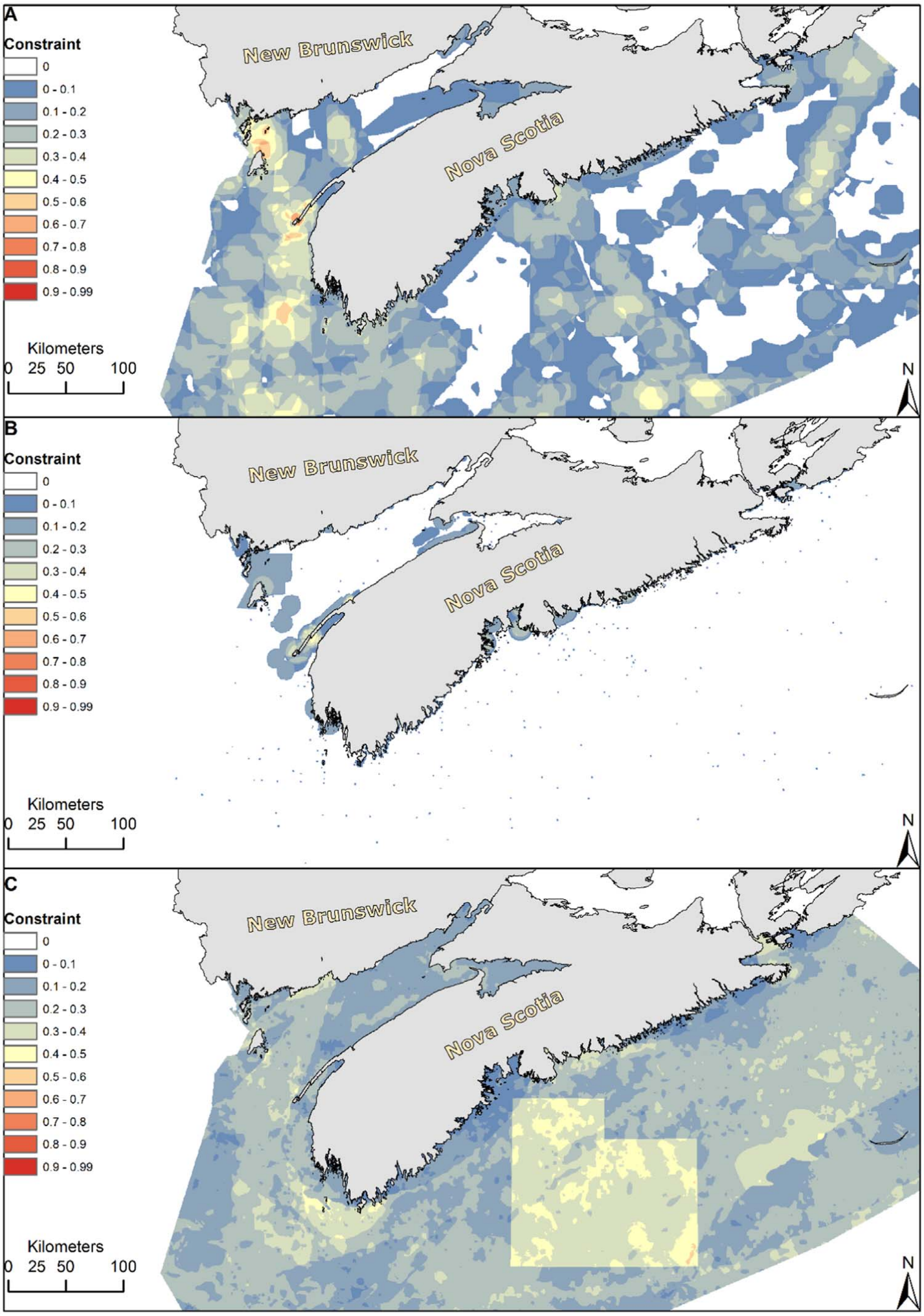

Fig. 6. Constraint Models Results from the three constraint models derived from the geographic data layers. **Panel A:** Represents the constraint model pertaining to the environment and eco-systems. **Panel B:** Represents the constraint model pertaining to socio-cultural activity. **Panel C:** Represents the constraint model pertaining to industrial activity.

Grand Passage POAs could accommodate 1.5 MW each, resulting in an aggregate installed capacity of 253 MW. The Minas Basin MREAs could accommodate 4.5 MW, the Petit Passage MREAs could accommodate 3 MW, and the Grand Passage MREA could accommodate 1.5 MW, culminating in an aggregate capacity of 9 MW, 244 MW less than the POAs

5. Discussion

Given vast tidal current resource potential of the Bay of Fundy, in conjunction with the capacity building in place in Nova Scotia, supply chain capabilities, government funding, and the current heavy reliance on fossil fuels, Nova Scotia has enormous potential to develop its tidal energy sector. Ultimately, the construction and implementation of a SMPTE may act as a strategic way to facilitate a regulatory regime that streamlines licensing and consenting procedures, and subsequently promotes the sustainable commercial-scale deployment of TCTs via a reduction in financial risk to government, communities, developers, and investors, and an increase in government and community support through the identification of POAs which takes into consideration technological, political, legal, environmental, ecological, social, cultural, and economic factors.

Given the geographical size of Canada and the resulting variation of ecosystem complexities, a Maritime Regional MSP should be drafted which takes into account drivers operating within the management boundaries of the Maritime Region in order to inform policies set out in a provincial Nova Scotia MSP, and the resulting SMPTE. Ideally, and in conformity to best practices witnessed in Europe, the provincial MSP would regulate spatial uses within provincial boundaries for various sectors identified in the province, such as aquaculture, shipping,

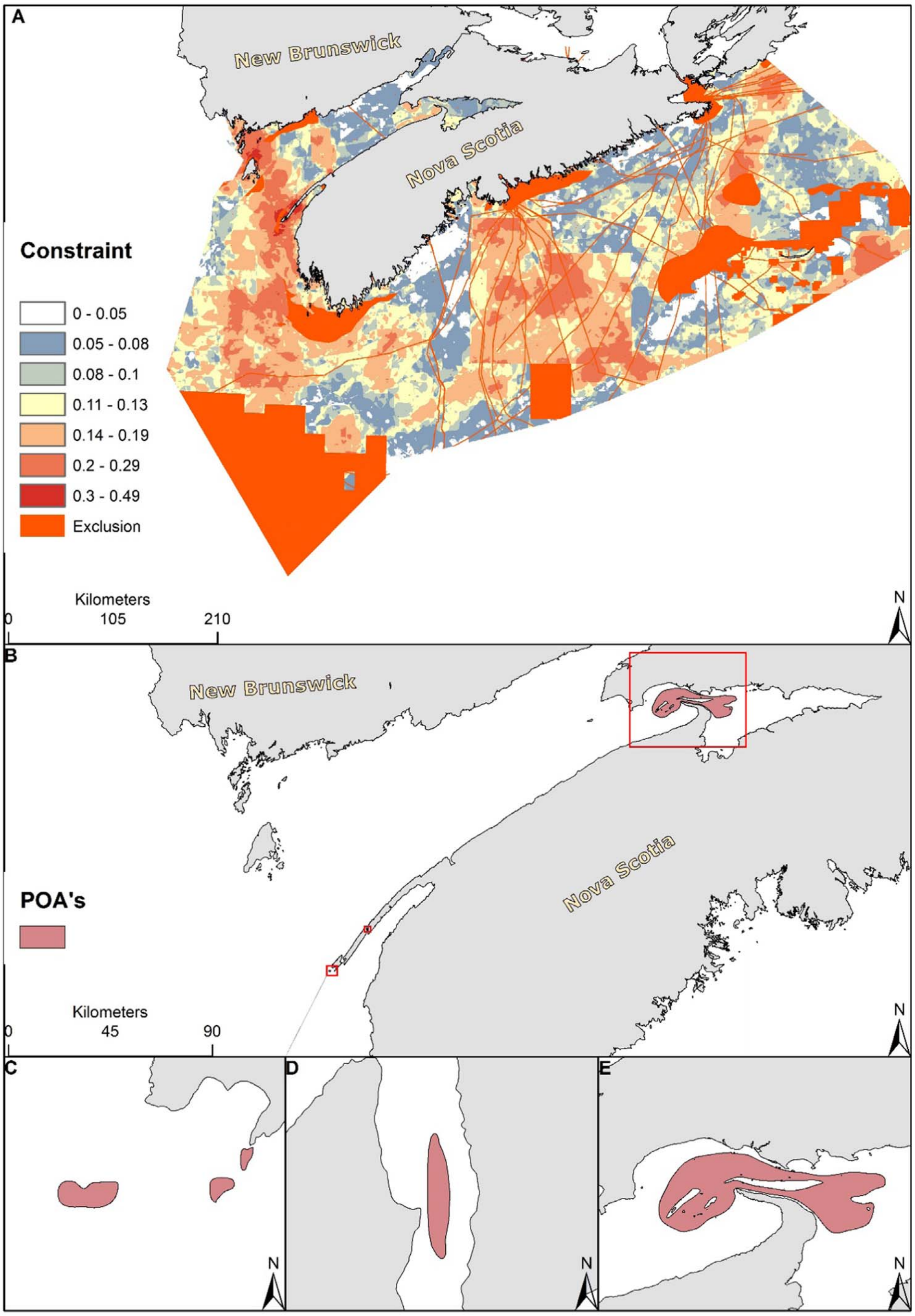

Fig. 7. Final results. Panel A: Represents the equally weighted constraint model as well the exclusion data regions. **Panel B**: Represents the draft Planned Option Areas, illustrating the most suitable regions to implement TCT.

commercial fishing, etc. These identified industries, whose data was incorporated into the SMPTE scoping analysis, could draw upon the same data and process utilized in this paper in order to construct their own sectoral plans which attribute constraint weightings to other users and uses of the marine environment within the context of their industry operations. Finally, in order to effectively facilitate such strategic hierarchical levels of planning, a Canadian National MSP should be implemented that established a number of policies in which the Maritime Regional MSP must be in conformance with, thereby informing the policies of the Provincial MSP that hosts the SMPTE.

The public policy agenda of the SMPTE presented in this paper was based on the restructuring of current legislation and policies in place in Nova Scotia and Canada, and therefore, in order to devolve powers to plan for the marine environment from federal to provincial authorities, it was recommended that regulations to do so be prescribed under the Oceans Act. However, in the absence of immediate necessities to transition Nova Scotia's tidal energy industry from the pre-commercial to commercial status, it is ideally recommended that new legislation be written that provides for jurisdictional provincial planning boundaries as well as an established provincial regulatory authority.

Furthermore, it is suggested that a new governmental body be created and authorized with powers to plan for Nova Scotia's TZ under the newly created legislation. The DoE was recommended as the MSP CA for this paper due to the establishment of the MRE Act which loosely provides for such powers in relation to tidal energy development. However, in the establishment of the recommended overarching provincial MSP, which would identify and plan for other sectors operating within the legislated TZ, either by industry or uniformly, a substantial amount of provincial legislation would inhibit the DoE from planning for aquaculture, shipping, commercial fishing, and other sectors. A newly created governing body legislated under a new MSP specific statute would not only account for the regulatory and authoritative complexities associated with the involvement of various sectors, it would also establish a single CA, as demonstrated in the Scottish context through Marine Scotland [13].

In order to properly inform the strategic siting of TCTs, as well as MSP in general throughout the province and nation, it is recommended that greater data analysis be undertaken and mapped to enhance spatial decision making procedures. Tidal current resource assessments have to be carried out in more depth, particularly in the Cape Breton region, as they provide for the initial analysis of TCT deployment suitability. Prior to conducting such resource assessments, no decisions should be made regarding the legislation of MREAs and allocation of public funding subsidies, as such decisions provide information on potential suitability to the public where no suitability is apparent, thereby facilitating distrust in government amongst associated stakeholders. For example, the analysis in this paper demonstrated that there was insufficient Vmsp in Digby Gut, Great Bras d'Or Channel, and Barra Straight, all of which were either designated as Marine Renewable-energy Priority Areas and MREAs or awarded Community Feed-in Tariffs (COMFITs). Once appropriate resource assessment is undertaken, the data should be mapped and made publically available through a central database which normalizes all data applicable to MSP in the province, as is the case with Scotland's NMPi [13].

6. Conclusion

Whether it be a case of correlation or causation, European nations who have constructed and implemented MSPs have also implemented offshore RETs. In the case of Scotland, the implementation of a SMPTE within their NMP has established a concrete regulatory regime and strategic siting process which gives consideration to all industries and ecosystem functions persisting within their national waters, and has subsequently supported the implementation of the first commercial-scale TCT array in the world. This paper has loosely adopted the MSP process utilized for the Scottish SMPTE and applied it to the Nova Scotia context. The scoping process identified prime resource areas for TCT implementation based on the operational parameters of current commercially viable technologies, while the sustainability appraisal identified cultural, industry, ecological, and socioeconomic areas of constraint and exclusion. Ultimately, the POAs emanating from the applied methodology demonstrated a 238.345 km^2 increase in suitable TCT deployment area than the MREAs under the MRE Act which did not undertake such a methodology. While the Scottish SMPTE process can serve as a technical exercise for the identification of suitable areas for TCT deployment, this paper has demonstrated that the complexity of Nova Scotia's legal framework must be thoroughly analyzed and structured in order to create a simplified regulatory regime which does not deter potential industry players. From Scotland to New Scotland, the younger province of Nova Scotia can learn from the best practices employed by its paternal figurehead nation via the construction and implementation of a cohesive MSP and SMPTE to meet renewable energy deployment and GHG emissions reductions targets.

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