Tidal Energy Development: Developing a conceptual framework for the integration of environmental and socio-economic impact information for management decisions, with particular reference to the lobster fishery in the upper Bay of Fundy

By

Patricia Rae Hinch

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Dalhousie University
Marine Affairs Program
Halifax, Nova Scotia, Canada

Dalhousie University
Marine Affairs Program
Halifax, Nova Scotia Canada

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Supervisor:

Signature: ______________________________ dated: ______________________

Dalhousie University

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Author: Patricia Rae Hinch

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Dedication

To my husband Bill Campbell for his patience, understanding, and ongoing support.

In memory of my parents Dr. Arthur and Edie Hinch, step-grandmother Annie Hinch, mother-in-law Margaret Campbell, sister-in-law Mary Ellen Campbell Stelzer, and brother-in-law Norman Campbell.

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ABSTRACT

Nova Scotia is moving ahead to develop the tidal energy resources of the Bay of Fundy using a new technology called tidal in-stream energy conversion (TISEC). Lack of prior impact experience does not provide a basis for management decisions or the development of indicators for monitoring and assessment. What is currently understood of TISEC socio-economic and environmental impacts is based largely on impact predictions. The study proposed a conceptual framework based on concepts from NRC (1990) to develop an effects monitoring program, collect appropriate impacts and research data and integrate data into the EIA decision process. An approach was suggested to identify and prioritize potential TISEC project interactions with environment and socio-economic components over the project lifecycle. Key interactions focusing on the potential effects of TISEC energy development on the lobster population and fishery were selected for indicator development. Management questions and an adaption of a PSIR model were used to identify indicators and indices to monitor potential changes in lobster populations and the fishery. Recommendations emphasize the importance of a long term monitoring program to assess development impacts over the project lifecycle, the need for TISEC development on an incremental basis, and avoidance of assumptions that short term monitoring results can be directly extrapolated to a commercial development scale. Approval to develop the next level must be based on evidence that no significant adverse impacts have occurred. Implementation of study recommendations and those in OEER (2008) and NSDOE (2008) reports are considered essential to future sustainability of the TISEC industry and lobster fishery in NS.

Keywords: TISEC; tidal energy; lobster fishery; monitoring; indicators; environmental and socio-economic impacts; upper Bay of Fundy; conceptual framework.

ABBREVIATIONS AND ACRONYMS

ACER	Acadia Centre for Estuarine Research (Acadia University)
Alta	Alberta
ATPPB	Atlantic Tidal Power Programming Board
BC	British Columbia
BoFEP	Bay of Fundy Ecosystem Partnership
DFO	Department of Fisheries and Oceans (Canada)
DTI	Department of Transport and Industry (UK)
Ecotec	Ecotec research and Consulting Limited
EIA	Environmental impact assessment
EMEC	European Marine Energy Centre
EPRI	Electric Power Research Institute
ERACL	Ecotec Research and Consulting Limited
FMAM	Faber Maunsell and Metoc
FRCC	Fisheries Resource Conservation Council
GOMC	Gulf of Maine Council
ICOM	Integrated Coastal and Ocean Management
LFA	Lobster fishing area
MEQ	Marine environmental quality
MMS	Minerals Management Service
NS	Nova Scotia
NSDOE	Nova Scotia Department of Energy
NRC	National Research Council
NSPON	Nova Scotia Provincial Oceans Network
PMSSL	Project Management Support Services Limited
OECD	Organization for Economic Cooperation and Development
OEER	Offshore Environmental Energy Research Association
PPT	Parts per thousand
PSIR	Pressure-state-impact-response model

SEA	Strategic Environmental Assessment
SEI	Sustainable Energy Ireland
SMART	Simple Measurable Accessible Relevant Timely
STD	Statistical district
TISEC	Tidal in-stream energy conversion
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
UNFCC	United Nations Framework for Climate Change
VA	Virginia

GLOSSARY

For purposes of this research several terms are defined and used within the context of tidal in-stream energy conversion (TISEC) energy development.

Environment - a natural system that includes biological, physical and socio-economic components that may influence or be influenced by, a TISEC device.

Impact - a change in environmental feature or characteristic, behaviour, or response resulting from the presence, operation or removal of a TISEC project, measured over and above change caused by natural variability (DTI 2002).

Physical environment - non-living features of the ecosystem (i.e. land, air, water) and associated interactive or inherent properties or processes (e.g. sediment regime, water circulation, tidal flow, currents, erosion, sea level rise, deposition, etc.) (DTI 2002).

Biological or ecological environment - living components of the coastal and marine ecosystem (flora and fauna) which may be influenced by natural processes (biological and physical, biochemical, biogeophysical) (DTI 2002).

Socio-economic environment - economic, industrial, business development sectors and their activities, as well as valued cultural, archaeological and historic features, and the social economic and cultural wellbeing of coastal communities (DTI 2002).

Baseline - “original (unimpaired by man) environmental or ecological conditions set at some arbitrary time. In the context of environmental effects (impact) monitoring ‘baseline data’ characterizes environmental conditions prior to project development against which subsequent changes following development can be detected through monitoring” (Beanlands and Duinker 1983).

Manager - a person in a position of authority who is responsible for decision making (Chapman 1977) relative to policy direction, and/or regulatory action or followup activity. “Indicator” refers to a parameter, a measure or statistic that describes the state, quality, or condition, of an environment, area or phenomenon that is valued with a significance beyond that directly associated with the parameter (OECD 1993).

Cumulative effects or changes - “impacts on the natural and social environments which occur so frequently in time or so densely in space that they cannot be assimilated or which combine with effects of other activities in a synergistic manner” (Sonntag *et al.* 1987).

Unknown unknowns - “processes which we do not yet know about which would lead to drastic revisions of present predictions” (Garrett 1992).

Migration - “mass directional movement of large numbers of a species from one location to another” (Thain and Hickman 2004).

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1.0 Introduction

1.1 Historical context

Throughout the world, there is a growing interest in the development of renewable energy forms. This is primarily due to uncertainties and concerns over the remaining supplies and security of energy reserves, increased awareness of the impacts of climate change from the use of fossil fuels, and the rising cost of oil, gas, and electricity. Development of renewable energy in Canada is seen as a means of assisting the country in meeting its obligations under the Kyoto Protocol (United Nations Framework for Climate Change 1998). The framework calls for a reduction in greenhouse gas emissions between 2008 and 2012, by 6% from 1990 levels (UNFCC 1998). As of 2008, the province of Nova Scotia generates ~ 12% of its total electrical production (2,293 MW) from renewable sources which include biomass, thermal, wind, and hydro forms (S. Farwell, NS Department of Energy, Halifax, NS, pers. comm.). The Nova Scotia Environmental Goals and Prosperity Act (2007) requires that by 2013 the province generates 20% of its electrical energy capacity from renewable energy sources and by 2020 reduces greenhouse gas emissions to a level that is 10% below 1990 levels (or 25% below 2005 levels). Although growth in commercial wind energy production is expected to meet most of this portfolio commitment, tidal power also is anticipated to play a role, but to what degree is uncertain.

For over 100 years, there has been an interest in tidal power development in the Bay of Fundy (P.G. Wells, International Ocean Institute, Dalhousie University, Halifax, NS, pers. comm.) Early initiatives in 1975 and 1977 had identified three sites in Nova Scotia that had the capacity to generate a total 8,500 MW of electrical energy with an annual production capacity of 22,000 GWh (Lipp *et al.* 2006). In the 1980s, the Department of Fisheries and Oceans and Acadia University in Wolfville, NS, assessed the feasibility of tidal development in the Cumberland Basin (P.G. Wells, International Ocean Institute, Dalhousie University, Halifax, NS, pers. comm.). As a result, a 20 MW power generation plant was opened in Annapolis Royal in NS in 1984 to assess the potential for power generation using a barrage form of technology. However, development of the barrage at a commercial scale was precluded by negative environmental impacts including fish mortalities, and changes in tidal and sediment regimes with consequent effects on local aquatic habitats and wetlands (Conley and Daborn 1983; Wells 1999).

Recently, there has been a renewed interest in tidal energy development in NS and NB focusing on a new form of turbine technology known as tidal in-stream energy conversion (TISEC). These devices operate on a vertical or horizontal axis in a similar manner to wind turbines, except that they operate underwater. Commonly these devices are anchored to the seabed by a piling or foundation or are mounted on a floating structure moored to the seafloor. Capturing the kinetic energy of the tidal currents as the tide moves in both directions, TISEC provides a predictable supply of energy throughout the tidal cycle. Data indicate that current velocities of between 2 and 5 meters per sec (m/s) are required for extraction of tidal energy to be economically viable at any particular site (MMS 2006).

In 2005, the NS and NB Governments reassessed tidal energy potential in the Bay of Fundy. A feasibility study conducted by the Electric Power Research Institute (EPRI 2006_a) identified 7 sites on the NS side with sufficient energy capacity for commercial scale electrical generation. Cape Blomidon and Cape Sharp in the outer Minas Basin were identified as the preferred locations for a pilot demonstration and commercial scale development respectively—both in the Minas Passage. EPRI (2006_a) indicates that 300 MW of power, sufficient to power 100,000 homes, could be safely removed from the Minas Channel. While initial costs of energy production per kwh are high relative to current energy sources, costs are expected to reduce as technologies further develop and as traditional fossil fuel costs continue to rise. The question is whether predicted nominal environmental impacts are proven through demonstration testing of TISEC devices under natural conditions in the Bay of Fundy and whether the devices themselves can withstand the environmental elements (e.g. strength of the tides and the scouring effect of suspended materials). Another crucial issue is whether the results of pilot demonstrations are scalable to a commercial development level. If proven to be economically and environmentally viable within the Bay, renewable tidal energy could make a significant contribution to Nova Scotia's renewable energy goal.

In 2007, the Offshore Environmental Energy Research Association (OEER) was commissioned by the NS Department of Energy to carry out a Strategic Environmental Assessment (SEA) focusing on tidal energy development in the Bay of Fundy. The purpose of the SEA was to provide advice on whether, when, and under what conditions tidal energy demonstration and commercial projects should be allowed. Input received from community forums, workshops and written submissions was incorporated into a final report containing 29 recommendations (OEER 2008) to guide the strategic development of marine renewable energy in the Bay of Fundy.

The NS Government issued a request in 2007 for proposals for the demonstration of TISEC technologies in the Minas Passage to assess their environmental impact and operability under natural conditions. In January, 2008, the Province announced three winning demonstration technologies and the availability of funding for a research and testing facility in Parrsboro (The Chronicle Herald and Globe and Mail, January 9, 2008). Provided that demonstration trials and environmental impact assessment reviews are favourable, the industry will be permitted to secure the necessary permits to begin operation of a limited number of turbines. Subsequent incremental additions of devices toward commercial scale development would be subjected to monitoring, review and assessment for cumulative impacts and change. Again if results are favorable, development and monitoring would continue through to commercial scale deployment which is anticipated to involve ~ 250-300 turbines in the Minas Passage area (EPRI 2006_a). As provincial regulators have not designed the monitoring program, this research study provides guidance on the components of a monitoring/research program and the selection of appropriate indicators to detect change from TISEC operation at each level of development.

1.2 The coastal management issue

On a global basis, TISEC energy technology is in its early stages of development. SEI (2006) reports that 25 different tidal energy devices are under various development stages and that several full scale or near full scale prototypes are currently undergoing sea trials. However, monitoring data are not as yet available. To date, there has been no demonstration of multiple commercial scale devices (SEI 2006) to assess their potential for causing negative cumulative change(s) to the marine environment. Little is therefore known about the environmental or socio-economic impacts that these devices pose. Current anticipation of commercial scale impacts is based solely on results of single prototype device testing over short periods of time (Ball 2002). It also is not known if the results of single demonstration units can be extrapolated to commercial scale multiple devices operating over the long term, i.e. whether cumulative impacts, if they occur, are additive or synergistic. The lack of impact data from TISEC devices operating under natural conditions presents a challenge to decision-makers both in terms of choosing appropriate locations for site demonstration and in evaluating costs and benefits of commercial scale development. The absence of a renewable ocean energy policy, appropriate legislation and an integrated coastal management strategy in NS has meant that there is no coordinated guidance or context to assist development decisions. As in other countries and Canadian coastal provinces, our current level of understanding of potential TISEC impacts is based on the demonstration of prototypes in other locations around the world, and such information is very sparse. Lack of previous demonstration or environmental impact assessment (EIA) experience with the technology has also meant that there is no basis upon which to design a monitoring program appropriate to the Bay of Fundy.

Approval to move forward with full scale commercial development in Nova Scotia will require proof that demonstration of single prototype devices and later incremental additions of turbines do not result in significant negative environmental or socio-economic impacts. In view of the fact that the monitoring program has not as yet been designed, it is crucial that it be based on an appropriate selection of indicators to measure changes in conditions from TISEC operation. It is essential that decision-makers and regulators understand what to measure and how to measure change over short periods for single demonstration units and longer timeframes involving multiple units operating in a commercial turbine array. In view of the current interest in tidal energy development in NS, this study identifies the information needed for management decisions relative to TISEC development and develops a conceptual framework for the collection of information and monitoring data.

1.3 Research questions

The overall research questions for this study were:

What kind of information is required for effective environmental and socio-economic management decisions relative to the development of tidal energy in the Bay of Fundy?
What are the key components of a conceptual framework that guides collection and integration of appropriate environmental and socio-economic information for management decisions?

1.4 Goals, objectives, and scope

The goals of this paper are:

i) to identify what information (baseline and research) is available and is required to evaluate environmental and socio-economic change from TISEC operation; and
ii) to identify key components of a monitoring program for the Bay of Fundy to measure change in socio-economic and environmental conditions from TISEC operation.

The primary study objectives are:

i) to determine if what is currently known about baseline information and environmental and socio-economic impacts of TISEC operation is appropriate or sufficient for management decisions relative to the advancement of the tidal energy industry;

ii) to determine what further information is required and the conditions necessary for the collection/collation of appropriate baseline and monitoring information for impact evaluation and decision purposes;

iii) to identify key integrated coastal and ocean management principles that apply throughout the lifecycle of a tidal energy development project;

iv) to develop an approach to identify and prioritize potential tidal energy project-environment interactions;

v) to select a minimal number of indicators to monitor the results of key priority project-environment interactions/issues; and

vi) to identify next steps to ensure that data and information i.e. what is currently known or found, are factored into the next phases of the decision making process.

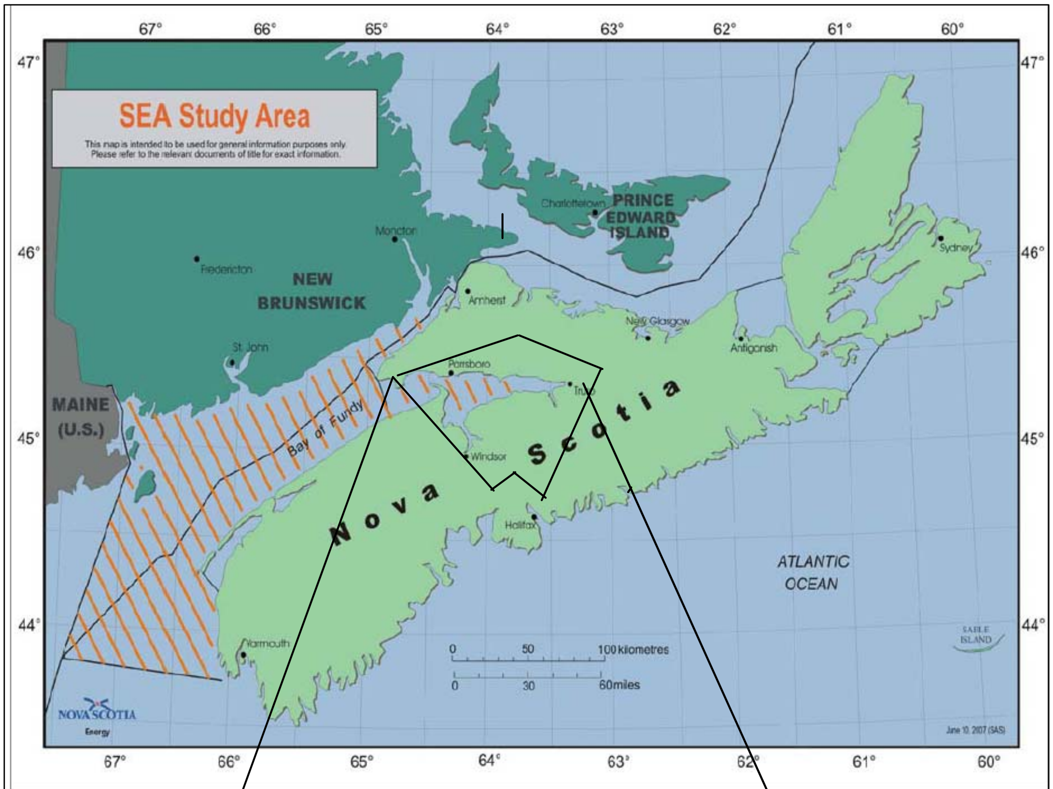
The study area for this project (Figure 1) is the Minas Basin area which includes Cobequid Bay, the Minas Basin, Southern Bight, the Minas Passage, the Minas Channel and the associated watershed. This marine area collectively known as the upper Bay of Fundy extends from the headwaters of Cobequid Bay to a line drawn from Cape Chignecto to the NS shore. Within the NS Strategic Environmental Assessment, Minas Passage was identified by NS proponents as having the highest energy potential and was the preferred siting location for future TISEC demonstration and commercial scale development (EPRI 2006_a).

2.0 Methods

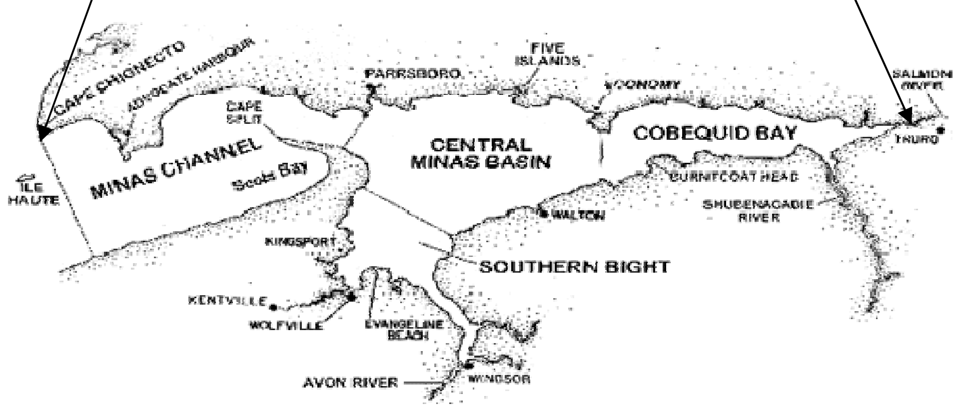
2.1 Analytical approach and research framework

The study initially reviews the available Bay of Fundy literature to provide background information on ecological and socio-economic conditions, tidal energy potential, and issues of concern in the project area. Subsequent sections focus on whether

Figure 1. Study area - maps of Minas Basin Watershed and the NS portion of the Upper Bay of Fundy (Source: NS Department of Energy 2008; BoFEP 2001)



(Source: NS Department of Energy, 2008)



(Source: BoFEP, 2001)

current information available on environmental and socio-economic baseline conditions and impacts of TISEC development constitutes an appropriate kind, amount and quality of information for decision purposes relative to tidal development. Where information is insufficient, the study outlines the kinds of information and conditions required for the collection of appropriate data and information.

Matrix models developed by Darce and Bullen (2001), EMEC (2005) and the US Department of Transport and Industry (2002) are adapted to identify and prioritize anticipated tidal project-environment interactions noted in the available literature on TISEC development including DTI (2002), EPRI (2006_a), EPRI (2006_b), OEER (2007), and OEER (2008) reports. Key environmental and socio-economic interactions involving the valuable lobster population and lobster fishery, respectively, were selected for the development of indicators for use in effects monitoring programs. A Pressure-State-Impact-Response model was adapted from OECD (1993) to identify potential TISEC impact scenarios on the lobster population and fishery as the basis for identifying indicator categories/indices and for developing management questions. Specific indicators were identified for each category to respond to management issues or questions. Environmental indicators are chosen from the scientific literature (Charles *et al.* 2002; FRCC 2007; DFO 2007_b; DFO 2007_c) to measure change in lobster composition, abundance distribution, health and sustainability. Socio-economic indicators are based on traditional measures of change in community economic and social well-being derived from Joseph and Gunton (2008), Vickers (2005), and Lockie *et al.* (2005).

3.0 Assessing tidal power in the Bay of Fundy

3.1 Overview of the literature

The following describes the information content of recent documents considered most relevant to this study (e.g. DFO (2007_a), EPRI 2006_a, EPRI (2006_b), Joseph and Gunton (2008), OEER (2007), OEER (2008), Willcocks-Musselman (2003)), i.e. those that focused specifically on the natural or socio-economic environment and the TISEC energy industry within the area illustrated by Figure 1.

The OEER (2007) Strategic Environmental Assessment (SEA) report summarized results from the first public consultation forum and workshop held on February 22-23, 2007. The document provided an overview of public issues of concern with development, discussed the energy potential of the tides, identified best locations for development, outlined information/knowledge gaps, and developed a preliminary research agenda to fill information needs. For purposes of this study, the document provided an indication of the status/availability of baseline information on environmental conditions in the Bay of Fundy, the current level of understanding of the impacts of TISEC device operation, and level of research effort required to understand development effects. It also provided information used in evaluating the sufficiency of information for decision-making purposes relative to the advancement of the TISEC industry.

OEER (2008) presented results and recommendations of the NS Strategic Environmental Assessment (SEA) process conducted in 2007 to provide advice on whether, when, and under what conditions tidal energy demonstration and commercial development should be permitted in the Bay of Fundy. Information on the status of the NS energy industry (e.g. energy supply and demand, changes in energy scenarios, role of renewable energy forms), fisheries resources in the Bay of Fundy, and human population changes (e.g. population changes in counties surrounding the project area) provided valuable information for background sections of this study. The document identified potential interactions between the TISEC project and biophysical and socio-economic environments over the lifecycle of the project. Although there was no attempt by OEER to predict the effects of these interactions or assess their significance, the possible interactions themselves helped in identifying indicators to monitor change in natural and socio-economic conditions. A summary table provided by OEER (2008) on ecological data and information gaps and how they might be addressed identified what is currently not known, which served as a basis to identify both indicators and components of a monitoring program for TISEC assessment. OEER (2008) also describes various types of cumulative impacts in the aquatic environment that could result from TISEC operation. This information was factored into the development of long term cumulative effects questions for indicator development. Fundamental to the research question on monitoring, OEER (2008) recommends incremental development of TISEC in stages supported by an appropriate effects monitoring and research program.

EPRI (2006_b) evaluated the tidal energy resource at various locations in the Bay of Fundy, and recommended preferred sites for pilot demonstration of TISEC devices and commercial scale development. The document predicted a series of impacts from TISEC development on the natural and socio-economic environment of the Bay of Fundy. The potential impacts information from this and other research sources (OEER 2008, OEER 2007, and Joseph and Gunton 2008) was combined with anticipated interactions information (identified in OEER 2008 and DFO 2007_a) to design an interactions matrix to summarize potential project-environment interactions throughout lifecycle stages.

EPRI (2006_a) examined the anticipated design performance, device reliability, and costs associated with testing pilot TISEC devices at two selected sites in the Minas Passage. The study concluded that many research questions remain which can only be answered through demonstration of TISEC technology under natural site specific conditions. Both EPRI documents were important in understanding the industry from a developer perspective, particularly in terms of development risks and benefits, issues of concern, and what is known, not known, and the additional information required for advancement. Information on potential environmental and socio-economic impacts was used to assess sufficiency of current impact information and baseline data (e.g. natural resources, ecological processes) for decision-making purposes and also to identify monitoring and indicator needs. This paper raised two important questions relevant to this study, namely: Can the results of the demonstration pilot be scaled to represent the cost and environmental implications of a full scale commercial plant? Must indicators to assess impacts of single turbine operation be changed to appropriately evaluate the impacts of multiple devices in a turbine array?

Department of Fisheries and Oceans (2007_a) is a background reference document that presents an overview of key ecological components of the waters of the Minas Basin and surrounding land area. Of interest to this study are sections that describe Minas Basin physical oceanography (e.g. ice cover, water masses and currents, underwater sound, waves and turbulence), biogeochemistry (e.g. sediment ecology; transport and deposition), biological components (e.g. planktonic, benthic, and pelagic communities; marine mammals; avian community; species at risk), and oceanographic information gaps. Also relevant was information on habitat use (e.g. spawning/reproduction, rearing and foraging areas; migration routes), tidal influence on coastal habitats, biological systems information gaps, and ecosystem relationships and data gaps. The Minas Basin study area described by this document includes a significant portion of the TISEC project development area. As such, the document provides essential information on ecological condition/features used in this study to describe the existing environment or baseline features, against which to monitor change from project-environment interactions. Data gaps helped to identify both project-environment interactions and specific indicator needs. The document emphasizes the importance of understanding seasonal and spatial use of the Minas Channel by fish (demersal or bottom-dwelling and pelagic) as a gateway into the Bay of Fundy and Gulf of Maine. An activity such as tidal power development and production has the potential to disrupt the lifecycles of many species as they move through this channel (DFO 2007_a).

The Jacques Whitford (2008) document is a background report to the NS Strategic Environmental Assessment conducted in 2007. The report identifies potential environmental concerns and describes the status of available technologies and the results of testing devices on a global basis. Included is a list of monitoring research topics. The document describes the development scenarios/phases for TISEC devices in the Bay of Fundy, the NS energy potential, and the environmental suitability and development potential for two preferred sites (Minas Passage and Digby Gut). Of particular relevance to this study, the document describes environmental components of the Bay of Fundy in detail (physical, biophysical, and biological) and to a lesser extent, socio-economic components (e.g. tourism and recreation, mariculture, historic resource development, economic development, and marine transportation). The report also defined key environmental issues and potential project-environment interactions, outlined management and planning considerations, and identified data gaps and followup activities. Explanations of how the project lifecycle stages potentially interacted with the natural environment were important in understanding the potential or possible impacts of the project on valued ecosystem components. In this study potential interactions identified by Jacques Whitford (2008) were used in selecting key interactions for indicator development. Information provided by Jacques Whitford (2008) on data gaps and recommended followup was used in this study to identify components of a monitoring program and appropriate indicators.

Joseph and Gunton (2008) provides a synopsis of socio-economic impacts of renewable ocean energy development (including tidal, wave and wind) on the coast of British Columbia. Of relevance to this study, the document a) described potential socio-economic implications of renewable ocean energy development for the BC coast, coastal communities and First Nations, b) identified knowledge and implications gaps, and c) proposed measures to mitigate project impacts. The document described tidal energy development phases, the resource potential, the status of renewable energy industry, and presented a socio-economic overview of coastal BC. Of interest to this research, the document identified socio-economic issues, key socio-economic indicators (population, employment and education), and examined the socio-economic impacts of development on a variety of coastal activities (including coastal defense, cultural resource protection, economics, existing industries, rural energy supply, health and recreation, rural demographics and migration, and traditional activities). It also outlined uncertainties associated with the prediction of ocean energy development impacts and measures to mitigate negative effects of energy development on existing industries. The document content and the overall approach to assess socio-economic implications was used as a model outline. Project-environment interactions and socio-economic information were used as a basis of comparison with similar Bay of Fundy information.

3.2 Definitions

For purposes of this research, several terms are defined and used within the context of TISEC development. “Environment” is defined as a natural system that includes biological, physical and socio-economic components that may influence or be influenced by, a TISEC device. “Impact” is a change in environmental feature or characteristic, behaviour, or response resulting from the presence, operation or removal of a TISEC project, measured over and above change caused by natural variability (DTI 2002). “Physical environment” refers to non-living features of the ecosystem (i.e. land, air, water) and associated interactive or inherent properties or processes (e.g. sediment regime, water circulation, tidal flow, currents, erosion, sea level rise, deposition, etc.) (DTI 2002). “Biological or ecological environment” includes living components of the coastal and marine ecosystem (flora and fauna) which may be influenced by natural processes (biological and physical, biochemical, biogeophysical) (DTI 2002). “Socio-economic environment” refers to the economic, industrial, business development sectors and their activities, as well as valued cultural, archaeological and historic features, and the social economic and cultural well-being of coastal communities (DTI 2002). “Baseline” is defined as “original (unimpaired by man) environmental or ecological conditions set at some arbitrary time. In the context of environmental effects (impact) monitoring ‘baseline data’ characterizes environmental conditions prior to project development against which subsequent changes following development can be detected through monitoring” (Beanlands and Duinker 1983). “Manager” refers to a person in a position of authority who is responsible for decision making (Chapman 1977) relative to policy direction, and/or regulatory action or followup activity. “Indicator” refers to a parameter, a measure or statistic that describes the state, quality, or condition, of an environment, area or phenomenon that is valued with a significance beyond that directly associated with the parameter (OECD, 1993). “Cumulative effects or changes” are defined as “impacts on the natural and social environments which occur so frequently in time or so densely in space that they cannot be assimilated or which combine with effects of other activities in a synergistic manner” (Sonntag *et al.* 1987). “Unknown unknowns” refer to those “processes which we do not yet know about which would lead to drastic revisions of present predictions” (Garrett 1992).

3.3 TISEC device descriptions and development scenarios

Three companies representing technologies developed in Canada, Ireland and the United States have been selected by the NS Government to demonstrate their TISEC technologies in the Bay of Fundy. These are: Clean Current (demonstrating Clean Current Mark III Turbine), Minas Basin Pulp and Power Co. Ltd (demonstrating UEK Hydrokinetic Turbine), and Nova Scotia Power Inc. (demonstrating OpenHydro Turbine) (NS Department of Energy 2008). Diagrams and design specifications of each of these devices are included in Appendix A. An analysis of information available on these devices from UEK, Clean Current and OpenHydro websites, indicate the following. To an untrained eye, these devices appear to be very similar in design and the way in which they operate. These devices consist of a cylinder housing encasing a horizontal rotating blade and a variable speed magnetic generator. The generator converts the kinetic energy of the tide moving through the blades, into electrical energy. The blades are bi-directional in that they capture energy from both ebb and flood tides. The devices are completely submerged at a minimum depth of 30 metres to minimize impacts on shipping (UEK, Clean Current and Open Hydro websites). All have a rotor as the only moving part. This eliminates the need for a gearbox and drive shaft and therefore the use of hydrocarbons as lubricants. All designs have open centres within the rotor which is believed to provide an escape for fish and marine mammals should they come within the range of turbine blades. Turbines differ in: their size, configuration, blade and outer diameter (ranging from ~ 5 to 20 metres), and their mode of attachment to the seabed (UEK, Clean Current and Open Hydro websites). Open Hydro is mounted either between two pole structures attached to a seabed foundation allowing the device to be raised for maintenance, or is attached directly to a foundation/base on the seabed. Similarly, Clean Current is mounted on a pole attached to a seabed foundation (Clean Current website). The UEK (underwater electric kite) twin turbine floats but is tethered to the seabed to maintain its position in the tidal current (UEK website).

On a global basis, TISEC is still an immature technology in comparison to wind energy. Developers have demonstrated several types of TISEC devices in marine waters, all at various stages of development. From an energy generation perspective, test results have shown that energy can be effectively extracted from the tides, proving that TISEC is a viable energy technology on a demonstration scale (Jacques Whitford 2008). Short term demonstration studies to assess the environmental effects of TISEC devices have been conducted in Race Rocks Ecological Reserve in British Columbia and in the UK at the European Marine Energy Centre in Orkney. However, results have not been publicly released. This has made it impossible to assess precisely what information is available and to what extent results might apply to the Bay of Fundy (Jacques Whitford 2008). What has been learned from these tests is that: 1) much effort has gone into study designs to address regulatory concerns, often times under difficult working conditions, 2) environmental effects of TISEC technology are site and technology specific, i.e. TISEC operation and environmental effects data from one site are not necessarily applicable to another site due to differences in environmental conditions and species present (e.g. numbers, diversity, distribution, lifecycle patterns/behaviours, etc.), 3) it is not known if or to what extent data obtained from the demonstration of small prototype devices is scalable to larger projects (Jacques Whitford, 2008). This implies that all TISEC technologies need to be demonstrated and monitored on a site specific basis to evaluate the tidal resource, project-site interactions, requirements to optimize technology design for the site, and overall project feasibility to proceed to the next development level.

The lifecycle process for a TISEC project follows a standard development model consisting of 5 stages: site evaluation, development, construction, operation, and site decommissioning (described in Appendix B). Demonstration and operational phases involving the placement of devices in marine waters which create the potential for project-environment interactions are the focus of this project.

There are generally three development scenarios for TISEC device placement in marine waters: pilot, demonstration and commercial. The pilot scenario involves a short term initial device test to evaluate prototype performance in tidal waters and the feasibility of developing the technology further into a demonstration or commercial scale project. The device at this stage is not connected to the electrical grid so the pilot is not assessed for economic viability.

The demonstration scenario involves the placement of one or more devices in the tidal current in an area favoured for commercial scale development to assess the feasibility of long-term operation and potential environmental impacts. Demonstrations provide the opportunity to assess and optimize performance to fit preferred site conditions and to monitor environmental impacts before decisions are made to invest further in commercial scale development. The selection of an appropriate site location is crucial in obtaining necessary baseline data on economic feasibility, identifying environmental effects, and operation issues. Seabed geology, location of shipping and navigation, availability of shipyard and infrastructure support, potential for conflict in space or resource use, distance to grid connection, and tidal current strength are critical site selection factors. Geology and sedimentation also have implications for foundation design and scour protection. Site locations that have deep water areas of 30 meters or more are preferred for further project demonstration and development (Jacques Whitford 2008). Because technologies are in early development stages (circa mid 2008) and environmental effects are uncertain, substantive testing is required to evaluate environmental interactions and potential impacts on marine species.

A commercial development scenario involves projects that have proven to be economically viable for electrical generation over the long term. Commercial generation involves connection of an array of turbine devices (up to ~400 units) to the electrical grid (NS Dept of Energy 2008). On a global basis, there are as yet (2008) no commercial scale TISEC projects under operation and therefore progress toward commercial development involves planning and short term demonstration of prototypes on an incremental basis. Two Nova Scotia locations in the Bay of Fundy have been identified as having the best capacity for commercial scale development—the Minas Passage and Digby Gut (Jacques Whitford 2008). Appendix C contains a description of relevant integrated coastal and oceans management principles an how they apply to each lifecycle phase.

3.4 Knowledge and understanding of TISEC implications

3.4.1 Current information available for decision purposes

As of mid 2008, no TISEC devices have actually been tested or demonstrated at any development scale in the Bay of Fundy. Only in Head Harbour Passage in 2007, on the US side have units gone through preliminary prototype pilot testing by a US firm (P.G. Wells, International Ocean Institute, Dalhousie University, Halifax, NS, pers. comm.). Therefore, there is currently no site information/data available on, e.g. TISEC performance or reliability, cost of energy production, or environmental and socio-economic development implications to the Bay of Fundy. What is currently understood about TISEC interactions and impacts is based on hypothetical projections or predictions of what is reasonably anticipated or expected to occur as a result of TISEC device presence or its operation on environmental and socio-economic components.

To illustrate these points, predicted impacts and interactions of TISEC from the Bay of Fundy literature can be divided into three categories: what is reasonably known, not known, and unknown as follows (P.R. Hinch, Marine Affairs Program, Dalhousie University, Halifax, NS, unpublished data): Predicted known impacts are obvious effects/consequences of an action, or are anticipated from previous similar experiences, e.g. construction of offshore wind, and oil and gas facilities. Predicted unknown impacts are anticipated effects for which the outcome is not known. Unknown unknown impacts are effects that we are not aware of because we are simply unaware of the interaction or that we do not know. The following summarizes what is currently known, not known and unknown from the literature on the possible impacts of TISEC operation in the Bay of Fundy.

3.4.1.1 Known impacts

A review of the literature indicates that much of what is believed to be known about TISEC impacts in the Bay of Fundy is based on predictions or assumptions without field verification, through limited testing elsewhere, extrapolations of models or chart data, or the extrapolated results of activities similar in nature. Most assumptions are unsubstantiated but are used to support the tenuous view that impacts of TISEC development in the Bay of Fundy will either be minimal or not significant, e.g. gray whales will avoid the construction zone noise by changing course (EPRI 2006_b); mortalities of fish passing through the turbine will be minimal during early life stages

(EPRI 2006_b); the effects of electromagnetic radiation on marine life will be minor and temporary (EPRI 2006_b); neither prototype or commercial developments are expected to alter siltation patterns or currents in the Minas Passage (EPRI 2006_b); effects of construction will likely be short term and will not extend beyond the construction stage (EPRI 2006_b); Atlantic salmon and other organisms will be minimally affected by TISEC operation in the Minas Passage; turbines are not expected to negatively affect drifting eggs (EPRI 2006_b); and fifteen percent is the maximum level of energy that can be extrapolated from the tidal current without noticeable or significant negative effect on the environment (EPRI 2006_a). Such viewpoints represent pseudoscience at its worst.

Other predicted impacts are based on model projections, e.g. estimates of the tidal current velocities in the Minas Passage were derived from Canadian Hydrographic Service charts and bathymetric data from nautical charts as opposed to actual field measurements. Some model projections appear contradictory, e.g. the economic analysis of the cost of electrical power production was based on model projections of first as opposed to second generation (commercial scale) devices and assumed that installation and operational costs of both stages would be the same (EPRI 2006_a). Later statements indicated that cost projections are uncertain as they may vary with fluctuations in current velocities, numbers of turbines installed per site, and design changes required to protect devices against ice scour (EPRI 2006_a). A further statement indicated that since no device has been operated over an extended timeframe, predicted costs are uncertain and will not be confirmed until devices have been demonstrated for ten or more years (EPRI 2006_a).

What is more precisely known about potential TISEC environmental impacts is based on the extrapolation of development impacts from construction and decommissioning activities in the offshore oil and gas industry, i.e. construction of underwater pilings or support platforms for offshore energy projects. These include: increases in turbidity (OEER 2007); noise and vibration from TISEC operation (OEER 2007); reduction in visibility (OEER 2007 Halifax, NS. unpublished data); disruption of sediments and release of chemical contaminants (OEER 2007); changes in water quality from releases of equipment fluids (EPRI $2006_{a;}$ EPRI 2006_b); fish mortalities from sediment disturbance (OEER 2007); and accumulations of organisms living on or around support structures (OEER 2007). Examples of known socio-economic impacts include: potential conflict over the use of land or ocean space (e.g. navigation and shipping, commercial fishing; construction of roads (OEER 2007)); and potential exclusion of recreationists and commercial fishers from the project zone with loss of access to commercial/traditional fishing areas (OEER 2007).

3.4.1.2 Unknown impacts

On a global basis, little is currently known of the actual impacts /interactions of TISEC operation. Few devices have been field tested under natural conditions over an extended period of time to assess the significance of environmental effects, device extraction performance, or to validate predicted reliability of designs (EPRI 2006_a; Ball 2002). SEI (2006) reports that 25 different prototypes at full scale or near full scale are undergoing sea trials but no data have been made available to evaluate their findings (EPRI 2006_b). On a commercial scale, no devices have been demonstrated (IEA 2006) to assess cumulative impacts, the effects of one device on another, or the effect of the environment on the project. The general lack of previous experience with these technologies in NS has made it difficult to fully visualize/anticipate the impacts of TISEC operation in the Bay of Fundy in advance of prototype demonstrations.

The Bay of Fundy has been well researched on a scientific basis for over 100 years and much is already known about its ecological attributes and baseline conditions (Wells 2005; Lotze *et al.* 2004; Milewski and Lotze 2004; Daborn 2007). However, there are many gaps in “baseline data” and what is known has not been collated to specifically respond to TISEC questions, i.e. until now, there has not been a need to undertake this form of collation.

There was little mention in the available Bay of Fundy reports (above) of potential socio-economic impacts of TISEC development in NS. For example, no attempt was made to anticipate/project the economic disbenefits of establishing an exclusion zone to fishing and navigational activities in the project area. Jacques Whitford (2008) speculated that TISEC development could create local business in providing support services throughout all phases of TISEC operation, e.g. project management, surveying, resource mapping/modeling, cable laying, utility and transportation upgrades, and facility management. TISEC development may also create new businesses, e.g. fabrication, installation, maintenance, and monitoring (OEER 2007). Jacques Whitford (2008) further predicted potential opportunity for energy export, benefit agreements, cooperative research, and development of centers of excellence. Specialized positions and training may also be available in technology design, materials research/testing, device transport/assembly, device operation, maintenance and deployment (Jacques Whitford 2008). However, such proposed benefits have not been confirmed through operational experience and little information is available from the industry in terms of the number and types of employment opportunities or economic spinoffs that result from TISEC development, particularly in the supply and service area (Jacques Whitford 2008).

Appendix D, derived from OEER (2008), and Appendix E generated from a literature review of key documents summarize what is currently not known about the implications of TISEC development in the Bay of Fundy and knowledge/data gaps in baseline information. To address information deficiencies in Appendix D, authors call for long term, site specific monitoring to define the baseline and/or to assess the effects of TISEC operation under natural conditions. The results would serve to test predictions of potential effects through project specific assessments (Jacques Whitford 2008).

3.4.1.3 Unknown unknowns

Although difficult enough to anticipate the unknowns, examples of possible “unknown unknowns” (Garrett 1992) may include the unanticipated cumulative environmental effects from long term operation and the effects of TISEC project interactions with other stressors. Unanticipated cumulative ecosystem changes may derive from the operation of multiple devices in a turbine array. From an environmental standpoint, cumulative effects of energy extraction may include such phenomena as changes in sediment deposition leading to reductions in *Corophium* populations in tidal mudflats and feeding potential for migratory birds, or unforeseen effects of an ecological cascade resulting from turbine interactions with plankton (Breitburg and Riedel 2005). From an socio-economic standpoint, cumulative effects include the unexpected spinoff effects from new businesses development on local and regional economies, including the export of TISEC technical knowledge or experience to a global market, or the collective long term effects of TISEC energy production (and other renewable technologies) on oil and gas consumption, production of green house gases and climate change.

Unanticipated interactions of a TISEC project with other multiple development stressors may result in synergistic, antagonistic or additive effects (Breitburg and Riedel 2005), e.g. the effect of turbine devices on a resident fish population which has already been stressed by loss of a significant portion of its habitat, overfishing, disease, displacement by invasive species, and contamination by toxic substances. The real "unknown unknowns" are, however, simply not yet thought about (P.G. Wells, International Ocean Institute, Dalhousie University, Halifax, NS, pers. comm.).

3.4.2 Information sufficiency and requirement for management decisions

TISEC is an emerging technology. Nova Scotia, as in many other locations in the world, has not yet had experience with these devices operating under natural conditions. There is no real information or data available on impacts of TISEC operating within the Bay of Fundy. Current understanding of impacts or interactions is based on assumptions, projections or predictions, the extrapolation of data from other industrial experiences, and educated guesses. The lack of factual site-specific data does not provide a defensible, sufficient or reasonable foundation, scientifically or otherwise, to base a decision to approve the advancement of an industry to a commercial scale. On a global scale, the lack of impact data is recognized as a significant barrier to the development of TISEC as a renewable energy technology (SEI 2006).

Information required for decisions relative to TISEC development can must be derived from three sources. These include: factual monitoring data from the demonstration of TISEC devices operating under natural Bay of Fundy conditions; synthesis and integration of existing ecological and socio-economic information and knowledge of current conditions in the Bay of Fundy area; and the identification of one or more reference sites for use as a baseline measure against which to monitor change(s) attributed to development. Factual information is needed to understand and assess true impacts, verify predictions, and ensure that TISEC devices can be operated responsibly over the long term without significant undesirable environmental and socio-economic consequences.

Five kinds of information are needed to assess TISEC implications as the basis for decision making. These include: accurate measurement of the tidal power resource; knowledge of the biological, physical and socio-economic environment of the Bay of Fundy; knowledge of site characteristics; an understanding of project-environment interactions; and an understanding of the implications of TISEC operation under natural Bay of Fundy conditions over the lifetime of the project. Resource assessments must be based on accurate measurements and monitoring of average depth current velocities and extractable energy levels in the Bay of Fundy to identify and select appropriate sites for energy extraction.

Knowledge of current condition/status of environmental components is essential for establishing a baseline condition of ecosystem health against which to measure change from alterations or disturbances of biota, habitats and physical processes (Dorward-King *et al.* 2001) and in understanding project-environment interactions. Although much is already known on environmental aspects of the Bay of Fundy, much research is needed to fill knowledge gaps and update resource information.

A syntheses of existing baseline information or collection of new data is also needed to respond to specific TISEC development issues. Knowledge of site characteristics is crucial in choosing an appropriate site for TISEC development. EPRI

(2006a) identified several site features important to site selection including: characteristics of the tidal resource (e.g. extractable power, depth average current velocities); proximity to a harbour and infrastructure; visual effects from the shoreline; seabed; bathymetry; ice features; capacity for grid connection; and development impacts on current use, fishing, shipping, navigation, recreational activities, protected areas, and biota. Site features have an influence on project development and operational costs, site development sensitivity, and the effects of the environment on the project.

An appreciation of project interactions is gained from an understanding of both site components and the effect that TISEC devices may have on valued components/features. From an environmental point of view, site assessment of the impacts of TISEC operation is the most important information requirement in terms of making decisions on whether a TISEC project should advance to the next development phase. Knowledge of potential interactions is essential in selecting appropriate indicators to monitor change and assess impact significance.

An understanding of the implications of TISEC operation under natural Bay of Fundy conditions through effects monitoring is required throughout all phases of development. During prototype demonstrations, monitoring is essential in assessing short term design reliability, performance, cost projections, design parameters, and to validate predictions. In moving toward full scale commercial deployment, monitoring is extended over time to assess long term/cumulative environmental impacts, economies of scale, project scalability, efficiency of multiple device extraction, and the effect of the environment on TISEC devices (SEI 2006). A crucial element of monitoring is the appropriate selection of indicators.

3.5 Prioritization of potential project interactions with environmental and socio-economic components

Table 1 matrix (Back pocket) illustrates interactions that may occur between development phases of a TISEC project and environmental components (i.e. socio-economic, biological and physical). Information for this study was derived from Bay of Fundy literature namely OEER (2007), EPRI (2006a), EPRI (2006b), Jacques Whitford (2008), and Joseph and Gunton (2008). The Jacques Whitford (2008) report has acknowledged in its references a wide range of Bay of Fundy literature. Potential project-environment interactions in the matrix are marked with an "x". The matrix is useful as a tool in identifying information gaps, research needs, and project implications overall. Its limitation is that it cannot be used to evaluate multiple interactions that can affect a given environmental component nor can it be used to evaluate the relative significance of impacts (DTI 2002; Breitburg and Riedel 2005).

Based on an approach from DTI (2002) and EMEC (2005), Table 1 interactions were reanalyzed to allow an assessment of their relative significance for the Bay of Fundy. Each interaction was rated in terms of its interaction frequency and magnitude (severity) and the results are presented in the Table 2 significance matrix (Back pocket). The interactions matrix key (adapted from DTI 2002) for Table 2 is described in Table 3 (Back pocket).

An analysis of results from the significance matrix (Table 2) indicates that there several key project-environment interactions and impacts throughout the project lifecycle. During the construction phase, a key impact/interaction is the disturbance of marine fauna (i.e. pelagic, demersal, benthos, invertebrates, pinnipeds, and cetaceans) especially benthos, demersal and invertebrate species, from seabed preparation, piling and foundation installation, and dredge spoil disposal. During the installation phase, the primary interaction/impact involves potential changes in water quality from seabed disturbance, increases in suspended solids, disposal of dredge spoils, and minor leakages of oils from installation equipment and boats/ships. The extraction of tidal energy during the turbine operational phase potentially causes six impacts: 1) change in tidal currents and sediment dynamics with consequent secondary impacts on biota (pelagic, demersal, benthos, pinnipeds, cetaceans, seabirds, and invertebrates); 2) ongoing physical risk posed by turbine rotation to biota particularly demersal and pelagic species, cetaceans, seabirds (diving) and pinnipeds; 3) disruption in navigational capacities of migrating fish and marine mammals due to noise (e.g. electromagnetic resonance) emitted from turbine devices; 4) impacts of turbine rotation on vertical mixing in the water column with associated potential for turbine damage from winter-spring ice or sediment scouring and bioaccumulation on turbine surfaces; 5) potential for a positive sanctuary effect created by the presence of the turbine structure on invertebrates, benthos and demersal species; and 6) positive impacts on atmospheric quality (reduction in greenhouse gas emissions). Key interactions during installation, operation and maintenance involve: potential impacts on shipping, fishing, navigation, coastal recreational activities, and other uses in the project area (i.e. the creation of an exclusion zone); potential stimulation of community economic growth through the creation of local employment, training and research opportunities; potential growth in the tourism industry from the presence of a tidal energy project; and potential reduction in the cost of electricity to local communities.

As indicated by the significance matrix (Table 2), a priority project-natural environment interaction for the Bay of Fundy is the effect of tidal energy extraction on tidal currents, sediment dynamics and the subsequent impacts on the biological environment. A key socio-economic interaction is the long term potential effect of TISEC operation on fish and invertebrate species and ultimately fishing industries that depend on them. These findings are consistent with the literature which identifies the study of implications of energy extraction as a major unknown and primary area for research (Jacques Whitford 2008, DTI 2002, EPRI 2006$_b$). Findings are also consistent results of the OEER workshop (OEER 2007) which identified key issues, from a community perspective, as being the potential impacts of TISEC development on the lobster industry and, from a scientific perspective, as being the impacts of energy extraction on ecology. Subsequent sections will focus on the development of indicators for specific aspects of these two key interactions.

4.0 The role of monitoring programs

A marine environmental monitoring system is defined by NRC (1990) as a "component of an environmental management system" comprised of a range of activities to document information on existing conditions (NRC 1990). The ultimate goal of monitoring is to protect the natural environment, human health and living resources (NRC 1990). Monitoring provides information useful in managing these elements or the human activities that impact them. Monitoring documents existing conditions and if conducted repeatedly, records trends and change in original conditions. In the absence of original condition data, it establishes a baseline for future measurement and comparison (NRC 1990). Monitoring can be used to: 1) determine compliance, to ensure that activities are carried out in accordance with regulations and permit requirements; 2) verify models, i.e. to check the validity of assumptions and predictions used as the basis for sampling design or permitting and for evaluation of management alternatives; 3) assess trends, i.e. identify and quantify longer-term environmental changes anticipated (hypothesized) as possible consequences of human activities; 4) obtain a better understanding or appreciation of environmental health/conditions in response to resource use questions; and 5) enhance knowledge of ecosystem variability and impacts of society (NRC 1990). A program designed specifically to monitor changes from TISEC development should ultimately provide information in all areas. This study focuses on the third, fourth and fifth element within the context of the development of indicators to establish baseline conditions and monitor and reflect change/trends resulting from TISEC operation.

4.1 Indicator development

4.1.1 Definition and development sequence

An indicator is defined as a qualitative or quantitative parameter or value that provides information on the condition, change in quality or change in state of something that is valued (e.g. whether a natural or cultural feature, or economic component) (OECD 1993). Indicators perform two key functions (OECD 1993): they decrease the number of measurements and parameters required to describe a situation (i.e. the number of indicators in a suite and their detail are limited); and they are selected to meet user needs (i.e. indicators simplify results communicated to users). Specific indicators are chosen to provide information on how a system functions to support appropriate decision making and management action. An indicator simplifies complex phenomena helping managers to understand how and why change is taking place. Used in combination or alone in a monitoring program, indicators are selected to determine whether conditions are improving or are deteriorating (Wells 2005; Shear *et al.* 2005). Indicators have been used in "measurement of environmental performance, integration of environmental concerns in sector policies, integration of environmental and economic decision-making more generally, and reporting on state of the environment" (OECD 1993).

The selection of appropriate indicators is crucial to the design of a monitoring program that can appropriately measure current socio-economic and ecosystem components (health and integrity) and change in quality/quantity over time and space. From an ecological standpoint, health and integrity refer to the current state, status or condition over a short timeframe while quality and change describes long term trends/diversion away from a baseline original condition (undisturbed by man) (Wells 2005) or reference state. Shear *et al.* (2005) indicates that the use of indicators requires two kinds of information - the observed state or status of the ecosystem and a reference value end point that reflects a desired state or condition. Change in condition is determined through monitoring over the long term and comparing results to the original condition, set at an arbitrary time (Wells 2005). Repeated measurements using the same suite of indicators establishes a record of change over time, assesses trends in conditions, and identifies site specific problems, thereby establishing the connection between key indicator monitoring and management action (Wells 2005).

The general indicator selection process involves the following steps: 1) identifying criteria for indicator selection; 2) selecting a framework for indicator classification and development; 3) scoping and selecting key the issues of concern; 4) assessing current status of the knowledge base; 5) preparing management questions; 6) developing indicators in response to management issues; and 7) incorporating indicators into a monitoring program (Mills 2006; Wells 2005; Shear *et al.* 2005). The first two components (criteria and framework) are described in the following paragraphs as they both apply to the development of environmental and socio-economic indicators in sections 5 and 6 that follow. Steps 3–6 inclusive, are discussed separately under each indicator development section. The last component, the incorporation of indicators into a management program, is included in the discussion section.

4.1.2 Indicator criteria

According to Mills (2006), environmental indicator development is guided by three primary considerations which may equally apply to socio-economic indicator development**:** 1) indicator relevance to management questions; 2) indicator relevance to the target audience (in this case the lobster fishery) or government agency using the indicator results for impact assessment decision purposes and regulatory purposes; and 3) scientific rationale behind indicator selection to support its use. The selection of indicators should include some that relate to ecosystem structure and function and some which are best used in combination (Wells, 2005). Each indicator must have an endpoint that can be "measured against values established as objectives, criteria, guidelines or standards" (Wells, 2005). Data to support indicator use should be updatable and readily available or available at a reasonable cost to benefit ratio (OECD 1993). Information generated through monitoring programs must be provided in formats useful to stakeholders and regulators (Giesy and Newsted 2007; Shear *et al.* 2005)).

For purposes of this study, indicator selection is based on the following criteria as adapted from the SMART indicator criteria framework developed by Taylor *et al.* (2000). Each of these criteria is considered in selecting indicators for monitoring impacts of TISEC energy extraction and operation. Indicators must be:

- Simple: easy to interpret, easily monitored, accepted by industry and professionals, and easily adapted for community use (Taylor *et al.* 2000), and sufficiently able to provide a representative description of conditions and identify trends through time (OECD 1993);
- Measurable: founded in scientific and technical terms (OECD 1993); verifiable,

reproducible, comparable, able to be combined to form indices, and capable of showing trends over time (Taylor *et al.* 2000); responsive to changes in environmental conditions, human activities (OECD 1993), and issues over time and of incorporating new indicator information (Shear *et. al.* 2005));

- Accessible: in regular use, cost effective, and consistent with other monitoring data/programs (Taylor *et al.* 2000); feasible (practical and implementable) (Shear *et al.* 2005);
- Relevant: related to a valued ecosystem or natural resource component, and linked to regional resource management goals and policies (Taylor *et al.* 2000); and
- Timely: current (EPA 2001); provide an early warning of potential issues and future needs (Taylor *et al.* 2000).

4.1.3 Pressure-state-impact-response model (PSIR)

Frameworks are generally used to organize and conceptualize large quantities of information used in indicator development to improve their accessibility and enhance the use of their information (EPA 1994). Several frameworks are available that can be used to describe and analyze resource uses and problems in the natural environment and document change or cause-effect. The framework chosen for this study is the pressure-state-impact -response framework used by the OECD (1993). Essentially, under the framework, human activities exert "pressures"/stresses on the environment (or socio-economic situation) which change its condition or "state". (Stressors can be physical, chemical, or biological and cause degradation in natural resources). Changes in state lead to " impacts" on organisms or change in human welfare. Impacts cause the organism, population, or human society to "respond" to change. Usually in human societies responses involve societal actions to ease effects. Response in turn feedback to mitigate or reduce pressures or repair the resource (OECD 1993). This model is be used to identify potential TISEC impact scenarios on the lobster population and fishery in the upper Bay to help identify indicator categories/indices and prepare management questions for indicator development.

4.1.4 Selection of key project-environment interactions for indicator development

The time allocated for this study is insufficient to allow development of indicators for all project-environment interactions. It was therefore decided to focus on indicators that specifically monitor the impacts of TISEC energy extraction on the lobster population (environmental implications) and fishery (socio-economic implications) of the upper Bay, the Minas Basin in particular. The reasons for choosing these interactions are numerous. The lobster industry is a primary fishery in the Minas Basin/Minas Passage area (as described in Section 6). The impacts of TISEC energy extraction are unknown and are a key area for research in the Bay of Fundy as identified by the previous interactions matrix. Lobster can and have been used previously as an indicator species to monitor change in benthic conditions/habitat **(**P.G. Wells, International Oceans Institute, Dalhousie University, Halifax, NS, pers. comm.). Energy extraction occurs over the operational lifetime of the project and therefore requires indicators of cumulative impact or change to a population of economic importance. Finally, an assessment of implications of TISEC operation on the lobster population and industry links both environmental and economic components.

4.1.5 Management objective

In the past, one general objective of a resource based industry was to ensure the sustainability of the natural resource base upon which it depends for continued economic use. In recent years the sustainability concept has evolved from a focus on a single resource or species to include both human use and ecosystem factors, balancing resource conservation and human concerns, i.e. the modern viewpoint of sustainable use involves the consideration of social, ecological and economic components together. As an example, based on this new concept of sustainability, the human use objectives based management system, developed for the Eastern Scotian Shelf Integrated Management (ESSIM) initiative (Walmsley 2005), addresses both the need for a healthy functioning ecosystem and needs associated with the human use of the resource, i.e. social, cultural, and economic well-being. It is suggested that for consistency with both the ESSIM and regional Gulf of Maine Council approaches, the overarching management objective for this study within the context of the lobster fishery and TISEC development industries would be "To contribute to social, cultural, economic well-being by achieving" ecological sustainability and "integrated use of the ocean space and resources" (Walmsley 2005) in the Bay of Fundy.

The framework for the Atlantic lobster has based its vision on the sustainability concept involving the maintenance of both the lobster resource and its fishery. The lobster resource and fishery must both be sustainable, achieving a balance in ecosystem conservation and long term benefits for all who participate; resilient to economic, social and natural changes; and creating equitable benefits (social, cultural and economic) for all participants; and governed by participatory, effective inclusive, adaptive and accountable decision-making (FRCC 2007). Within this context, the sub-objective for environmental components for this study would be to ensure the sustainability of the lobster population ecologically. The sub-objective for economic and social well-being would be the same.

5.0 Environmental indicator development

5.1 Assessing the current status of the knowledge base

The current knowledge base for the lobster population is comprised of our understanding of lobster lifecycle stages and knowledge of population numbers, ecology, behaviours, predator and prey relationships, migratory patterns, growth, habitat requirements, environmental parameter needs, and their distribution in the upper Bay of Fundy.

5.1.1 The lobster population in the upper Bay of Fundy

Among marine crustaceans, lobsters are considered among the largest and longest lived. The species found off eastern Canada, *Homarus americanus*, is unique to the northwest Atlantic. As voracious scavengers and predators, lobsters feed on available benthic organisms including crabs, scallops, sea urchins, other lobsters, and both living and dead fish. Much of the fishery is conducted in shallow water (3–20 m) using small to medium size fishing boats (10–20 m) (Jacques Whitford 2008). As described by FRCC (2007), among others, the lifecycle of the lobster has 6 primary stages: reproduction, larvae, settlement, cryptic, emergent, and adults.

Female lobsters brood their eggs externally. The timing of ovarian maturation, egg extrusion, egg development and larval hatch are all controlled by water temperature. The first hatch of eggs requires surface temperatures of between 11 and 13°C. Ovarian maturation and egg extrusion requires an extended period below 5°C and an increase to 10°C (Harding 1992). The length of time at temperatures above 5°C controls egg development and egg hatch timing. Harding (1992) stated that berried females seek areas high in turbulence or energy to release their young. Larvae are planktonic and drift primarily in surface waters and moult three times (Stages I to IV) over 2 weeks at about 20°C and a two month period at 10°C or below (Harding 1992; P.G. Wells, International Ocean Institute, Dalhousie University, Halifax, NS, pers. comm.). Larval lobsters feed on plankton but mainly on crab larvae, copepods and cladocerans (Harding 1992). After three successive molting stages, the post-larval lobsters (Stage IV) or juveniles resemble small adults, are approximately 1 cm in length, and have developed swimmerets which enable them to better control their movements in the water column (FRCC 2007). They are unidirectional swimmers at stage 4. Halfway through the stage, they become negatively phototaxic and migrate from surface waters to settle preferentially on cobble/gravel bottoms to begin life as members of the benthic community. Young lobsters become cryptic, i.e. hide from predators in self dug solitary tunnels or crevices under cobble. Post-larval lobsters continue to feed on plankton near bottom creating currents in their tunnels using their swimmerets, supplemented by meiobenthos and other near-by lobsters. Juveniles continue to molt and grow until such time as they reach 40 – 50 mm in carapace length (FRCC 2007). Lobsters then emerge from the nursery area, seek new shelter and begin to forage over a wider region (FRCC 2007) Diet reflects seasonal and local availability of food (FRCC 2007). Lobster primarily prey on crabs, mussels, polychaetes, periwinkles, starfish, sea urchins, brittle stars, seaweeds and dead substances (Harding 1992). Lobsters are preyed upon by bottom-feeding fish including wolfish and cod. Mortality in lobster is highest when they undergo changes between lifecycle phases, i.e. during the larval stage, from predation and currents carrying them into unfavourable areas, during movement and settlement on the bottom, when they leave shelter areas (FRCC 2007), and during molts. Normally lobsters take from 5 to 9 years to reach full harvestable size (Harding 1992). Female lobsters are estimated to mature as early as 4 years of age at >63 mm carapace length (Harding 1992).

Lobsters in adult life continue to molt ~ 15-20 times to reach minimum legal catch size over a 6–9 year period (FRCC 2007). Mating occurs immediately after a mature female molts and eggs develop over a 9–12 month period on the underside of the female known as a berried female (FRCC 2007). Larval release occurs a year after mating (FRCC 2007). As females increase in size, egg production increases exponentially, but mating and molting occur only every 3–5 years, producing 2–3 clutches between molts (FRCC 2007). Adults prefer rocky, cobble or gravel substrates as these offer protection from predation but they can also can live on muddy and sandy bottoms (FRCC 2007) and they often do, especially in the offshore (P.G. Wells, International Ocean Institute, Dalhousie University, Halifax, NS, pers. comm.). In some locations, in response to change in water temperature, lobsters migrate seasonally to shallow waters in spring to moult, reproduce or release eggs, returning in fall to deeper waters (FRCC 2007). Exchange between adjacent populations may occur along the coast (FRCC 2007).

Key factors identified by FRCC (2007) that influence lobster growth and distribution are quality of habitat, predator abundance, availability of prey throughout lifecycle stages, and water temperature (influences physiological rates, development and catchability, migration and distribution, and moulting). Adult and juvenile lobsters tolerate temperatures ranging from -1 to 30.5°C (Harding 1992). Adults can withstand sudden temperature increases of 16°C and decreases of 20°C (Harding 1992). Temperatures less than 8° to 10°C are needed during the winter season to synchronize moulting and reproductive cycles (Harding 1992). Larvae are found in surface waters of between 6 and 25°C with a minimum temperature of 12°C for development to settlement.

Adult and juveniles can withstand salinities ranging from 15 to 32 ppt (Harding 1992). Larvae are sensitive to salinities less than 20 ppt and change depth to avoid these waters (Harding 1992). Prior to and during molting, the osmotic permeabilities of lobster exoskeletons makes lobsters less resistant to low salinities (Harding 1992).

The lobster industry in the Bay of Fundy is both economically and socially important to Nova Scotia and communities of the upper Bay of Fundy. The lobster is commercially fished in all areas of the Bay of Fundy with the exception of the inner Cumberland Basin and Cobequid Bay which have extreme levels of turbidity (DFO 2008), extreme siltation, low salinity, and muddy substrates (Daborn 1977). In past years, fishermen in NS have not found it economical to set their traps beyond the Economy Point entrance to Cobequid Bay as few lobsters have been caught in this area (Campbell 1984). Ice scouring in winter cause severe lobster mortalities in these areas (Gordon and Desplanque 1983), which may in part explain why few lobster are caught.

Berried females, larvae, and juveniles have been found in Minas Channel and the Minas Basin (A. Redden, Acadia Center for Estuarine Research, Acadia University, Wolfville, NS, pers. comm., D. Robichaud, Huntsman Biological Station, DFO, St. Andrews, NB, pers. comm.). The lobster population within the Minas Basin is derived from the local resident population and from larval drift from areas outside of the basin (i.e. from NB shores, e.g. Alma area, and from NS, Digby, e.g. Delaps Cove) (D. Robichaud, Huntsman Biological Station, DFO, St. Andrews, NB, pers. comm.) This is supported by Campbell (1984) in identifying the Chignecto Bay as a potentially important source of larval recruitment both for the Upper Bay and other downstream areas. It is believed that movement and migration are strongly influenced by water temperature (A. Redden, Acadia Center for Estuarine Research, Acadia University, Wolfville, NS, pers. comm.). A more detailed description of the lobster fishery follows in section 6.

5.1.2 Ecosystem overview of the Minas Basin, upper Bay of Fundy

The Nova Scotia portion of the Bay of Fundy has traditionally been divided into three regions: the Upper Bay, Inner Bay and Outer Bay as illustrated in Figure 1. Ecosystem components of each region are described below within the context of the primary needs of the lobster. The Minas Basin area overall is considered to be a macrotidal semi-enclosed estuary which receives freshwater drainage from 33 rivers (DFO 2007_a). Most of the area is characterized by shallow turbid waters, that rise and fall twice daily with the world's highest tides to expose extensive (~ 15,400 km^2) intertidal mud and sandflats and saltmarshes in the Cobequid Bay, Southern Bight and Central Minas Basin (BoFEP 2001).

Extreme high tides in the Minas Basin area create an inter-tidal environment that is physically stressing for organisms in terms of potential for dessication, temperature fluctuation, and predator exposure (Craig 1976). Summer surface water temperatures range from 12°C in the Channel, to 22°C in Minas Bight to 20°C in Cobequid Bay (DFO 2007_a). Fall surface temperatures range from 6°C to 12°C with warmer inshore temperatures (Simon and Campana 1987). Minas Basin waters are colder in winter and warmer in summer than Bay of Fundy waters due to the cooling/warming effect of large intertidal mudflat surfaces during winter and summer respectively (Craig 1976). Being sheltered, basin waters can warm in summer months to > 15°C in some areas (Bousfield 1975). Studies have shown that surface water salinities range from 31 ppt in Minas Channel to 24 ppt in Cobequid Bay (Huntsman and Rice 1946, Dalrymle 1977) to <25 ppt in Southern Bight (Daborn and Pannachetti 1979). Salinities average 30 ppt in the Central Minas Basin (Dalyrmple 1977; Daborn and Pannachetti 1979). In winter salinities are more uniform and slightly higher with less freshwater input (Greenberg 1984). The strength of tidal currents and shallow depth ensure that Minas Basin waters are well mixed. Freshwater runoff causes only a slightly lower salinity level than found in the open ocean (DFO 2007_a). Trophic relationships and community structures are largely dominated by physical processes mainly sediment dynamics driven by tidal forces. Species in all areas of the Upper Bay are less diverse than in Outer Bay, but abundant and adapted to strong tidal currents. In winter, the Upper Bay particularly the Central Minas Basin, is subjected to physical changes resulting from winter ice formation and spring turnover of surficial sediments (Jacques Whitford 2008). In summer, the ecology of the inter-tidal area is influenced by biological interactions involving the mud shrimp, *Corophium volutator,* migratory fish and birds (Hamilton *et al.* 2006; Jacques Whitford 2008).

Descriptions of key characteristics of each segment of the Minas Basin are as follows. Cobequid Bay, which is 8 km in width and 30 km long (Dalrymple 1977), is characterized by low primary productivity due predominantly to high levels of suspended sediment likely derived from the resuspension of sediments from mudflats (DFO 2007_a) from wave and current action. During low tide, two thirds of the area is exposed to reveal salt marshes and sand bars (Dalrymple *et al.* 1975; Amos and Joice 1977). As indicated previously, lobster are not typically found in significant numbers to support a fishery in this area.

The Central Minas Basin is characterized by extremely turbid waters, tidal ranges of up to 16.3 meters (extreme tide), shallow average depths of 15–20 meters and high benthic productivity strongly influenced by the substrate (DFO 2007_a). Wave erosion of Triassic sandstone cliffs along the Central Minas Basin shoreline has resulted in the Minas Basin having a predominantly sandy substrate with accumulated clays and silt in sheltered bays, such as the Southern Bight (Daborn 1996). The Southern Bight contains extensive mudflats inhabited by large numbers of benthic amphipods, *Corophium volutator,* an important food source for migrating shorebirds, particularly semipalmated sandpipers. The shorebirds use the mudflats and those in Cobequid Bay as a primary foraging area en route north in spring to Arctic breeding areas and on return south in mid to late summer. Much of the commercial harvesting of bloodworms and groundfish occurs in this area. Subtidal areas beyond the mudflats have a variety of substrates consisting of sand, mud, gravel and bedrock (DFO 2008) which may serve as primary habitat for lobster.

The Central Minas Basin and Minas Channel serve as transitional areas to Bay of Fundy open waters. Twice daily, ~ 15 km^3 of water pass through the Channel in and out of the Minas Basin (Godin 1968). The Minas Passage, which is 4 km wide and 11 km long (DFO 2007_a), is characterized by low turbidity, allowing light penetration for primary production. Turbulent high velocity currents (5 m/s) cause heavy rip tides along the Cape Split shore (DFO 2008) and have scoured sediments to depths of 120 meters to a coarse bedrock (Dalrymple 1977). While lined with bedrock, the bottoms of southern and northern areas of the Passage, however, are covered with gravel and cobbles, again likely habitat for lobsters. A diversity of diadromous fish species migrate through the Minas Channel and Minas Passage into the Upper Bay to feed and reproduce in summer, including Atlantic salmon, eels, shad, gaspereau, dogfish, herring, striped bass, and Atlantic sturgeon (DFO 2007_a).

Within any one area, conditions are harsh and change quickly. Certain sections of the Upper Bay may be more favourable than others as lobster habitat. Data show that lobster requirements for substrate, temperature and salinity change with lifecycle stage. Various portions of the Upper Bay meet favorable substrate requirements. Physical parameters generally fall within the ranges of tolerance for temperature and salinity, i.e. the fact that lobsters are found in the Upper Bay means that they have found suitable niches to meet their needs.

Recent research has indicated that primary factors that affect benthic communities are temperature, salinity, turbulence, turbidity (influencing light availability) current speed, and availability of nutrients (Daborn 1984; Wildish 1984). Scientists generally agree however that substrate is the primary determining factor for benthic viability (Nicol 1960; Rhoads and Young 1970; Daborn 1984; Wildish 1984).

5.1.3 Physical processes in the Bay of Fundy

Ecological and biological characteristics of the Bay of Fundy are dominated and defined by physical processes, predominantly tidal current movement, sediment dynamics and ice formation. Tidal currents control exchange of materials (including oxygen, nutrients, contaminants) in saltmarshes and estuaries; vertical mixing processes and turbidity, and export of macroalgal and estuarine production that influence energy exchange and biological productivity of pelagic and benthic systems; sediment properties which impact benthic subtidal and intertidal communities; and water circulation patterns and thus migratory routes and distribution of fish (Brylinsky *et al.* 1997). Sediment dynamics, influence the benthic and epibenthic community (e.g. habitat, species composition, abundance, distribution, presence, productivity) (Brylinsky *et al.* 1997). Ice formation is the primary factor controlling the movement and deposition of sediment in the development of intertidal mudflats in the Cobequid Bay and Southern Bight of the Minas Basin (Brylinsky *et al.* 1997). The extent of ice cover in winter in the Minas Basin is such that ice completely reworks the surficial sediments so that each spring a new ecological succession process occurs in intertidal areas (DFO 2007_a). Any significant changes in critical physical processes, particularly tidal energy and current movement, therefore have the potential to alter the ecosystem and economic activities dependent on biological resources.

TISEC energy extraction, particularly at a commercial scale of operation, has the potential to change tidal current velocities and movement patterns and therefore affect sediment transport, distribution, deposition and resuspension rates, and sediment characteristics (e.g. surface weathering, grain size, contaminant and organic content, and cohesiveness) (Jacques Whitford 2008). Reduced downstream current velocity may, for example, modify seabed conditions required for marine larval settlement, decrease upwelling or increase stratification, reduce supplies of food available to benthic filter feeders, affect primary production by influencing turbidity, light and nutrient levels, and indirectly affect other species (e.g. fish and birds) dependent on the benthic community (e.g. fish and birds) (Jacques Whitford 2008). The potential implications of TISEC energy extraction on physical processes are therefore a key environmental concern in TISEC development.

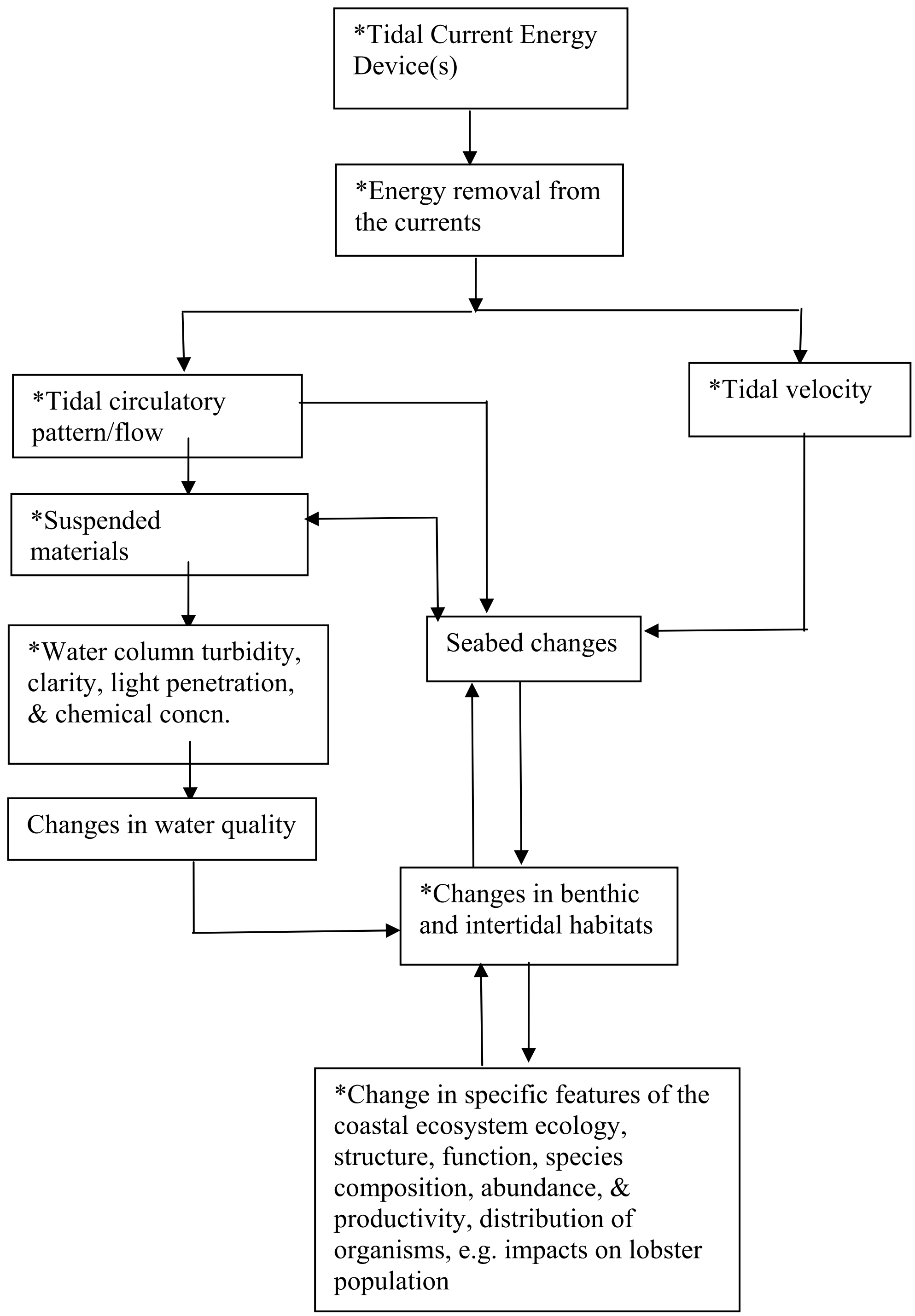
5.2 Anticipated project interactions with lobster populations

The extent to which TISEC devices and their operation enhance or decrease lobster productivity and lobster fishing in the Minas Channel, Minas Passage, and Minas Basin area, is a key socio-economic and environmental concern. TISEC device demonstration and operation on a commercial scale will likely take place in the Minas Passage area which is currently used by the lobster fishery. Appendix F, containing a project-lobster interactions matrix, illustrates that there are many possible interactions between TISEC devices and lobster populations over the lifecycle of the project. Matrix information was derived from proposed interactions identified in the literature, personal communications with lobster scientists, and original analysis of the entire project.

Focusing on the operational/energy extraction phase of the project, proposed key interactions (shaded) include: potential effects of energy extraction, sediment redistribution, and changes in currents, water circulation and flow on habitat substrate, population health/disease, growth, abundance, distribution, migration, and predator/prey populations; potential effects of noise, vibration, EMR emissions, and water quality on health, growth, abundance, disease, distribution, migration; and potential effects of turbine operation on predator/prey populations, and subsequent survival, health, growth, abundance, migration, and distribution of lobsters. Figure 2 presents a simplified conceptual representation of interactions and impacts of TISEC kinetic energy removal on the lobster population.

Generally, TISEC impacts on lobster may be direct or indirect. Direct impacts include behavioural change in the individual lobsters and change to population numbers from the creation of fishing exclusion zones in the project area (Jacques Whitford 2008). Indirect TISEC impacts may include impacts on lobster prey and predators, and habitat change(s) through alterations in sediment depositional patterns, substrate characteristics or shelter through kelp harvesting (Jacques Whitford 2008).

Figure 2. Conceptual diagram of potential impacts of tidal kinetic energy removal on the Bay of Fundy (Adapted from DTI 2002) (*indicates additions made by the author to the DTI flow diagram)



The following presents an overview of current thought on the potential effects of TISEC energy extraction within the Minas Passage and Minas Basin on the lobster population. Impacts are anticipated to vary by site/area depending on lobster population size, distribution, and lifecycle stage, site characteristics, and distance from TISEC devices. Some impacts are projected from similar activities and scientific research on lobster while others are unknown and/or are predicted. The potential implications for TISEC development in the Minas Passage are as follows.

Lobster larvae are particularly sensitive to pollution (Harding 1992; Jacques Whitford 2008; Wells 1976). As the Minas Passage as the preferred site for TISEC demonstration and operation in NS, lobster migration routes bring lobster in close proximity of TISEC devices and associated potential near field effects, i.e. lobsters may be subjected to vibration, noise, EMR emissions, oil discharges, water movement, and changed circulation patterns.

Crustacea such as snow crabs have been found to respond negatively to seismic noise during oil and gas exploration and therefore research is needed to determine if the sound from TISEC devices generate a similar response in lobsters (P.G. Wells, International Ocean Institute, Dalhousie University, Halifax, NS, pers. comm.). Also, electrical fields generated by transmission cables are expected to influence lobster behaviour (Jacques Whitford 2008). Further research is required to assess the effect of electromagnetic resonance emissions on lobster health and productivity, avoidance response and migration patterns.

Although lobster larvae (stages 1–3) and postlarvae (stage 4) may be too small to be affected by the turbine rotation if they pass through a turbine device, they could be affected by pressure gradients (G. Harding, Bedford Institute of Oceanography, Dartmouth, NS, pers. comm.). Research may be needed to determine larval population numbers in the Minas Channel, Minas Passage and how they are affected by pressure gradients and distributed by tidal currents.

Any disturbances of bottom sediments during installation or operation of TISEC devices may have significant effects on bottom topography and resuspension of bottom sediments (G. Harding, Bedford Institute of Oceanography, Dartmouth, NS, pers. comm.). High energy in the Minas Passage tidal currents prevents sediments from settling. Beneath the upper compacted surficial seabed crust of the Minas Passage, the substrate is very soft. Past disturbances of this crust by activities such as clam dredging have resulted in the creation of large winnowed areas (G. Harding, Bedford Institute of Oceanography, Dartmouth, NS, pers. comm.).

Large substrate areas in the Minas Passage covered by gravel, cobbles, and boulders provide a preferred habitat for lobster. Displacement of lobsters from these substrates by TISEC installation may be of concern if the area of habitat loss is significant (Jacques Whitford 2008). Habitat loss may, however, be offset by the creation of a fishing exclusion zone, creating a fish sanctuary effect in the project area over the construction period or the lifetime of the project (Jacques Whitford 2008).

It is not known how changes in substrate composition from a cobble to sandy or silt bottoms will affect lobster movement to or from the Minas Passage /Minas Basin area. Depending on the degree and extent of substrate change from preferred compositions, lobsters may migrate seaward to unchanged cobble areas in the Minas Passage or move outside the area entirely. Jacques Whitford (2008) indicates that changes in habitat substrate to silt or clay, or the protection offered by TISEC devices from sediment scour, may benefit the lobster population in creating a variety of habitat. Local substrate changes in the Minas Passage both downstream and upstream of TISEC devices are anticipated to influence both lobster distribution and productivity (Jacques Whitford 2008).

Within the Minas Basin, should change occur in tidal kinetic energy to alter current movement patterns and sediment distribution, habitats in the Minas Basin may be altered. If water currents and circulation in the Minas Basin are sufficiently reduced, it is possible, that upper water layers will stratify and become warmer and in doing so, create a move favourable habitat for the survival of lobster larvae (Harding, G., pers. comm.). As portions of the Minas Basin water column are already stratified, it may not take much of an energy reduction to increase the degree of stratification (Harding, G., pers. comm.). The question is, how much of an energy reduction would it take to cause these changes?

A decrease in turbidity resulting from tidal energy extraction could result in an increase in light penetration in upper waters favouring phytoplankton over benthic diatom production. This in turn could increase overall biological productivity in the water column including productivity within the benthic community (Harding, G. pers. comm.). It is also not known how increased light and increasing exposure to ultraviolet rays might affect larval health, numbers, and recruitment.

Research is required to model the consequences of commercial scale TISEC changes in water flow and substrates on crucial benthic and epibenthic communities that sustain populations of migratory fish and birds (Jacques Whitford 2008). During winter months in the Minas Basin, seasonal changes in tidal range and current velocities reduce tidal mixing (Jacques Whitford 2008). It is anticipated that any further reduction in mixing potentially by TISEC operation may extend ice formation and its persistence (Jacques Whitford 2008). It may also and possibly delay lobster migration into the basin and therefore the reproductive season.

Overall there is an extensive body of knowledge on lobster populations, biology, and ecology in the Bay of Fundy based on decades of scientific research and investigation. However, as indicated above, what is currently known about the impacts of TISEC device operation on the upper Bay is limited due to a general lack of effects monitoring data from operation under natural conditions. The current level of knowledge of the implications of energy extraction on natural systems and lobster populations is insufficient for management decisions. In the absence of site related data, it is important to use what is currently known about lobster populations, natural processes, and results of past marine development experience to anticipate or propose possible TISEC project-environmental interactions and questions for research and investigation.

5.3 Potential environmental impact scenarios (PSIR Model)

Adapting the Pressure-state-impact-response framework from OECD (1993), Table 4 illustrates examples of possible scenarios of change within the lobster population that may result from project-lobster population interactions. Results indicate that the potential effects of tidal energy reduction namely, a reduction in tidal flow, increased sediment deposition and redistribution are the same both in the short and long term. Over the short term sediment and seabed changes potentially result in altered substrate, habitat disruption, smothering effects, lobster movement from the area, decreases in lobster productivity, and increases in population distribution. Long term operation of multiple TISEC units could change the character of the coastal environment resulting in shifts in species composition.

Over the short term, TISEC operation may increase deposition of suspended sediments, reduce water column turbidity, increase light penetration, and increases in pollution levels in the water column from sediment disturbance. This may lead to either a decrease or a increase in the lobster population and productivity levels depending on how these and other factors affect lobsters. Over the long term, increased water column contamination from sediment redistribution, could led to chronic disease and reductions in ecological productivity. The short and long term effects of increased noise from TISEC operation on the lobster population health and productivity is unknown and is a primary area for research. Similarly, how lobster predators and prey will be affected by TISEC operation is currently unknown. Generally, a decrease in lobster predator species resulting from interactions with the TISEC device or habitat change could result in a lobster population increase over time. Likewise, a decrease in lobster prey, would likely cause a decrease in the lobster population or lobster migration/movement from the area. These scenarios although limited in terms of their ability to capture all possible outcomes, were used to identify indicator indices /categories for indicator development.

Table 4. Potential environmental impact scenarios resulting from TISEC energy extraction using a PSIR Model (PSIR model from OECD 1993)

PSIR	Pres-sure	Env. state changes	Impact on Lobster populations		Response of Lobster populations		Indicator category
			Short-term (0-5yr.)	Long-term (>5 yr.)	Short-term (0-5 yr.)	Long-term (> 5yr.)	
Environmental component pot. impacted by TISEC energy extraction	**Tidal currents**	↓ tidal flow and circulation; ↓turbidity; Pot. ↑ light penetration	Local sediment & tidal implications; Change in benthic env.; Habitat disruption; Smothering effect; Adaptive cap.	Change in coastal environment with ecological implications; Habitat shift; Migration	Altered substrate; ↑Migration; ↓ population nos. Pot. ↓ in productivity	Altered coastal env., & sediment/coastal dynamics; Ecol. effects; pop./species shifts; ↑ Migration & spatial distribution;↓ Presence, abundance; ↓ Pop. & prod.	Population abundance; Productivity; Environmental features; Resiliency
	Sediment dynamics	↑ Sediment deposition/ re-distribution ↓Turbidity; Pot. ↑ light penetration	Sediment/seabed change; Habitat disruption; Smothering effect; Adaptive cap.	Coastal env. change; Ecological implications; Habitat shift; Migration	Altered habitat substrate; ↑ Migration; ↓ Pop. size & production; ↑Migration & spatial distribution	Shift in pop. structure & species composition; Ecol. implications; ↓ Presence/ abundance; ↑Spatial redistribution	Population abundance; Productivity; Environmental features Resiliency
	Water quality	↓ Turbidity/ turbulence; ↑ deposition; Pot. ↑ light Penetration & visibility	Potential ↑ in pollution & sediment toxicity. Migration Pot. ↑ tissue contamination; Acute illness; Adaptive capacity;	Sediment toxicity; Water contamination & ecological implications; ↑Tissue bioaccumulation & toxicity; ↑ incidence of chronic disease; ↓health, growth, abundance & presence	↑ Water pollution levels ↑Migration; ↓ Species presence, abundance & productivity; ↑ Spatial distribution;	Water contamination ↑Visibility/ light levels in water column ↓ Species presence, abundance; ↑Spatial re-distribution; ↓Ecological productivity with pollution; Pot. ↑ productivity with ↑ light	Population abundance; Productivity; Environmental features; Resiliency

Table 4 (continued). Potential environmental impact scenarios resulting from TISEC energy extraction using a Pressure-State-Impact-Response Model (basic model from OECD 1993)

PSIR	Pressure	Env. state changes	Impact		Response		Indictor category
			Short-term (0-5 yr.)	Long-term (>5 yr.)	Short-term (0-5 yr.)	Long-term (> 5yr.)	
Environmental component pot. impacted by TISEC energy extraction	Ambient noise from rotor operation	↑ Ambient noise levels; ↑ Noise propagation	↑ Noise levels and EMR emissions Pot. ↑ migration; Adaptive capacity	Chronic effects of noise and EMR; Impact unknown: Potentially no effect/or habituation <u>or</u> Pot. ↓ health, productivity abundance & presence; Pot. ↑ mortality rate	Sound propagation Pot. avoidance response, mortality/re-distribution; Pot. ↑ in migration and spatial distribution	Marine ecological disturbance Unknown impact on health, productivity& population nos.	Population abundance; Environment-al features; Productivity; Reproductive capacity/ health; Resiliency
	Lobster predators and prey	Pot. ↓ in predators (turbine collision or habitat change) <u>or</u> Pot. ↑ in predator nos. from sanctuary effect	Pot. ↑ lobster population nos. from loss of predator species; <u>or</u> Pot. ↓ in lobster pop. from ↑ predator nos.	Unknown - ↑ or ↓ in lobster population nos. and production	↑ Lobster production, abundance and ↑ predation on prey species; <u>Or</u> Pot. ↓ predation on prey and pot. ↑ in prey nos.	Unknown - Lobster population ↑ or ↓	Population abundance; Productivity; Ecosystem interactions /effects

5.4 Environmental management questions and indicators of change in lobster populations

The management questions (Table 5) relate to the effects of energy extraction on lobster sustainability. Questions fall into two categories: those pertaining to short term impacts and those relating to long term/ cumulative effects. Management questions to assess short term impacts relate to local effects of a small number of devices operating in proximity to lobster populations (e.g. during short term device testing, demonstrations, or early pre-commercial stages of TISEC development).

Questions pertaining to short term changes in baseline conditions relate generally to lobster population itself, i.e. stock abundance, distribution, size structure, health status, migratory patterns, reproductive capacity, and recruitment. Questions also relate to current sediment distribution patterns, suspension load, seabed morphology, and characteristics of the water column (e.g. chemical composition, temperature and salinity). Questions relating to short term change from TISEC operation relate to the effects of energy extraction on tidal current flow, speed, direction, sediment dynamics, and water quality. Additional questions address issues such as the effects of TISEC operation on lobster larval distribution and settlement, habitat substrate, predators and prey species, and avoidance or attraction responses. Other questions relate to whether or not the presence of the TISEC device provides an artificial reef or sanctuary effect for lobster and the impact of sound on lobster migration, movement, and health. In general, the potential for longer term cumulative change within the natural system increases with the length of time that devices operate and the number of operating devices in a given spatial area.

Management questions for long term impacts relate to a) the cumulative effects from multiple devices operating in a turbine array in the Minas Passage on the sustainability of the lobster population; b) potential cumulative effects of lobster interactions with other activities/projects taking place or anticipated to take place in the same area; and c) cumulative effects on natural processes/ abiotic environment (e.g. tidal current level, water level, sedimentation, hydrodynamics) potentially leading to substrate

Table 5. Environmental management questions relating to the lobster population

Short term - Changes to baseline conditions 1. What is the current stock abundance and distribution of lobsters in each segment of the Minas Basin? 2. What is the size structure of the lobster population within the Minas Channel, Minas Passage and Minas Basin? 3. What is the status of health of the lobster population? 4. What are the migratory patterns of lobsters in the Minas Channel, Minas Passage and Minas Basin? 5. What is the current reproductive capacity of the lobster population? Where are breeding females located, spatially and temporally? 6. What is the level of recruitment for lobster populations in the Minas Basin area and their range of distribution? 7. What is the impact of energy extraction on habitat substrate in the Upper Bay of Fundy? 8. What are the current tidal current circulation and sediment suspension, distribution, settlement patterns, in the Upper Bay of Fundy (modeling)? How do these patterns affect lobster productivity? 9. What are the current sediment characteristics, suspension load, seabed morphology, and turbidity parameters in the Upper Bay of Fundy? 10. What is the current chemical composition of the water and temperature and salinity profile? How do these characteristics affect lobster distribution and health?
B. Short term - Changes from TISEC operation 1. How much energy is removed from the tide from the operation of a single device? What level can be extracted without causing change in lobster habitats leading to reductions in lobster abundance, and productivity? 2. To what extent does energy extraction effect local tidal current flow, speed, and direction (e.g. vortices, wake effects, turbulence, wave reflection or defraction)? 3. How does TISEC operation affect larval dispersion and settlement? 4. How does energy extraction effect local sedimentation processes (scour effect, erosion around the device)? Do these eroded areas provide appropriate habitat for lobster adults & do adults aggregate in these areas? 5. How does TISEC operation change local sediment dynamics (change in suspended sediments, seabed characteristics, movement, and sediment type)? 6. How does TISEC operation alter the quality of the water column? 7. How does short term TISEC operation affect lobster movement/migration (avoidance or attraction response?) 8. What is the survival rate of larvae and post-larvae (stage 4) moving through the TISEC device? 9. What is the collision risk for lobster predator and prey species? 10. What is the effect of sound generated by TISEC operation on lobster migration and health? 11. Does the presence of the device provide a sanctuary effect to offset any loss in lobster habitat from substrate changes due to tidal energy extraction? To what extent do TISEC devices contribute to lobster productivity in providing an artificial reef or refuge for fish and lobster populations?

Table 5 (continued). Environmental management questions relating to the lobster population

C. Long term TISEC operation - change to baseline conditions 1. How do baseline conditions (noted above) change over time? 2. What are the impacts of TISEC operation on the water column (e.g. stratification, upwelling, light penetration and ultraviolet exposure) on larval survival? 3. What are the impacts of TSEC operation on lobster predators and lobster prey (collision risk)? 4. What are the impacts of bycatch by the lobster industry of key prey species e.g. rock crab or predator species on the lobster population? 5. To what extent do new depositional patterns contribute to increased lobster production by creating new habitat for the lobster and benthic community? 6. How will TISEC operation affect lobster predator and prey abundance over time? 7. What constitutes an acceptable and unacceptable level of change to environmental and biological conditions/characteristics of the Bay of Fundy?
D. Cumulative impacts from TISEC operation and other stressors 1. How will the establishment of an exclusion zone in the project area, impact lobster population numbers over an extended period of time? 2. How do current flows and directional patterns, wave and sediment dynamics (suspension, movement and distribution, re-deposition) change with increasing numbers of TISEC devices in operation and what is the impact on lobster health, productivity, and survival? 3. What is the long term impact of changes in water quality (from discharges of hydraulic fluid and oil spills and noise from TISEC operation on lobster health & productivity? 4. How does energy extraction affect upwelling and stratification in the Minas Basin area and what is the impact on the lobster productivity and recruitment? 5. How are invasive species populations changing in the Upper Bay of Fundy (distribution, abundance, diversity) and how will they impact the health and productivity of the lobster community? 6. How will TISEC operation contribute to greenhouse gas reductions & coastal productivity? 7. How will climate change (temperature change, ocean acidity levels) affect marine resources, ocean circulation, coastlines, trophic structures, and in turn lobster productivity, predator-prey relationships and recruitment? 8. How will energy extraction causing reduced turbulence and turbidity levels affect stratification, light and nutrient supply in the Upper Bay and what will be their impact on benthic community and lobster production? 9. How will the lobster populations abundance and distribution change as a result of the combined impacts of TISEC energy extraction and other development activities that contribute to change in physical processes (e.g. pollution in the water column, noise, circulation, sediment dynamics)? 10. What is the combined effect of all multiple stressors mentioned above (e.g. combined effects of pollution/MEQ, productivity, noise and EMR emissions, habitat disruption, increases/decreases in predator and prey species) on lobster productivity, migration, distribution, and survival? 11. What is the capacity of the lobster population to adapt to multiple stressors/impacts over 12. time while maintaining overall health, integrity and function? 13. Is the lobster population sustainable? What actions will be taken to ensure sustainability?

and habitat alteration. Results show that as time of operation increases so do the number and complexity of possible interactions and interrelationships among project and environmental components. Over time, it may become difficult or impossible to separate ecosystem/lobster changes due to natural variability or multiple stressors from change due to TISEC operation. This emphasizes the need for a single or multiple number of reference site(s) as a means of separating change from several sources.

Questions pertaining to long term changes to baseline conditions from TISEC operation measure changes over time to original baseline and reference site characteristics. Cumulative impacts questions begin to examine the potential effect of an increasing number of TISEC devices on the size of the exclusion zone, the degree of lobster habitat alteration, water quality, upwelling and stratification, predator and prey species, and their impacts on lobster recruitment, productivity, and distribution. Other questions begin to examine the combined effects of multiples stressors including invasive species, greenhouse gas reductions, other development activities, changes in predator-prey relationships, and in turn, their impacts on lobster population resiliency/ adaptability and sustainability. Overall responses to management questions would contribute to an overall understanding of cumulative effects and changes with increasing time and numbers of TISEC devices in operation.

PSIR scenarios (Table 4) were used to identify possible indicator categories or indices as the basis for selecting appropriate indicators. These indices included population abundance, environmental features, productivity, reproductive capacity/health, resiliency, ecosystem interactions or effects, and sustainability. Together the suite of indicators constitute the suggested lobster index shown in Table 6. The management issues and questions that each set indicators address are also included in Table 6. Information to identify indicators was derived from multiple sources including: Charles *et al.* 2002; DFO 2007$_b$; DFO 2007$_c$; FRCC 2007; and Wells 2005.

Table 6. Suggested Lobster Population Index: indices and indicators for measuring potential change from tidal energy extraction (using information from Charles *et al.* 2002; FRCC 2007; DFO 2007_b; DFO 2007_c; and Wells 2005)

Key indices or features	**Indicator**	**Issues addressed & management questions addressed (Question #)**
Population abundance/ stock status	– Landings – Population (density & biomass) – Spatial distribution – Source of recruits – Migration patterns – Catch rate – Fishing effort – Legal sizes (moult classes) – Berried female numbers – Pre-recruit numbers	– Measurement of stock size, availability, catchability, fishing effort, fishing efficiency – Community structure, status, spatial & temporal distribution, and change in stock size (Question #: A1,A2, A3, A4, A6, B1, B4, B7, B8, B9, B10, B11, C4, C6, C7, D1, D3, D9, D10, D11, D12)
Productivity	– Landings Settlement densities – Spawning areas/aggregations (location, numbers) – Pre-recruit abundance	– Community structure, species abundance, potential for recruitment – Potential change in biomass &population growth (Question #: A6, A8, B1, B3, B4, B8, B9, B10, B11, C5, C7, D1, D3, D4, D5, D6, D7, D8, D10, D11, D12)
Environmental Features/ Marine environ-mental quality (MEQ)	– Ambient noise and produced noise from TISEC operation – Sediment dynamics (suspension, movement, settlement) – Upwelling& stratification – Current circulation patterns (flow, speed direction) – Habitat quality & substrate character – Temperature – Salinity/conductivity – Turbidity and visibility – Chlorophyll a – Nutrients (P and N) – Bacteria – Dissolved oxygen – Lobster tissue examination (contaminants, bacteria, disease) – Extent of migration – Greenhouse gas emission levels	– Evaluation of habitat and environmental conditions necessary for population growth and development – Availability of suitable habitat for larval settlement and adult development – Species tolerance or sensitivity and response to change in physical and chemical parameters (Question #: A7, A8, A9, A10, B1, B2, B3, B4, B5, B6, B10, C1, C2, C5, C7, D2, D3, D4, D6, D7, D8, D9, D10, D11, D12)
Resiliency	– Maintain ability to reproduce; – Able to develop naturally; – Ability to either increase population numbers or return to a considered or established baseline population number	– Assess extent to which lobster population can recover from change resulting from multiple stressors and maintain structure, function, and integrity (Question #: D11)

Table 6 (continued). Suggested Lobster Population Index: indices and indicators for measuring potential change from tidal energy extraction (using information from Charles *et al.* 2002; FRCC 2007; DFO 2007_b; DFO 2007_c; and Wells 2005)

Key indices or features	**Indicator**	**Issues addressed & management questions addressed (Question #)**
Reproductive capacity /health	– Recruitment rate (settlement density) – Average size and proportion of each group of recruits – Size of stock of mature spawning lobsters – Size specific sex ratios – Maturity size – Reproductive success (health condition, distribution,& abundance of berried females) – Eggs per recruit – Interactions with adjacent lobster populations/recruitment – Disease incidence	– Assessment of health status – Prediction of reproductive success and potential growth in population numbers, and future stock availability – Determination of the effectiveness of lobster management plans (Question #: A3, A5, A6, A10, B1, B10, C7, D3, D4, D5, D7, D8, D10, D11, D12)
Ecosystem interactions or or effects	– Upwelling and nutrient fluxes – Stratification (water column) – Climate change (temperature, UV exposure, water acidity levels; habitat change) – Fishing practices – Abundance of predator/prey species – Loss of predator/prey species and lobster larvae from TISEC operation – Bycatch of predators/prey/invasive species – Cumulative impact/change (combined effects of multiple stressors, e.g. habitat change, pollution, fishing pressure, predator-prey relationships, stratification, light penetration, other industry impacts)	– Assessment of the effects of other environmental factors influencing population abundance, distribution & growth – Appreciation of the complexity of cumulative effects/changes resulting from multiple stressors (Question #: C3, C4, C6, D1, D2, D4, D5, D6, D7, D8, D9, D10, D11, D12)
Sustainability	– Sustained recruitment (source of recruits, migration patterns, pop. influx; connection to other populations) – Sustained stock abundance and biomass – Effective production (see productivity above) – Biodiversity (species richness, presence, abundance, and equitability) – Sustained abundance of prey	– Assessment of the ability of the lobster population to maintain population abundance, reproductive capacity & health over time – Assessment of the level of maintenance of ecosystem structure and function – Determination of the effectiveness of lobster management plans – Measurement of exploitation rates (see fishing effort and ecosystem interactions or effects) and the area of altered habitat – Population capacity to maintain stock abundance and biomass (Question #: all)

6.0 Socio-economic indicator development

In a modern society decision makers are faced with the challenge of how to balance environmental, social, and economic goals as economic development activity and communities continue to grow. A socio-economic impact assessment process anticipates how a proposed development project might affect the quality of life of residents in a given community or area. In doing so, the process helps communities to understand potential future change from development activity and make appropriate decisions to support sustainable economic prosperity, social well-being, and community health. An appropriate selection of socio-economic indicators enables managers to monitor and assess change from development activity. For this study, the lobster fishery provides the basis for the selection of one or more suitable socio-economic indicators.

6.1 Assessing the current status of the knowledge base

6.1.1 The lobster fishery in the upper Bay of Fundy

The lobster fishery has been an important fishery in Canada, particularly in Eastern Canada for over 100 years (FRCC 2007). Even though there has been scientific investigation of lobster for most of this time, there have not been any estimates of the total size of the lobster stock in Canadian waters (FRCC 2007). Lobster landings are used as the measure of stock size. The Bay of Fundy lobster (*Homarus americanus*) fishery is divided into lobster fishing areas (LFAs) and statistical districts (STDs). The upper Bay study area for this project includes LFA 35 (illustrated in Appendix G) i.e. Chignecto Bay, Minas Channel, Minas Basin, and Cobequid Bay. STDs divide the LFA into smaller units as illustrated in Appendices H and I. The relevant STDs for the lobster fishery in upper Bay of Fundy study area are STD 40, 41, 43, and 44. Appendix J provides lobster landings data in metric tonnes (mt) in each statistical district (STD) and for lobster fishing fishing area (LFA) 35 from 1983-84 to 2005-06 (DFO 2007$_c$). Appendix K provides a graphic illustration of upper Bay lobster landings from 1990 to 2002 by STD (Dyer *et al.* 2005). Appendix L indicates the number of licenses by STD (Dyer *et al.* 2005).

Upper Bay lobster landings in LFA 35 have shown a steady increase over the past ten years (Appendix J). Dyer *et al.* (2005) indicates that in 1990, the landed volume was 187 mt with a corresponding value of $1,369,555 (or $7,323.82/mt) while in 2002 landings had increased to 673 mt with a value of $8,359,861. The highest upper Bay landings have been recorded in district 79, Alma, NB followed by district 44 and 40 (Appendices J and K). Data for study area STDs 44, 43, 41 and 40 illustrate that lobster landings have shown a similar increase from the mid to late 1990s (Appendix J). Peak levels were reached in STD 43 (28 mt) in 1995–96, in STD 41 (67.1 mt) in 1997–98, in STD 44 (198.6 mt) in 1998-99, and in STD 40 (114.2 mt) in 2004-05 (DFO 2007$_c$). By calculation, total landings for these STDs in 1990 was 89.2 mt which represented 38.23% of the total landings for the upper Bay (LFA 35). In 2001–02, total landings reached 308.9 mt representing 24.68 % of LFA 35 landings. By calculation, the total landed value of lobster in these STD areas in 1990, was approximately $653,300 and approximately $3,837,000 in 2000 which corresponds to the data presented in the graph in Appendix K. Dyer *et al.* (2005) indicates that in 2004-05, there were a total of 36 lobster licenses in STD 40, 41, 43, and 44 (Appendix L). The lobster fishery is of significant value to the local economy and fishing communities in the upper Bay area particularly since lobster landings over the past 20 years have continued to rise and market values have almost doubled. Prices for lobster have risen from the 1990 levels of $6.70/kg to $13.00/kg in 2006 resulting in the lobster fishery becoming the most valuable fishery in the Bay of Fundy and Maritime area (FRCC 2007).

6.1.2 Establishing the socio-economic baseline

In order to understand the socio-economic effects of tidal power project development, base-line information must be collected from those sectors/aspects of the community potentially effected by TISEC development. This will establish the “original” or pre-development condition against which to measure change resulting from development. TISEC will impact both the local economy of communities and some industrial sectors including the lobster fishery. To separate TISEC development impacts to the lobster fishery, from development impacts to the community at large, baselines for both the lobster fishery and broader community must be established. While it is beyond the scope of this study to conduct a full socio-economic analysis, Table 7 outlines the types of information required to establish community and lobster fishery baselines for the Minas Basin area. As indicated by the table, information to identify and evaluate socio-economic impacts of TISEC development can be both quantitative (i.e. to estimate change in community socio-economic characteristics) and qualitative (i.e. to establish community perceptions concerning TISEC development). While socio-economic assessment is oftentimes complex, difficult to quantify, and overlooked, socio-economic impact evaluation is a crucial component of a development assessment process.

6.2 Anticipated key tidal power project interactions with the lobster fishery

In the previous environmental section, the impact of TISEC energy extraction on the lobster population was chosen as the for analysis and indicator development. For socio-economic analysis, the impact of TISEC operation on the lobster fishery is chosen for several reasons. The lobster fishery is considered as a major industry of key economic importance to Nova Scotia especially to communities within the project area. The potential interaction between turbine operation and fisheries is identified as a key area of concern as indicated by the interactions matrix (Table 2). Consideration of socio-economic implications to the lobster fishery links socio-economic and environmental components which allows development of a combined (and balanced) indicator index. In addition, if significant change is to occur to socio-economic aspects, it is assumed that it will most likely occur during the operational phase of TISEC operation although change during other stages (construction and decommissioning phases) should not be ruled out. Socio-economic impacts of TISEC operation can occur at the level of a community/individual or at a specific industry/business level, i.e. the lobster fishery as shown below.

Table 7. Examples of baseline information requirements for socio-economic components of the lobster fishery (using information from Joseph and Gunton 2008)

Socio-economic features: General human population	**Lobster fishery**
1) Population demographics a) Population numbers – current population characteristics and composition (e.g. age, gender, ethnicity; population distribution, and densities in coastal communities and urban areas; numbers of permanent, temporary, and seasonal residents) – assess population changes (past and projected trends for both coastal and urban areas (i.e. incoming and outgoing population) b) Education level – education level (gender, race, ethnic origin, culture) – assess skills and anticipated opportunities for future education and training	1) Population demographics – current number of people involved in all aspects of the lobster fishery (#people and #licensed boats, #people involved in processing plants and marketing) – population changes (past and projected numbers of fishers involved in the fishing industry) b) Education level – education levels by gender, race, ethnic origin, culture; – assess skills and opportunities for future education & training in fisheries management & the TISEC industry
Employment aspects a) Employment and income – employment by sector – employment opportunities and sector growth projections – major source of income by sector and region (e.g. construction, fishing, forestry, mining, agriculture tourism, technology, research, public sector, other) – unemployment rates (by sector, gender, ethnicity, age, culture, etc.) – employment and income profile: income range, average, minimum and maximum for the community b) Employment trends and economic interests – anticipated changes in employment opportunities by sector (e.g. derived from land use planning documents, or anticipation of opportunities in future development projects, i.e. opportunities for specialized skills, scientific investigation and research, and export of knowledge) – immigration versus emigration in employment by sector – traditional use, e.g. First Nations economic and traditional interests, activities, and resources – existing and proposed development activities c) Revenue – local revenue generation by sector (e.g. property taxes, corporate, sales tax, fees, income) – expenditures on new public services and infrastructure demands	2) Economic aspects a) Employment within the lobster fishery (# individuals, #licensed boats) & growth – determine extent that the lobster fishery is the major source of income – unemployment rate in the lobster fishery by gender ethnicity, age, culture, etc.) – employment income range, avg. max. and min. – opportunities for employment in future development projects, scientific research and TISEC development b) Economic interests and trends: – anticipated changes in fishery employment (from lobster population projections; expressed views of fishermen) – extent of traditional use of the fishery – project how other development activities operating in the same area (temporal and – spatial conflicts) might impact the lobster fishery c) Revenue – current landings (weight & value) in lobster fishing area (LFA) # 35 & each fisheries statistical district (FSD) surrounding the Upper Bay (i.e. FSD #40,41, 43,44) – anticipated future growth in lobster productivity and landings – overall assessment of the sustainability of the lobster fishery

Table 7 (continued). Examples of baseline information requirements for socio-economic components of the lobster fishery (using information from Joseph and Gunton 2008)

General human population	Lobster fishery
3) Market analyses and trends a) Housing market assessment: – housing diversity, concentration, patterns, and cost by area – existing and anticipated housing needs – housing availability and affordability – housing accessibility to public services and facilities (i.e. effect on transportation costs or lifestyle) b) Retail market assessment: – assessment of economic health of local retail (e.g. retail mix, property value, business turnover, tax revenues, new businesses, retail vacancies, goods and services) – anticipated growth in public/community demand for goods and services by retail category and impacts on existing retailers (e.g. potential competition) – analysis of supply chain capacity for anticipated development projects including TISEC development	3) Market analyses a) Housing market assessment: – same b) Retail market assessment: – assessment of current and anticipated economic health of the lobster fishery – history of landings over past 20 years, and anticipated future values and level of demand and supply – assessment of export market (past and future trends)
4) Social impacts a) Public services – current public services capacity and distribution (e.g. parks, open space, protected areas, fire and police protection; health care, education, libraries, criminal justice, recreational and cultural facilities; special care facilities; water; sewer, social services, transportation) – anticipated future need for service delivery b) Aesthetic quality – assessment of design (i.e. visual appropriateness of development and sensitivity to potential environmental impacts on resources, species, current uses, and conservation of protected/special areas) – assess the impact of change in visual quality on social well-being & perception of quality of life c) Social well-being and quality of life: – perception of personal & community health (maintenance of culture, heritage resources, and community cohesion; contribution to society, health environment; crime level/dysfunctional behaviours; impacts on specific groups) – equitable opportunities in business and employment (business competitiveness, employment opportunities, training and career development; equitable benefit distribution) – sustainable income and lifestyle – attitudes toward social change from new & proposed developments (e.g. overall opposition/support; dev't references/nonpreferences perceptions of anticipated effects; arising controversies or potential areas of conflict; emerging issues; patterns of opinion; alliances formed)	4) Social impact assessment a) Public services – same b) Aesthetic quality – same b) Social well-being and quality of life: – assessment of effects that current & future development (including TISEC) have on the fishery and social well-being of fishermen, i.e. perceptions of personal & community health, maintenance of cultural/heritage resources; provision of equitable business and employment opportunities, opportunities for a sustainable income and lifestyle, and attitudes toward social change

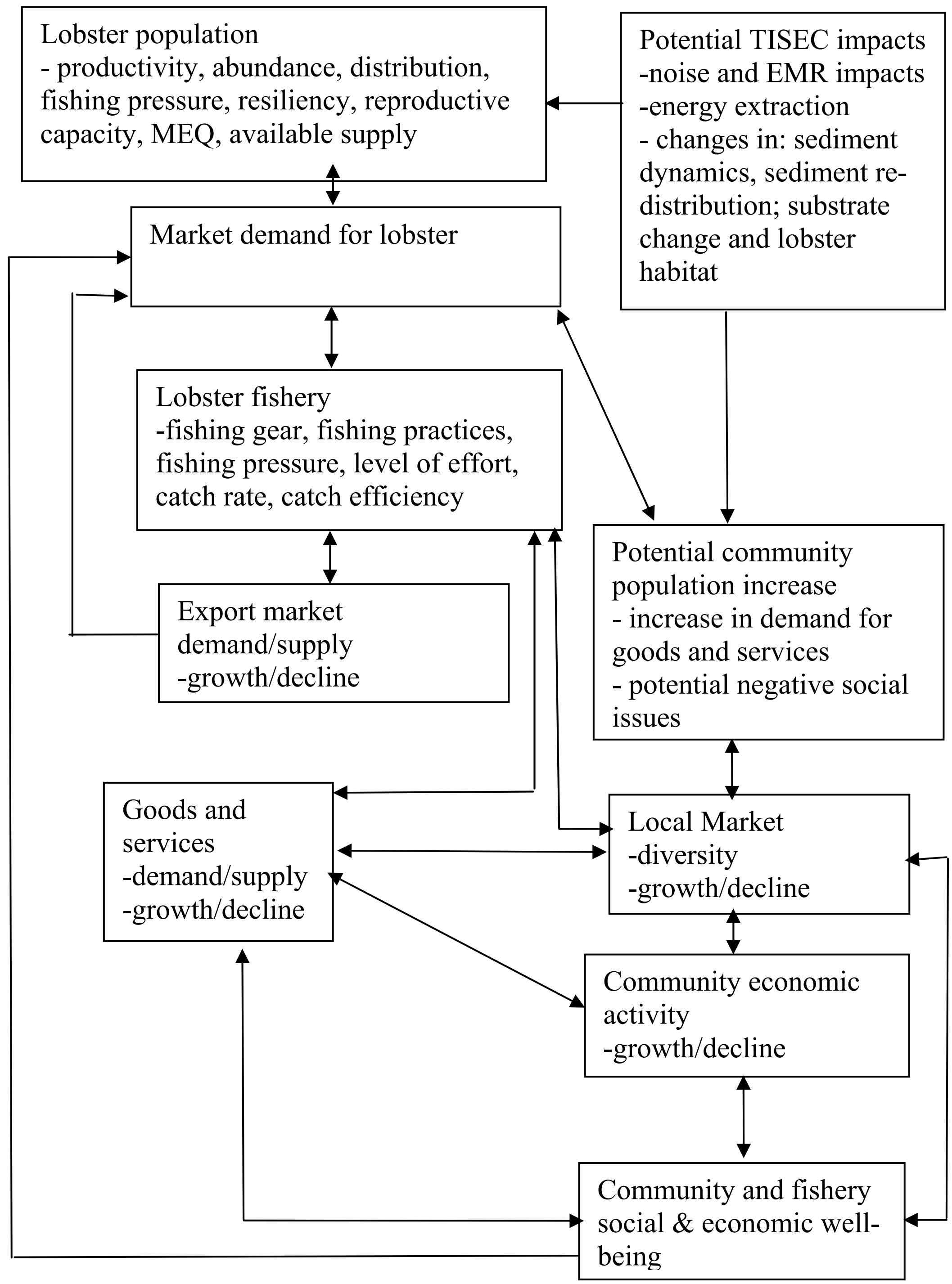
6.2.1 Socio-economic interactions: Project-community

The interactions matrix (Appendix M) illustrates the potential interactions that can take place between a TSEC project and the community (including the fishing community) over the lifecycle of the project. Figure 3 presents a more conceptual diagram of these interactions. Impacts of TISEC energy development can be either direct (e.g. employment within the industry) or indirect/spinoff effects (e.g. economic activity stimulated by TISEC development). Indirect effects may include production of goods and services to meet the needs of those employed by the TISEC industry, production of TISEC equipment/technology, and expenditures of rents and profits from TISEC development within the community or region.

The interactions matrix (Appendix M) also shows that population demographics may potentially change from a temporary influx of workers assuming short term employment opportunities in technical fields particularly during initial development construction phases. Over the operational and maintenance phase, human population demographics may again change, from the replacement of larger numbers of temporary workers by a smaller number of specialists offered permanent employment e.g. in turbine operation or maintenance, scientific and socio-economic research, and TISEC development.

The interactions matrix also suggests that throughout all TISEC lifecycle stages (construction, operation/maintenance and decommissioning), local/regional economies may be stimulated by increases in demand for goods and services to support TISEC employees and their families and for manufactured products/materials for industry development. Universities and research facilities are already becoming involved in TISEC environmental and socio-economic research and development. Individuals and local governments may benefit financially through employment or contracts, collection of taxes/rents, royalties, and compensation. In addition, change in social conditions may arise from increases in demand for goods, services and housing, opportunity for employment, shifts in resources (labour) from other sectors, and influxes of new residents

Figure 3. Conceptual diagram of potential TISEC project socio-economic interactions with the lobster fishery



from other areas. Social attitudes toward development and public perceptions of well-being/health may change or be influenced by anticipated opportunities in economic growth, education/training, employment and research.

As there is currently no information/data available on socio-economic impacts of TISEC operation in the Bay of Fundy, one can only anticipate what they might be for the Minas Basin area. If TISEC development follows employment trends in the wind energy industry, most employment will be generated during the construction phase (Ball 2002) while longer term positions would be offered during operations or maintenance phases. Top Pond (2006) estimated that the 26 MW onshore wind farm in Newfoundland would generate 7 positions during the operational phase which was down from 33 positions during construction. This equates to 1.3 direct jobs for each MW of power generated (Joseph and Gunton 2008). The degree to which people in the project area are able to take advantage of employment opportunities depends on many factors e.g. whether the industry is required to hire locally; the education and skills of the local community relative to the technical design, labour, administrative, or management skills required by the industry; and the willingness of the industry to invest in the community through education/training to build local skill capacity (Joseph and Gunton 2008). Preference for employment in subsistence over alternative positions like TISEC may influence employment impacts in rural areas. Energy development schedules that conflict with fishing activities could result in lower participation in energy development projects (Detomasi 1977). In addition, the structure and capacity of the supply chain in the region is a critical factor that affects levels of community employment and social implications. Greatest benefits to the community may arise from development of expertise in resource extraction, manufacturing and export as opposed to the development of the resource in itself (ERACL 2002).

It is possible that the immediate development area which is largely rural may experience some boom and bust phenomena including social tension caused by influxes of more people, changes in local area culture and pace of development, overburdening of infrastructure, price inflation, and economic downturns following the construction phase.

There is also the possibility that the project overall will bring needed employment and greater economic stability to an area traditionally dependent on natural resources (i.e. predominantly fishing, forestry, agriculture). Incremental additions of TISEC devices (building toward commercial scale turbine array) over time will tend to extend the construction phase and secure employment over several years, as would the purchase of power agreements for the operational stage.

Overall, for more accurate prediction/assessment of socio-economic implications, additional information is needed from the TISEC industry on labour demands, (skilled labour requirements, employment opportunities), hiring policies, required goods and services (by sector), purchase agreements and revenues expected/generated for all phases of development. Such information would also assist defining the original pre-development baseline by identifying sectors/areas of the community likely affected by development from which baseline information could be collected. However, only through actual experience of TISEC devices operating in the Minas Basin can predicted socio-economic implications be confirmed.

6.2.2 Socio-economic interactions: Project-lobster fishery

The extent to which TISEC devices and their operation enhance or decrease lobster productivity and therefore affect the lobster fishery in the Minas Channel, Minas Passage, and Minas Basin area is a key socio-economic concern. As indicated in the project-fishery interactions matrix (Appendix M), key interactions are again both direct and indirect. The major direct impact on the fishery stems from the loss of access to fishing areas and boat passage resulting from the TISEC industry establishing an exclusion zone in the project area to ensure installation safety (Ball 2002; Joseph and Gunton 2008). Generally, mobile fisheries including longliners, seiners, and trawlers are excluded in project areas due to potential damage caused by fishing gear to project equipment or possible entanglement or collision with electrical cable devices themselves (Sorensen *et al.* 2003). Also of direct consequence to the fishery are possible impacts on catch levels; damage to fishing gear from entanglement with project seabed debris or obstructions in boat passage due to changes in anchoring mounds (PMSSL 2005; FMAM 2007).

Two key indirect effects of TISEC devices are potentially positive for the lobster fishery and fishermen. The first effect relates to the belief that the TISEC structure itself may create a sanctuary or artificial reef effect by providing a surface on or around which marine organisms can establish a community and therefore increase population numbers (Sorensen *et al.* 2003). The extent to which the sanctuary effect enhances the lobster population/productivity and ultimately the lobster fishery and social well-being of the community is unknown. Questions in fisheries research remain as to whether artificial reefs actually increase fish productivity or merely shift their distribution by drawing populations away from other areas (Patin 1999; Manago and Williamson 1998). The second indirect effect is that the exclusion zone may lead to an increase in lobster populations, i.e. by excluding fishing activity/pressure from the area, the zone potentially provides a protected space for population growth (Sorensen *et al.* 2003). Further research is required to determine the overall implications of the no-take exclusion zone and the artificial reef on the lobster productivity and the fishery in the Minas Basin, i.e. production in these protected areas may also be affected by other aspects including pollution, noise, suitability of habitat, and predator/prey abundance which in turn may affect lobster productivity. The length of the exclusion time, spatial extent of the exclusion zone, and the degree of lobster migration from these protected areas may influence lobster availability to the fishery. Again monitoring data from the operation of TISEC devices under natural conditions in the Bay of Fundy is needed to confirm socio-economic implications to lobster populations and the fishery.

6.3 Potential environmental impact scenarios (PSIR Model) of socio-economic indicators

The same pressure-state-impact-response framework used in the previous environmental section is applied now to socio-economic components of the lobster fishery. Within this context, pressure refers to forces placed on the environment by society or societal action that cause changes in the condition or quality of the environment. State refers to changes in environmental and socio-economic conditions resulting from pressures of human activities. Impacts refer to changes to human welfare as a result of changes in state. Responses are actions taken by management/society to mitigate or ease effects, avert conflict, correct damage, or conserve the natural resource base.

Table 8 illustrates that three kinds of pressures are exerted on the fishery, those from the establishment of an exclusion zone which restricts access to fishing grounds, from the sanctuary effect created by the devices themselves, or from fishing pressure exerted on the lobster population. It may or may not be possible for the fishing community to withstand a short term loss of access to fishing grounds depending on the time of year or degree of dependence on the fishery for income. Undoubtedly, this loss would result in lost income opportunities, reliance on savings/investments and decreases in social and community well-being. Negotiation and settlement or development of policy or regulation to allow access at certain times may however be possible. Longer term or permanent loss of access may lead to an inability to make a living from the fishery, and hardship for coastal communities largely dependent on the fishery. Partial access to fishing grounds may restore the fishery to near-former or former catch levels. In worst case scenarios, losses in income may cause some fishermen to leave the fishery.

Whether or not TISEC structures would provide a sanctuary effect is largely unknown, i.e. cause an increase, decrease or cause no change in lobster productivity. The effect of an increase in lobster numbers short term or long term would, however, benefit the fishery only if they actually move outside both the sanctuary zone and the exclusion zone (both encompassing the project area) and to become available to catch. A decrease in the lobster population in the sanctuary area, for whatever reason, would over the short term and long term cause decreases in both local economy and social well-being. Fishing effort is identified as a third form of pressure but many other forms could also be added or substituted. Regardless of whether the lobster population increases or decreases as a result of fishing pressure, loss of habitat, or changed physical conditions,

Table 8. Potential socio-economic impact scenarios resulting from TISEC operation using a Pressure-State-Impact-response Model (Model adapted from OECD 1993)

PSIR	Pressure	Socio-economic state changes	Impact on Lobster fishery		Response of lobster fishery/management		Indicator category or focus area
			Short-term (0-5 yr.)	Long-term (> 5 yr.)	Short-term (0-5 yr.)	Long-term (>5 yr.)	
Socio-economic component potentially impacted by TISEC operation	**Exclusion zone**	Loss in access to commercial and traditional resources; ↓ fishing pressure and pot. ↑ lobster population in exclusion zone; With little migration of lobster from exclusion zone, ↑ pressure on pop. outside exclusion zone with pot. ↓ in pop. available to the fishery	Scenario 1: ↓ Lobster catches with loss of access in the exclusion zone; Loss in employment income; ↑ Reliance on savings or investments; ↑ Borrowing or lending rates; ↑ Unemployment rates; ↓ Social well-being; ↑ opposition to dev't; ↑ perceptions of unfair treatment & distribution of dev't benefits; Adaptive capacity	Scenario 1: Permanent loss of access → inability to make a living from the fishery; ↓Social well-being; Economic downturn in communities dependent on the fishery; Exit from the fishery to seek alternative employment; Pot. ↑ conflict; ↑ Legal settlements &compensation from loss of access & income; ↑ Dependency on social assistance; ↑ Education & training in new field; Adaptive capacity Scenario 2: Partial access or return of full access → Pot. return to former fishing levels with regulated access to exclusion zone	Scenarios 1 & 2: Negotiation and settlement with industry & fishermen; Policy and/ or regulatory change re extent of exclusion zone and timing of fishery access	Scenario 1; Collapse of the fishery; Compensation for damages; buy-out of existing fishing licenses Scenario 2: Ongoing regulated management of the exclusion zone to allow access with possible return to former catch levels	– Pop. demographics – Lobster fishery – Fishing pressure – Market conditions – Quality of life & social well-being – Human resiliency – Management response

Table 8 (continued). Potential socio-economic impact scenarios resulting from TISEC operation using a Pressure-State-Impact-response Model (Model adapted from OECD 1993)

PSIR	Pressure	Socio-econ. state changes	Impact		Response of lobster fishery/management		Indictor category
			Short-term (0-5 yr)	Long-term (>5yr)	Short-term (0-5yr)	Long-term (>5yr)	
Socio-economic component potentially impacted by TISEC operation	**TISEC Sanctuary effect**	Unknown Scenario 1: Pot. ↑ in lobster pop. with lobster migration out of sanctuary and exclusion zone Scenario 2: Pot. ↓ in lobster population (fr. ↑ predator pop.) Scenario 3: No change in lobster pop., fishery impacts, or responses	Scenario 1: If ↑ pop., →↑ migration outside exclusion & sanctuary zone:→ pot. ↑ landings and returns to fishery; ↑ Social well-being in community; ↑ effort Positive perception of industry Scenario 2: If ↓in pop. & little out migration, effects are as in short term scenario 1 above	Scenario 1: ↑ local economy & long term social well-being & economic benefits to the community Scenario 2: If decrease in pop. and/or pop. access, the effects are the same as in scenario 1 (long term exclusion zone) above	Closely monitor changes in fish and lobster populations resulting from the sanctuary effect	Scenarios 1 & 2: Encourage or discourage industry from creating additional reef habitats for lobster depending on productivity outcome	– Pop. demo. – Lobster fishery – Fishing pressure – Public service needs & availability – Quality of life & soc. well-being – Market conditions
Socio-economic component impacted by other pressures	**Fishing effort**	Scenario 1: ↑ fishing pressure and catch efficiency→ ↑ landing Scenario 2: ↓ fishing pressure and catch efficiency →↓ in landings	Scenario 1: ↑ pressure landings & economic returns; ↑ Social well-being in community; Pot. ↑ local spending with positive economic effects to the community Scenario 2: ↓ landings with opposite effects	Scenario 1: Pot.↓ Lobster pop. with same effects as scenario 1 (long term exclusion zone) above; Scenario 2: Pot.↓ landings with same effects as scenario 2 above ((long term exclusion zone)	Closely monitor impacts of fishing pressures on landings and population numbers	Monitor fishing pressure and catch efficiency impacts on long term sustainability of the lobster population and fishery	– Lobster fishery – Fishing pressure – Market cond. – Public service needs & availability – Quality of life & social well-being – Human resiliency – Man. response

the lobster population would need to be closely monitored to assess the effects of combined stressors on productivity levels.

It is realized that many fishery scenarios are possible. Those presented in Table 8 provide just a few examples of project-socio-economic interactions and effects (oversimplified) that may occur in the natural world. The purpose of presenting scenarios is to provide a general sense of possible indicator categories/indices for later indicator development. Eight category types/indices were identified including: fishing pressure; population demographics; lobster fishery; public service needs and availability; quality of life & social well-being; market condition; human resiliency or adaptive capacity; and management response or action.

6.4 Environmental management questions and indicators of change in the lobster fishery

The management questions in Table 9, relate to the effects of TISEC operation on the lobster fishery. In keeping with the environmental objective for lobster population sustainability, the overall socio-economic management objective is to sustain the lobster fishery. Management questions again fall into two categories, those pertaining to short term impacts and those relating to long term/cumulative effects of TISEC operation. Short term impact assessment examines the effects of a limited number of possible interactions. Long term and cumulative effects monitoring examine interactions between or among many multiple factors and stressors over the lifecycle of the project and possibly beyond to establish whether conditions return to baseline or a new status.

Short term baseline questions focus on the characteristics of the fishery (e.g. landings, employment, fishing effort and efficiency, development activity impacts, market demand/supply, employment, contribution of the fishery to the local economy, fishery management practices); perceptions of social well-being, and lobster migratory patterns. Short term TISEC impacts questions address issues relating to: the sanctuary effect on lobster productivity; the impact of the exclusion zone to access, lobster productivity, and

Table 9. Management questions relating to potential socio-economic effects of TISEC operation on the lobster fishery

A. Short term - Changes to baseline conditions

1. What is the current number of people involved in all aspects of the lobster fishery?
2. How many lobster fishermen and licensed boats are registered in the Minas Basin area, & how have these numbers changed over the past 20 years? Where are the home ports for these boats?
3. What levels of growth in the commercial and traditional lobster industry are projected over the next 20 years?
4. What are the current lobster landings (by weight and value) in lobster fishing area # 35 & within each fisheries statistical district surrounding the Upper Bay of Fundy? (i.e. FSD 40,41,42,43,44)? Do these landings values accurately reflect actual population numbers?
5. Where are lobster fishing grounds located in the Minas Channel, Minas Passage and Minas Basin?
6. What is the current employment rate within the lobster fishery?
7. What is the average employment income and range for lobster fishermen?
8. What percentage of the income of lobster fishery households is derived from the lobster fishery?
9. How have landings changed over the past 20 years and how are they projected to change 20 years in the future?
10. How have lobster fishing effort and efficiency changed over the past 20 years?
11. What influence do fishing effort and efficiency have on lobster landings and change within the lobster population (to lobster biomass, recruitment) and to available stock?
12. What is the current market demand/supply ratio for lobster and how is this ratio anticipated to change over the next 20 years? What are the causes of this change?
13. What is the current export market value ($ and weight) and how is this anticipated to change over the next 20 years?
14. How have past development activities (particularly other fishery practices) affected lobster habitat, productivity and landings?
15. What are the patterns of lobster migration between the Minas Passage and Minas Basin? i.e. what percentage of the lobster population migrates from the Minas Passage into the Minas Basin to become available to the lobster fishery outside the exclusion zone?
16. What is the current and anticipated demand/need of the lobster fishing community for social services? Is the current level of service sufficient to meet requirements?
17. How do lobster fishermen feel about their current quality of life and social well-being?
18. What is the current contribution of the lobster fishery in the Upper Bay of Fundy relative to other fisheries? to the overall local economy?
19. What other existing or planned developments are having or are anticipated to have social and economic impacts on the lobster fishery in the project area?
20. How have past lobster management practices affected lobster habitat, and ultimately lobster stock abundance and the fishery?

Table 9 (continued). Management questions relating to potential socio-economic effects of TISEC operation on the lobster fishery

B. Short term - Changes from TISEC operation

1. Does the presence of the TISEC device provide a sanctuary effect for lobster and if so, how does it affect lobster productivity and ultimately, lobster landings?
2. To what extent will the establishment of an exclusion zone affect access to lobster fishing grounds?
3. Will the exclusion zone affect the ability of lobster fishermen to provide a sustainable income & lifestyle for their families? If so, to what extent will landings & income levels change?
4. How will the exclusion zone affect boat passage between Minas Channel and Minas Passage?
5. How does the exclusion zone impact lobster fishermen's perception of their quality of life and social well-being, and attitudes toward social and development change in the community?
6. What employment opportunities might be available to fishermen within the TISEC industry? Would fishermen be willing to accept these positions if offered?
7. Can a negotiated agreement between the TISEC industry and the lobster fishery be struck to provide access for lobster boats to fishing areas (appropriate access points and schedule)?
8. How will the cost of housing, housing availability and affordability change with the influx of new residents associated with TISEC development? How will these changes affect the lobster fishing community?
9. To what extent will demand for goods and services change as a result of TISEC development? How will these changes affect lobster fishermen and the fishery?
10. To what extent will the price of goods and services change as a result of TISEC development? How will the price of lobster change?
11. How will the availability/supply of goods and services to the general and fisheries communities change as a result of TISEC development?
12. How will the presence of TISEC development activity change fishermens' perceptions of the visual quality/appearance of the sea landscape and in turn the quality of their lives?
13. What are fishermens' concerns/perceptions of the potential impacts of TISEC operation on lobster habitat, water quality, and ambient noise levels in the Upper Bay of Fundy? on lobster predator and prey species?
14. What are fishermens' opinions on the appropriateness of TISEC technology design in terms of its capacity to cause/avert environmental impacts to fisheries, lobster resources, and to protect conservation/special designation areas in the Upper Bay?
15. How will TISEC development change fishermens' perceptions of social well-being and quality of life in the lobster fishing community and for their own family? i.e. To what extent will TISEC operation affect their personal welfare, the health of their community, and their ability to maintain their culture and way of life?
16. Do fishermen believe that TISEC development will provide them equitable opportunity to maintain or enhance their income and lifestyle within the lobster fishery?
17. What are fishermens' attitudes toward potential social change within the general population and the lobster fishing community from TISEC development?
18. What changes are anticipated by fishermen to their own lives and fishing community from TISEC development? How would fishermen respond to these changes?
19. Are there programs, policies, & regulations in place elsewhere that have addressed access issues that might be applied in Nova Scotia? Is it possible to provide partial access to fishing grounds at specified times and locations?
20. What will be the effect of various levels of access on lobster landings?
21. To what extent does the exclusion zone itself lead to an increase in lobster productivity and lobster stock availability to the fishery?

Table 9 (continued). Management questions relating to potential socio-economic effects of TISEC operation on the lobster fishery

C. Long term - Changes to baseline conditions 1. How have baseline conditions (noted above) changed between a short and longer period of TISEC operation? 2. What is the long term effect of reduced fishing pressure in the exclusion zone on lobster stocks and landings? 3. How will lobsters respond to the reef effect created by TISEC devices (avoidance due to sound/EMR, attraction to fish communities or new habitat)? How will the reef effect lobster numbers? 4. How will TISEC energy extraction ultimately change habitat characteristics and quality for lobster settlement? How will habitat changes affect lobster abundance, distribution, and availability of stock in the Upper Bay? 5. To what degree will the creation of an exclusion zone contribute to growth in the lobster population and fishery landings? 6. How will TISEC operation affect employment/unemployment rates and income levels in the lobster fishery? 7. How many lobster fishermen over time will exit the fishery as a result of the economic impacts of the exclusion zone? 8. To what extent will lobster migrating from the exclusion zone into the Minas Basin, contribute to lobster stock landings? 9. How will lobster fishermens' quality of life and social well-being change within the lobster fishing community and community at large, with increasing TISEC operational time and numbers of devices installed? 10. What is the capacity of the lobster fishery to adapt or recover from fluctuations in the lobster population/stock availability over time? 11. Does the presence of the TISEC device provide a sanctuary effect to the extent that increased productivity offsets any losses in lobster numbers from habitat disruptions due to tidal energy extraction? 12. What constitutes an acceptable or unacceptable level of change to the fishery? 13. To what extent will TISEC development will allow fishermen to maintain or enhance their livelihood within the lobster fishery?
D. Long term - Cumulative assessment - cumulative changes from TISEC operation 1. How will altered habitat affect lobster productivity, distribution, health, abundance, predator-prey relationships and the future availability of lobster to the fishery? 2. How will climate changes alter trophic structure, species presence, composition, abundance, density, and distribution in the Upper Bay and what effect will these changes have on the lobster population? How will these changes affect the lobster fishery? 3. What is the combined effect of all multiple stressors (e.g. combined effects of pollution/MEQ, noise and EMR emissions, habitat disruption, increases/decreases in predator and prey species, fishing pressure/efficiency, climate change, invasive species, and other fishing practices, etc.) on lobster productivity, migration, distribution, survival and in turn, the sustainability of the lobster fishery? 4. How do cumulative changes from the commercial operation of TISEC farms, alter the perceptions of social, economic, and cultural well being and health of lobster fishing communities in the Upper Bay of Fundy? 5. To what extent can an ecosystem and fishery recover following removal of tidal energy devices in the Bay of Fundy?

stock availability to the fishery; employment opportunities; perceptions of social well-being; perceptions of TISEC development; potential for partial access/negotiation for access; and changes in available goods and services, housing availability and affordability.

Long term changes relate both to changes in baseline conditions in the fishery, and cumulative effects of TISEC operation on the fishing industry. Questions on baseline conditions focus on the potential long term effects of the sanctuary (reef effect) and exclusion zone on lobster population abundance and landings and ultimately income levels for fishermen. Additional questions focus on change to the social well-being, quality of life, and the ability of fishermen to make a living from the fishery as the number of TISEC devices in operation increase and the exclusion zone potentially expands. Cumulative questions relate to the sustainability of the fishery which includes the lobster's ability to adapt to potential changes in habitat, the extent of lobster movement from the exclusion zone to an area that is accessible to the fishery, and the ability of the fishery to adapt or recover from fluctuations in the lobster stock availability over time. A key question is whether the lobster can withstand effects of combined multiple stressors including climate change, increases or decreases in predator and prey species, invasive species, noise and EMR emissions, and fishing practices and pressures.

It is important to note that some questions in Table 9 relate to environmental aspects of the lobster population illustrating the linkage between socio-economic and environmental components, i.e. the fact that one cannot really separate socio-economic from environmental aspects in managing a resource based industry. The ability to sustain a lobster fishery is dependent on the maintenance of a sustainable lobster population.

From the management questions and the scenarios presented in Table 8, eight socio-economic categories/indices of change to the lobster fishery were identified. These include fishing pressure, human population demographics, lobster fishery characteristics, public service needs and availability, quality of life and social well-being, market condition, human resilience/adaptive capacity, and management response/action. A series of indicators was developed for each category to produce the suggested lobster fisher index outlined in Table 10. The specific management questions that each indicator category addresses are identified. Choice of indicators were based on an analysis of the current document literature (Charles *et al.* 2002; FRCC 2007; DFO 2007_b; DFO 2007_c; Walmsley 2005; and Lockie *et al*. 2005).

7.0 Discussion

The following presents a discussion of key issues or considerations in the development of a monitoring program for TISEC assessment. These relate to the design of a conceptual framework to monitor TISEC effects and integrate baseline and impact information into an EIA management decision process, issues to consider in the development of indicators, and the selection and application of ICOM principles to management decisions and TISEC development. A final issue pertains to research issues or questions that remain unanswered.

7.1 A conceptual framework for integrating impact information into management decisions

The Bay of Fundy is a complex and dynamic marine environment in which biological, physical, chemical and geological processes occur and influence biodiversity, ecological structure, function and integrity and the abundance and distribution of organisms. Results of this study have indicated that there are many unknowns and uncertainties regarding the socio-economic and environmental implications of TISEC operation in the Upper Bay of Fundy. What we currently know about impacts is insufficient to enable environmental managers to make an appropriate decision at this time to approve the development of TISEC on a commercial level. In the absence of full information and uncertainty, the burden of proof rests with the developer of the resource to demonstrate that the proposed activity will not cause significant harm to the environment, natural resources, or socio-economic conditions in the area. In the absence of information to illustrate that no harm will occur, it is important that regulatory authorities

Table 10. Suggested lobster fishery index: Indices and indicators for measuring potential change in the lobster fishery from TISEC operation (Information derived from Charles *et al.* 2002; FRCC 2007; DFO 2007_b; DFO 2007_c; Walmsley 2005; Lockie *et al.* 2005)

Key indices	Indicator	Issues & management questions addressed (Question #)
Fishing pressure	– Landings (past, current and projected) – Trap hauls – Fishing location – Vessel size – Navigation equipment – Trap design – Fishing strategy – Sample at-sea size – Fishing efficiency (past, current, projected) – Catch rate/effort (catch per unit of effort) – Changes in extent of fishing area – Change in level of effort – Level of exploitation – Lobster habitat disruption/change – Bycatch of lobster by other fisheries – Bycatch of non-lobster species – Bycatch of lobster predator or prey species	– Changes in population numbers due to fishing effort/practices/ efficiency (Question #: A9, A10, A11, A14, A15, A19, A20, B1, B20, C1,C2, C8, D1, D2, D3, D4, D5)
Pop. demographics	– Population numbers (lobster fishery pop., licensed # boats by port) – Population characteristics and projected changes from TISEC development – Population growth/change (lobster fishery historic and projected change) – Level of education – Skills development	– Change in community characteristics as a result of changes in development activity or economic growth (Question #: A1, A2, A3, A18, A19, B5, B6, B9, B10, B11, B17, B18, C1, D4, D5)
Lobster fishery characteristics	– Lobster migration patterns (from sanctuary and exclusion zone to Minas Basin; from Minas Channel to Minas Passage to Minas Basin) – Available biomass – Recruitment rate – Available stock – Reef effect (on population numbers) – Annual catch rate/landings and historic trends – Location, number and extent of fishing grounds – Catch projections – Condition of the stock – Changes in composition of catch – Overfishing – Seafood quality – Level of incidental mortality or bycatch – Substrate impacted by development or fishing practices – Fishery policies, regulations, practices – Area of coastal waters off limits to the fishery – Effectiveness of lobster management programs and strategies – Overall health of the lobster fishery	– Historic, current conditions, and anticipated changes in health and abundance of the lobster stock – Effectiveness of stock management programs (Question #: A4, A5, A11, A12, A15, A18, A20, B1, B2, B3, B9, B21, C1, C2, C3, C8, C11, C12, D1, D2, D3, D4, D5)
Public service needs and availability	– Social services currently available and projected needs (e.g. education; medical and dental care housing; social assistance; electricity; parks, open space, protected areas; fire and police protection; libraries; criminal justice; recreational & cultural facilities; special care facilities; water and sanitation; transportation; telecommunications; and postal service)	– Assess current and anticipated demand for public services and capacity to meet needs (Question #: A16, B8, B9, B11, C1, D4, D5)

Table 10 (continued) Suggested lobster fishery index: Indices and indicators for measuring potential change in the lobster fishery from TISEC operation

Key indices	Indicator	Issues addressed & management questions addressed (Question #)
Public service needs and availability	– Social services currently available and projected needs (e.g. education; medical and dental care housing; social assistance; electricity; parks, open space, protected areas; fire and police protection; libraries; criminal justice; recreational & cultural facilities; special care facilities; water and sanitation; transportation; telecommunications; and postal service)	– Assess current and anticipated demand for public services and capacity to meet needs (Question #: A16, B8, B9, B11, C1, D4, D5)
Quality of life & social well-being	– Employment rate, income level and opportunities (in the lobster fishery, TISEC industry, or socioeconomic and science research fields) – Percentage of household income derived from the fishery – Sustainable income and lifestyle – Cost of living (inflation) – Equitable employment opportunities (knowledge of the fishery; socio-economic and scientific research) – Population growth and social development character – Level of crime/disruptive behaviours – Perception of quality of the coastal landscape – Access to coastal & marine resources (acreage boat passage/access to fishing grounds) – Visual and operational appropriateness of technology design to minimize environmental and resource impacts – Perception of personal health – Perception of development impacts on the lobster population and fishery sustainability – Perception of unity and support within the community – Maintenance of cultural/heritage resources – Equitable distribution of benefits from development – Perception of social change from development – Contribution to society – Participation in community activities (volunteer; coastal and marine management programs) – Public awareness of coastal and marine development activity and coastal issues – Information access	– Assess community values and perceptions of current social conditions and future trends – Extent to which current and future social conditions meet social values, expectations and needs (Question #: A6 A7, A8, A17, A19, B2, B3, B4, B5, B6, B8, B12, B13, B14, B15, B16, B17, B18, C1, C2, C7, C9, C12, D4, D5)
Market condition	– Lobster price and price changes over time – Economic diversity/health of local retail and growth opportunities – Anticipated economic effects of other developments on the lobster fishery – Demand/supply ratio (past, current, projected) – Resource market values and growth potential (landings weight and dollar value) – Export market value and opportunity (lobster) – Housing (diversity, affordability, projected needs)	– Potential areas for market growth and development (Question #: A12, A13, A18, A19, B10, C1,C12, D3, D4, D5)

Table 10 (continued) Suggested lobster fishery index: Indices and indicators for measuring potential change in the lobster fishery from TISEC operation

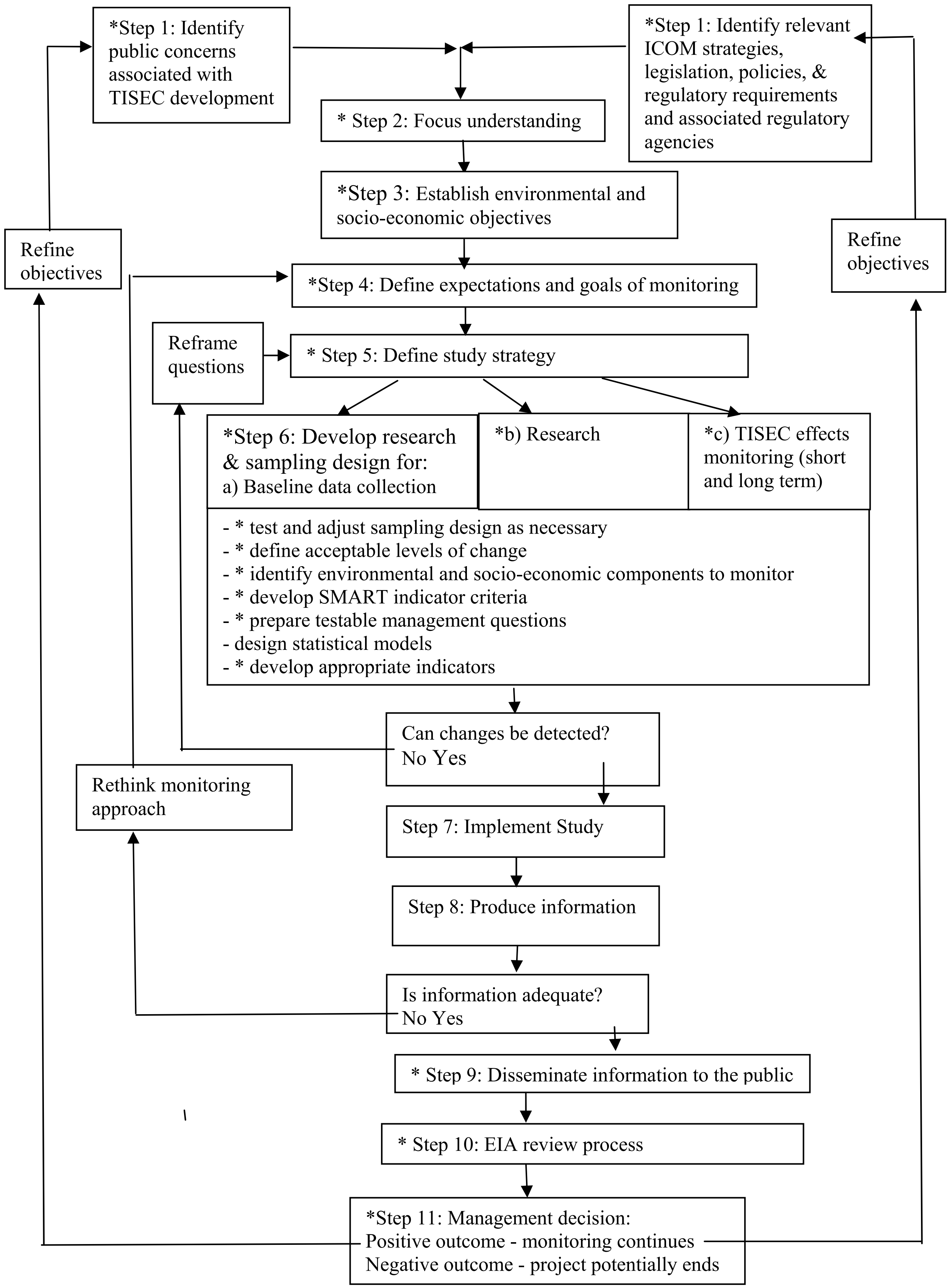
Key indices	**Indicator**	**Issues addressed & management questions addressed (Question #)**
Human resiliency or adaptive capacity	– Ability to adapt/accept change, uncertainty and risk – Capacity to learn from experience and crises – Ability to anticipate the unexpected – Capacity to alter activities/reorganize to minimize threat to livelihood – Willingness to learn/experiment with new approaches – Ability to collaborate, resolve conflicts, and share information	– Assess community/individual capacity to adapt to stress or change while maintaining overall health (Question #: B3, B6, B9, B10, B11, B12, B14, B15, B16, B17, B18, C1, C4, C5, C6, C7, C9, C10, C12, D1, D2, D3, D4, D5)
Management response/action	– Management actions/responses to address: o bycatch management o level of species richness o designation of protected areas and species o conservation/protection of threatened species o invasive species o oil and hydraulic fluid spills and leakages o lobster population sustainability o lobster fishery sustainability o loss of priority lobster habitat /habitat degradation o extent of exclusion zone and level of access provided to fishing grounds o levels of unemployment in the fishery – Measurement of level of public acceptance/ satisfaction with management action: o ability to balance TISEC energy development with sustainable lobster population and fishery o community perceptions of industry, TISEC development project and government action o community perceptions of quality of life, social well-being, and health o funding availability for research, e.g. impacts of TISEC energy extraction/operation over time with increasing numbers of turbines on substrate, physical coastal processes, and natural populations and fisheries; and impacts of climate change and fishery practices/ pressures on species composition, distribution, abundance and availability to the fishery o funding grants given for NGO Bay of Fundy research	– Extent to which management actions/ responses meet management policy, program, and regulatory goals, objectives, and targets – Effectiveness of lobster management programs and management actions/responses (Question #: B2, B3, B7, B19, B20, C1, C2, C7, C11, C12, D1, D2, D3, D4, D5)

proceed on a conservative basis using a precautionary approach, until appropriate information and understanding is attained (Cicin-Sain and Knecht 1998).

Appropriate information is essential for an assessment of impact significance. An appropriate suite of indicators and indices are needed to direct information collection and to monitor the impacts of TISEC operation under natural conditions in the Bay of Fundy. To assess these impacts and link information to decision processes, an appropriate framework is needed to guide the collection of information generated by original research and TISEC effects monitoring, and to synthesize existing baseline data.

In the absence of prior monitoring information relative to a new technology, the challenge lies in designing a monitoring and information management framework that appropriately identifies what information is required, where applicable/relevant information exists, how data and information gaps can be filled, and how to organize and integrate information into a form that is useful for decision making (Cicin-Sain and Knecht 1998). Figure 4, based on concepts in NRC (1990), presents a conceptual framework for the development of an effects monitoring program to collect environmental and socio-economic impact data from TISEC energy development and ensure that information is integrated into the next phases of the decision making process. In accordance with NRC (1990) guidelines for the development of monitoring programs, the model calls for clearly defined objectives, appropriate procedures to identifying priority management and public issues, and a method to synthesize, interpret and report data. Monitoring information is derived from three sources: baseline data collection and monitoring, effects monitoring from TISEC device demonstration and operation, and original research designed to address unknown issues and fill information/knowledge gaps. Opportunity is provided through a feedback loop to allow program objectives and questions to be refined or redefined (i.e. to rethink the approach and objectives, or reframe management questions) as new information becomes available over the course of the development project (e.g. on interactions or impacts, more sensitive/appropriate indicators required) or as program evaluation calls for change. This feedback mechanism also allows the linkage of data collection and analysis to the needs of decision makers and the public (NRC 1990).

Figure 4. Conceptual framework for the development of a TISEC effects monitoring program and information management system (based on concepts in NRC 1990) (*indicates where author has made changes to the source information)


*Step 1: Identify public concerns associated with TISEC development
*Step 1: Identify relevant ICOM strategies, legislation, policies, & regulatory requirements and associated regulatory agencies
* Step 2: Focus understanding
*Step 3: Establish environmental and socio-economic objectives
Refine objectives
Refine objectives
*Step 4: Define expectations and goals of monitoring
Reframe questions
* Step 5: Define study strategy
*Step 6: Develop research & sampling design for:
a) Baseline data collection
*b) Research
*c) TISEC effects monitoring (short and long term)
- * test and adjust sampling design as necessary
- * define acceptable levels of change
- * identify environmental and socio-economic components to monitor
- * develop SMART indicator criteria
- * prepare testable management questions
- design statistical models
- * develop appropriate indicators
Can changes be detected?
No Yes
Rethink monitoring approach
Step 7: Implement Study
Step 8: Produce information
Is information adequate?
No Yes
* Step 9: Disseminate information to the public
* Step 10: EIA review process
*Step 11: Management decision:
Positive outcome - monitoring continues
Negative outcome - project potentially ends

7.2 Indicator development

Many challenges are associated with the development of effects monitoring programs. Major challenges in relation to TISEC monitoring are described below under four topics relating to the establishment of the baseline and reference condition, the separation of natural variability from TISEC development impacts, temporal and spatial monitoring, assessment of cumulative impact/change, and selection of appropriate indicators.

Establishing the baseline and reference condition comes first. In order to assess impacts of development, developers must establish the baseline condition against which to measure further change. In trying to establish this baseline condition it is difficult to find a natural location or socio-economic condition that would qualify as being undisturbed (or in "original condition") by human activity or influence in the Bay. The common practice is to choose a location that is as natural as possible and possesses the same/very similar environmental conditions as the development site. Differences in conditions between the reference and development sites over the lifecycle of the project presumably provide a measure of the impacts posed by development, provided that the reference site is not itself impacted by other kinds of human activities, i.e. care needs to be taken in selecting a reference site that is undisturbed as possible, reflects environmental conditions of the pre-development site, and remains as free as possible from human impact over the lifetime of the project.

Separation of natural variability from TISEC development impacts also needs to be considered. What has been learned from studies of ecological systems and change is that natural systems are complex, incompletely understood, oftentimes chaotic, and are constantly undergoing change (Wells 2005). Natural ecological change and variability are subtle, gradual or abrupt, and vary both temporally and spatially (Wells 1999; Wells 2005). An assessment of TISEC development impact however relies/depends on the ability to separate natural ecosystem change and variability from change resulting from TISEC operation and from change resulting from a combination of the two (Wells 2005).

Changes in conditions at both the reference and development sites would be measured over the project lifecycle and continually compared with original measurements at both sites. This practice should separate natural change variation (occurring at the reference site) from change due to TISEC operation (at the development site) as long as the reference site itself is free from further anthropogenic impact.

Temporal and spatial monitoring must also be addressed. TISEC operation must be monitored over an appropriate timeframe and space to define an appropriate baseline of natural change and variability to establish the reference condition against which to measure change from development activity. In the absence of baseline data, it is important that developers and researchers are given appropriate time and opportunity to establish baseline information either through original research or through the collection and synthesis of existing distributed information. Otherwise, an appropriate assessment of impacts will not be possible. Once the baseline is established, long term funding must be provided to allow monitoring to continue over an appropriate spatial extent and time to evaluate cumulative change and implications.

The environmental boundary area to monitor direct TISEC effects on lobster populations is clearly defined by the location of TISEC devices in the Minas Passage and lobster grounds, both bounded by the shorelines of the Upper Bay. However the area of socio-economic impact extends onshore to include Minas Basin watershed and beyond. The task of identifying socio-economic effects in such a vast watershed area, is made more difficult by the fact that socio-economic effects are also influenced by variations in local and regional socio-economic conditions. Oftentimes impacts are difficult to link to actual locations. Within the context of the lobster fishery, a practical consideration is to use the boundaries of the statistical district areas (STDs) to define socio-economic impact limits. The STD boundaries appear to largely coincide with those of the Minas Basin watershed. The true boundaries of socio-economic influence actually extend well beyond the study area to include an international lobster export market. It is important that proponent and regulatory agencies agree on an approach to define the boundary limits within which to evaluate environmental and socio-economic impacts.

The issue of cumulative impact/change assessment must also be addressed. Indicators must have the capacity to describe impacts of over three time scales: the short term demonstration of prototypes/single units; medium term operation of pre-commercial incremental additions of devices; and long term operation of a commercial scale turbine array (involving potentially 200 or more devices in Minas Passage). Cumulative effects may only become apparent when TISEC devices are added incrementally and operated over long periods of time (e.g. effects of other development activities; changes in other fishery practices on the lobster fishery and fishing community; the effects of climate change on species composition and distribution; and lobster interactions with other species and invasive organisms). Monitoring programs must have the flexibility to accommodate additional indicators as necessary to potentially assess the implications of a broader range and number of interactions with increasing numbers of TISEC devices in operation.

A major question is whether short term studies conducted on a demonstration project will provide information that is sufficient and reliable enough to enable managers to decide whether commercial scale development is appropriate or not. Developers and managers must not assume that the results of short term turbine demonstrations or even medium scale development can be directly extrapolated to a larger or commercial scale project. Impacts may be incremental (linear) or additive but they may be also synergistic, exponential, or even antagonistic. To assess the impacts of TISEC as a new technology, it is best that development proceed only on an incremental basis. Impact monitoring should continue to monitor cumulative ecosystem and resource changes with each incremental addition of TISEC devices. Only on the basis that incremental additions show no significant harm to the environment and its resources, should further incremental development be permitted. Devices should be removed if monitoring results show that significant adverse effects have occurred.

Finally, the choice of indicators is essential to the development of a successful monitoring program that can comprehensively assess ecosystem and socio-economic status, processes of change, and project-environment interactions. One of the key requirements of a monitoring program is that selected indicators can provide information to answer management questions, assess the impacts of shifts in baseline conditions (i.e. the range of variation in natural conditions) and monitor both short term and long term cumulative interactions anticipated over the project lifecycle. Care should be taken to choose a limited number of essential indicators that can provide answers to key issues across a broad number/range of indicator categories. Developers and managers should also consider the cost and time required for indicator use and the expertise required to analyze the results. Insofar as possible, chosen natural indicators should monitor and integrate both ecosystem structure and function (Boesch and Paul 2001).

Indicators used for short and medium monitoring timeframes may remain the same. However, the number and type of indicators to assess cumulative impacts may need to be adjusted to assess a broader array of interactions /impacts currently unknown and unanticipated. It is important that developers and researchers continue to watch for cumulative changes with each incremental addition of devices and have the flexibility to adjust monitoring programs to incorporate additional indicators as necessary to monitor cumulative effects. Cumulative effects modeling could be used as a planning tool to anticipate cumulative impacts and indicators needed in later development phases.

Developers and managers should also keep in mind the limitations of indicator use. OzEstuaries (2003) notes the following four limitations. While indicators are used to monitor change, there may be a gap between identifying change and defining the causes and the effects i.e. monitoring change using indicators does not necessarily identify the causes of an impact or its implications. Indicator monitoring cannot be used as a substitute for a comprehensive research program. Interpretations of indicator results may oversimplify the actual situation leading to erroneous or misleading conclusions. Many indicators noted in the literature have not been validated (i.e. tested to determine whether they address what they claim to address). Their applicability to any given situation must be examined carefully.

7.3 Integrated coastal and ocean management (ICOM) principles

Several ICOM principles are particularly relevant to the development of new technologies for which effects based monitoring data is not yet available. These include the precautionary approach, sustainable development, adaptive management, and integrated resource use.

The precautionary principle indicates that remedial or preventative action should be taken based on best available scientific proof, to avoid policy decisions that have irreversible adverse environmental impacts/consequences, threaten the resource base, or foreclose future generational options to resources use (Cicin-Sain and Knecht 1998). In the absence of acceptable scientific certainty, as in the case of current knowledge of TISEC development impacts, a conservative approach should be taken by regulators until the appropriate substantiation is obtained (Cicin-Sain and Knecht 1998). The lack of information should not be used to postpone adoption of cost effective measures or action to prevent potentially irreversible significant environmental harm (Cicin-Sain and Knecht 1998). The onus to demonstrate that irreversible harm has not occurred is or should be placed on the developer of the proposed project.

The principle of sustainable development emphasizes the importance of ensuring that current resource use(s) do not compromise the availability or quality of resources for use by future generations. The operation of TISEC devices must demonstrate that there are no significant adverse effects on ecosystem integrity, living resources, or physical processes essential to the long term sustainability of the marine ecosystem and natural resources. TISEC development must also contribute to the social, economic and cultural well-being of coastal communities and the general population.

Adaptive management refers to a management approach that is flexible i.e. can be changed occasionally as new information or evidence becomes available. It is important that the TISEC industry have the capacity to accommodate changes in the information requirements as new issues/interactions become evident over the lifecycle of the project.

Indicators may need adjustment to assess cumulative impacts of the incremental addition of devices over time. Also, plans for technological design, locations of demonstration and commercial deployment sites, or possibly development schedules may need adjustment should monitoring or environmental impact assessment identify significant adverse effects to the environment and natural resources (e.g. fish and invertebrate species). Plans should also be flexible to accommodate other uses of the project area (e.g. fisheries, shipping, boat transport) and safety issues, and address the effects of the environment on the project (e.g. tidal strength, ice and sediment scouring). Valuable lessons may be learned from offshore wind and oil and gas development and long term monitoring programs currently dealing with many of the same development issues (e.g. temporal and spatial scale monitoring and indicator development; short term versus long term cumulative effects monitoring and indicator needs, or meeting the needs of multiple stakeholders and regulatory agencies).

Integrated use "implies that multiple use of the ocean space and resources will be managed in a co-ordinated manner so that no single activity is seen outside the context of other users" (Walmsley 2005). DFO (2003) defines integrated management as: "a comprehensive and co-ordinated approach to planning and decision-making for sustainability, based on the balanced consideration of the full range of interests and environmental, social, cultural, economic and institutional objectives for a management area". For other industries including the lobster fishery and TISEC project to be able to work in the same marine area, there must be an acceptance that both serve a valued purpose. The TISEC industry should be granted approval to demonstrate the feasibility of a new technology and the lobster fishery should continue to have access to lobster resources. Both fisheries and TISEC industries must be willing to work in cooperation to find appropriate equitable solutions to resolve space-use and resource access issues.

7.4 Key remaining issues and management questions

During this study, it became obvious that several key management issues/questions have not been researched, fully explored in the literature, or for which there is not clear answer to date. Responses to these questions are considered important in establishing the baseline condition or in evaluating impact significance. Questions/issues fall under nine topic areas: baseline formation, energy extraction limit, impacts and change from TISEC operation, resiliency, socio-economic impacts, social well-being, exclusion zone, cumulative assessment and management response.

The baseline must establish what the tidal current circulation and sediment suspension, distribution, settlement patterns, are in the Upper Bay of Fundy and how these patterns currently influence lobster habitat and productivity. As the basis for change measurement, managers and developers must determine what is considered by stakeholders to be an acceptable, reasonable, or significant level of change within the lobster fishery resulting from TISEC development in the Upper Bay of Fundy. Also, it is important to determine the migratory patterns and movements of lobsters in the Minas Channel, Minas Passage and Minas Basin to assess the lobster population potentially impacted by TISEC development.

One of the primary issues relating to the extraction of tidal energy is the amount of energy that is removed from the tide from the operation of a single device and by each incremental addition of TISEC devices. Within an environmental context, developers need to determine how much tidal energy can be extracted without causing detrimental impacts to the ecosystem in this instance, to lobster habitat, abundance, productivity and distribution in the Upper Bay of Fundy. EPRI (2006_a) had recommended an upper limit (of 15%) could be removed without causing detrimental significant environmental impacts. However, no explanation was given on how this was derived. Nova Scotia Department of Energy (2008) attempted to explain the 15% but the explanation was not definitive or clear. What level of extraction is considered appropriate, defines not only the level of change within the ecosystem, but also the engineering design, performance, and economic feasibility of the project.

In terms of impacts and change from TISEC operation, there are four primary issues. Currently scientists do not know what the effects of sound generated by TISEC operation will be on lobster migration and health or how potentially altered habitat will affect lobster productivity, distribution, health, abundance, predator-prey relationships and the future availability of lobster to the fishery. Another key concern to the fishing community is the extent to which TISEC devices provide an artificial reef or refuge and increase fish and invertebrate productivity. It is also important that managers and developers determine as a baseline, what society will accept and not accept in terms of change to environmental and socio-economic conditions of the Bay of Fundy from TISEC energy development.

Resiliency is an important aspect of impact evaluation. With respect to resiliency there are two issues. The first concerns the capacity of the lobster population to adapt to multiple stressors/impacts over time while maintaining overall health, integrity and function. The second relates to the capacity of the lobster fishery to adapt or recover from fluctuations in the lobster population/stock availability over time. The ability to recover from stress or change will lessen negative implications but cannot be continually relied upon to reduce/mitigate effects over time. Ultimately, the ability to recover will diminish as a population is continually subjected to change or stressed beyond its natural/inherent ability to recover.

A full socio-economic evaluation is a fundamental component of the environmental impact assessment process. The literature provides very little information on potential socio-economic impacts of TISEC development. Community members who attended the OEER meeting in February 2007 in Wolfville, NS, made suggestions on what should be incorporated into a socio-economic assessment. This included an overview of current uses of the Bay of Fundy (particularly fisheries and shipping) and possible local or community development benefits including opportunities in employment, investment, community monitoring, research, manufacturing, export market development, and opportunity for reduced electrical rates.

A primary socio-economic issue relates to the potential impacts of TISEC operation on the sustainability of the lobster fishery and the well-being of the fishing community. The establishment of an exclusion zone and its affect on the ability of fishermen to access fishing grounds, sustain a livelihood and way of life is a key issue of concern expressed many times during public SEA sessions held in 2007 and 2008 (OEER 2008). The uncertainty over the potential extent and expansion of the exclusion zone and possible denial of access to fishing grounds, has caused considerable anguish within the fishing community. Fishermen may want to examine what recourse they may have if excluded from lobster fishing areas. On the other hand both TISEC industry and fishing industry may be willing to negotiate a fair reasonable agreement to share the ocean space and lessen the economic impact on the fishery. A more positive aspect of the exclusion zone is that it may itself serve as a sanctuary/conservation area for lobster to increase the lobster stock. However, fishermen will only benefit from the sanctuary effect if lobsters actually migrate or move out of the exclusion zone into an area accessible to the fishery. The extent to which the exclusion zone increases lobster numbers and lobsters move from the Minas Passage (likely exclusion zone) into the Minas Basin are therefore key areas of research.

With regard to cumulative assessment there are three major issues. The first relates to the need for a method to monitor cumulative effects from TISEC development with incremental additions of TISEC devices. Had there been previous EIA experience with TISEC development the regulatory requirements and process would already have been established. The experience of the oil and gas and offshore wind industries in cumulative impact assessment may however provide valuable guidance. The second concern relates to whether or not the results of short term demonstrations will be used as the basis for deciding if commercial scale development is appropriate. As earlier discussions have indicated TISEC development must only proceed on an incremental basis with monitoring as a regulatory requirement at each sequential development stage to assess whether or not development should proceed further. This is consistent with the precautionary principle noted above. The third issue relates to the extent to which cumulative impacts from TISEC energy extraction will be reversed following project decommissioning. This can also be expressed as the extent that the Upper Bay will recover to original reference conditions after TISEC devices have been removed. In essence, changes both in the natural and socio-economic environment from removal represent the cumulative impact or change from development.

There are several issues pertaining to management response. The first relates to the fact that regulators may wish to examine how new technologies in the past have been assessed for impacts (environmental and socio-economic). Past experience and approaches may be applicable to TISEC development. The second issue pertains to the need to establish what constitutes an acceptable and an unacceptable level of change in natural or socio-economic conditions at each incremental stage of TISEC development and operation. These levels confirmed through a long term monitoring program, would serve as a basis for decisions to move forward with development on an incremental basis, to halt further additions of TISEC devices, or to remove devices from marine waters. The third issue relates to the need to establish how the costs and benefits of TISEC development to society will be evaluated. The fourth issue calls for an examination of the information required for appropriate decision making and the development of a strategy to obtain the necessary information. The final issue relates to the need for an effects monitoring program to assess implications/impacts of demonstration prototypes and each incremental stage of development.

8.0 Recommendations

The following recommendations in most instances go beyond the recommendations made in the Government response (NSDOE 2008) to the SEA (OEER 2008). While NSDOE (2008) recommendations focus primarily on the prototype demonstration stage of development, recommendations in this paper apply to all project lifecycle stages in particular the incremental and commercial scales of development. A major focus of this paper was the development of a conceptual framework for the integration of impact monitoring information into management decisions within the context of the upper Bay of Fundy. It is recommended that regulatory agencies and the proponent consider this framework as a guide to decision making.

Within the context of this conceptual framework (Figure 4), recommendations that follow suggest a series of actions to obtain available information, generate impact monitoring data to respond to management questions, and ensure that all relevant data and information on the Bay of Fundy, are factored into the EIA decision process. Recommendations focus on coastal strategy development, relevant ICOM principles, relevant legislation, effects monitoring, cumulative effects, baseline and reference condition, boundary limits, the lobster fishery, coordination of research, and funding for research and monitoring programs.

Nova Scotia currently lacks an integrated coastal and ocean management (ICOM) strategy and legislation to set the context for future planning and development of coastal areas and to guide the decision-making process. While the NS Provincial Oceans Network (NSPON) is in process of developing such a strategy (circa July 2008), it is recommended that the government provide all possible support to expedite this process, drawing on the expertise and broad base of knowledge in universities, coastal communities, and fisheries to assist/provide advice wherever possible. It is further recommended that NSPON consider collaboration with the New Brunswick and the Federal government in developing an ICOM Bay of Fundy strategy to ensure management continuity on an ecosystem basis. The development of TISEC energy further provides an opportunity to initiate the work of the NSPON. The TISEC project can serve as a case study to illustrate how agencies of NSPON can effectively interact to manage coastal zone activities in support of sustainable energy development.

Relevant sustainable ICOM principles should be incorporated into the NS ICOM framework and be used to guide future management decisions and actions relative to TISEC development. The precautionary approach, integrated use, adaptive management principles, ecosystem integrity, and sustainable development principles are particularly applicable to the development of a new tidal energy technology where factual effects monitoring information is currently unavailable.

It is recommended that primary agencies responsible for TISEC regulation prepare a document that outlines legislation, policies, guidelines, and specific information or process requirements relevant to TISEC development in Nova Scotia. This would include legislation and policies pertaining to habitat destruction or alteration, species protection (threatened, endangered, commercial, traditional use), release of deleterious substances, traditional resource access rights (e.g. shipping and navigation, fishing) and EIA process and requirements. A document such as this would help to clarify the roles and responsibilities of the proponent in the environmental impact review process, identify legislative, policy and information gaps, and prioritize issues of concern. Such information would also assist the lobster fishermen to understand the EIA decision process, timelines, opportunities for public participation, and possible avenues for assistance.

Extensive effort is required in designing a monitoring program that appropriately addresses public concerns, impact assessment and regulatory requirements. To date, there is no indication that a TISEC developers in NS have developed their monitoring programs to assess TISEC development impacts for demonstration or commercial scale projects. As prototype demonstration tests are scheduled to begin in early 2009, it is imperative that the developer and regulatory agencies begin now to design an appropriate environmental and socio-economic effects monitoring program. The program must have the capacity to assess short term impacts of prototype demonstrations, and medium and longer term impacts from incremental additions of TISEC devices. In designing the program, it is suggested that the designers follow the guidelines outlined by NRC (1990). Program objectives must be clear, measureable and achievable and define what constitutes an acceptable and unacceptable level of change in natural or socio-economic conditions for each stage of TISEC development. A lifecycle effects monitoring program will require a long term financial commitment to support original research and the collection of existing baseline information and data. It is therefore recommended that the proponent allocate sufficient funding to evaluate the impacts of TISEC operation over each development phase of the project.

Within the context of cumulative assessment it is recommended that developers and regulators agree on cumulative evaluation criteria and an approach to assess cumulative changes. Monitoring programs must have the flexibility to incorporate additional indicators as necessary to monitor cumulative changes resulting from incremental additions of TISEC devices and other stressors on baseline conditions as development proceeds toward commercial scale.

Proponents must be granted the appropriate time to establish the environmental and socioeconomic baseline conditions through original research, monitoring and the collection and synthesis of existing distributed information. Since baseline and knowledge gaps information will be derived from multiple sources, it is recommended developers acquire the necessary expertise to validate information which may not necessarily be their own. It is also recommended that the proponent carefully select several reference sites in order to separate natural ecosystem variability from change resulting from TISEC development.

Proponents must set clearly defined boundary limits for environmental and socio-economic impact assessment. While the environmental boundary area to monitor direct TISEC effects may be defined by the shorelines of the Upper Bay, the socio-economic boundaries are less clear. It is suggested that the proponent consider the Minas Basin watershed or the statistical fishery districts boundary limits for socio-economic assessment purposes.

It is important that a sufficient level of funding be allocated for renewable marine energy research particularly TISEC development. The NS Government recently allocated \$2 million to OEER for research in tidal energy and an additional \$300,000 through the NS Ecotrust fund for environmental monitoring and research. It is suggested that the Province consider allocating a portion of this funding to collect existing baseline data on lobster populations in the upper Bay of Fundy and conduct further original research on the impacts of TISEC development. Baseline information is needed on the extent of migration of adult lobster between the Minas Channel and Minas Basin (currently underway at Acadia University 2007/08), settlement patterns/densities, larval recruitment, and population sustainability. Original research could address the effects of electrical fields and noise on lobster movements and health, avoidance/attraction response to TISEC devices, larval mortality from effects of turbine pressure gradients (Harding, G., personal communication), effects of the exclusion zone on population growth, and cumulative changes in substrates from sediment redistribution. Socio-economics research may involve studies on the effects of the exclusion zone on the sustainability of the lobster fishery, effects of community growth from TISEC development on quality of life and standards of living, and potential conflicts from the common use of coastal space and shore based infrastructure.

A key issue of concern in this study was the possible use of TISEC demonstration results to represent the impacts of multiple units. Developers and managers must not assume that the results of short term turbine demonstrations or even medium scale development can be directly extrapolated to a larger or commercial scale project. In the absence of information on TISEC development impacts, it is recommended that TISEC development proceed only on an incremental basis to allow impact monitoring and evaluation at each incremental stage. Only on the basis that no significant harm to the environment is shown by monitoring results, should development be allowed to proceed to the next incremental stage. TISEC devices should be removed if monitoring results show that significant unacceptable/adverse effects have occurred.

Providing the answers to management questions on the TISEC development effects requires a multi-disciplinary cooperative approach (Jacques Whitford 2008). Most importantly it involves collection, synthesis and evaluation of research and monitoring data from multiple sources by an appropriate coordinating body. The Province has recommended (NSDOE 2008) that the OEER and its Advisory Committee coordinate the design and implementation of a research program and agenda in renewable energy. This level of coordination is very important in ensuring that the appropriate research is conducted and that all data is integrated into next phases of the decision process. The continued work of the OEER should be supported.

Several key potential project interactions and impacts were identified in this paper through project interactions matrices. Among the most important were the impacts of TISEC development on the lobster population and fishery. It is recommended that lobster population and lobster fishery be a major focus of ecological and socio-economic assessment under the EIA process. Within the context of the Bay of Fundy, it is recommended that indicators developed by this paper should be incorporated into the effects monitoring program.

The twenty-nine recommendations of the Strategic Environmental Assessment report (OEER 2008) relating to TISEC development in NS should be supported and implemented. Both the OEER (2008) and Government response to the SEA report (NSDOE 2008) made recommendations relating to fishing industries. These included the development of a geo-referenced database of fisheries activities and resources as a tool in development planning for tidal energy, a study of potential requirements for the exclusion zone by activity type with possible impacts and mitigation strategies. In addition recommendations called for development of an acceptable compensation agreement in the event that fisheries are displaced or the environment and subsequently fisheries are adversely affected by TISEC development (NSDOE 2008). The response document (NSDOE 2008) also recommended the development of protocols and procedures to ensure that fishermen and fisheries stakeholders are consulted and informed at each stage of the tidal development project. Collectively, these recommendations address several concerns of the lobster fishery identified in this paper. Successful implementation of OEER (2008) and NSDOE (2008) recommendations is considered crucial to the future success of the TISEC industry in NS.

9.0 Conclusions

The extraction of energy from the tides in the Bay of Fundy potentially offers many environmental and socio-economic benefits. From a socio-economic standpoint TISEC energy development provides an opportunity to reduce dependency on foreign oil supplies, to expand local business development, employment, investment and research.

Environmentally, tidal energy is seen as a renewable, sustainable, predictable and clean source of electrical energy.

The report literature reviewed in this study has shown that what we currently know about development impacts is based largely on impact predictions relying on extrapolations of results from experience with other renewable energy forms, conclusions drawn from short term demonstration studies conducted elsewhere, and assumptions from preliminary research opinions. These predictions have not been confirmed through monitoring of TISEC energy devices operating under natural conditions in the Bay of Fundy. Impacts are therefore essentially unknown and unproven. What is currently understood about environmental and socio-economic impacts of TISEC operation is insufficient for management decisions to approve the advancement of the industry on a commercial level.

This study has shown that five types of information are considered necessary for better understanding of TISEC implications in Nova Scotia. These include comprehensive knowledge of the biological, physical and socio-economic baseline conditions of the Bay of Fundy; characteristics of the project site/area, accurate measurement of the tidal energy resource, an understanding of project-environment interactions, and function of the TISEC devices under natural Bay of Fundy conditions. Much is currently known about the natural and socio-economic environment of the Bay of Fundy region. However, this information has not been well organized or synthesized to respond to the many TISEC energy development questions or issues. Given the current lack of information on TISEC development impacts, the only basis on which TISEC development could proceed is on an incremental basis. Monitoring on an ongoing basis would be needed to assess the potential impacts of cumulative change from incremental additions of devices. Only on the basis that no significant harm to the environment is shown by monitoring results, should development be allowed to proceed to the next incremental stage. TISEC devices should be removed if monitoring results show that significant unacceptable adverse environmental effects have occurred.

A TISEC project interactions matrix was developed to illustrate the relative significance of potential interactions that may occur between development phases of a TISEC project and environmental components. Results identified a number of important interactions for future research. To focus research for this study, two key interactions, one environmental and one socio-economic, were selected for further discussion and the development of monitoring indicators. The environmental interaction was the environmental effects of TISEC energy extraction on the lobster population resulting from potential changes in tidal currents and sediment distribution patterns and habitat alteration. The socio-economic interaction was the effect TISEC operation on lobster abundance, productivity and distribution and consequent change(s) to the lobster fishery and surrounding communities.

This study examined the purposes of indicators and their role in monitoring programs, and identified the pressure-state-impact-response framework and Gulf of Maine Council indicator development process as appropriate models for indicator development. The criteria chosen from the literature for indicator development, were classified under the SMART (simple, measureable accessible, relevant and timely) results framework developed by Taylor *et al.* (2000). The chosen overall management objective relative to the lobster fishery and TISEC development for indicator development was "to contribute to social, cultural, economic well-being by achieving" ecological sustainability and "integrated use of the ocean space and resources" (Walmsley 2005) in the Bay of Fundy. Within this context, the sub-objective for environmental components for this study, was the sustainability of the lobster population including the maintenance of ecological structure and function to sustain the fishery. The equivalent sub-objective for economic and social well-being was the sustainability of the lobster fishery through maintenance of ecosystem health and quality for the lobster population.

A series of short term and long term/cumulative effects management questions (socio-economic and environmental) were developed to assess potential changes from TISEC development to the lobster population and fishery. A pressure-state-impact-response model was used to identify possible scenarios of change within the lobster population and fishery to identify environmental and socio-economic indicator indices or categories.

Eight environmental indices/categories of indicators were identified. Population abundance indicators emphasized stock size and availability as measures of population size, fishing effort and distribution. Productivity indicators focused on landings, settlement densities and pre-recruit abundance to assess potential population growth and changes in biomass. Environmental features/MEQ indicators emphasized chemical and physical characteristics of the environment to evaluate suitability of the environment for lobster populations. Resiliency indicators focused on maintenance of reproductive capacity, natural development, structure and function, and ability to return to a considered population baseline as measures of recovery from stress and ecosystem change. Reproductive capacity or health indicators focused on assessments of reproductive success, recruitment, incidence of disease as measures of health status, potential population growth and stock availability. Ecosystem interactions indicators emphasized measurements of multiple environmental stressors to assess cumulative effects on the lobster population. Sustainability indictors focused on recruitment, productivity, and exploitation rates to assess lobster population capacity to maintain abundance and biomass and reproductive capacity and health over time.

Eight socio-economic indices or categories of indicators were also identified. Fishing pressure indicators emphasized fishing efficiency and practices, landings and habitat disruption to measure change in population numbers from fishing effort. Population demographics focused on numbers of fishermen involved in the lobster fishery and projected growth as measures to assess change in community characteristics; Lobster fishery indicators emphasized lobster migration, available biomass, reef effect, stock health condition, extent of fishing areas and habitat substrate as measures of current conditions and change in the fishery. Public service indicators concentrated on social services available and projected to assess current and anticipated demands and capacity to meet needs. Indicators for quality of life and social well-being emphasize employment, income, employment opportunities, levels of crime, community participation, maintenance of culture and perceptions of development change to assess the extent to which current and future social conditions will meet social values, expectations and needs. Market condition indicators examine market values and growth potential, lobster prices and changes over time, and potential effects of TISEC operation on the fishery to assess potential for market development. Human resiliency indicators focus on abilities to learn, collaborate, alter activities, recover, and accept or adapt to uncertainty or change as measures of human capacity to deal with stress or recover from change. Indicators for management response focus on actions to address issues/concerns pertaining to the lobster population and fishery and measures to assess public acceptance of management actions to assess the effectiveness of lobster management programs. A series of indicators (noted above) were identified under each indices/category for use in monitoring programs in response to management questions.

A series of remaining key management issues were identified for further research as presented in section 7.4. Although each issue is important and will be addressed either through original research or the EIA and regulatory processes, six are of key concern relative to the future sustainability of the lobster fishery and population. The first issue pertains to the amount of energy that can be extracted from the tides without detrimental impacts to lobster habitat, abundance, productivity and distribution in the Upper Bay of Fundy. The second issue relates to the capacity of the lobster population to adapt to multiple stressors/impacts over time while maintaining overall health, integrity and function. The response to both of these issues will only come through continuous monitoring of impacts and assessments of the significance of cumulative changes to lobster populations.

The third issue pertains to a baseline understanding of what is considered to be an acceptable, reasonable, or significant level of change within the lobster population and fishery from TISEC development in the upper Bay of Fundy. The fourth issue focuses on the need to determine the level of change in natural conditions or socio-economic conditions at which the proponent will be required to halt further additions of devices or remove devices from marine areas as significant adverse cumulative effects are determined. Change in environmental conditions from natural variations or causes are inevitable and in many cases cannot be controlled or reversed. However, the degree of change from TISEC development is controllable by three actions. These involve knowing what level of change to environmental and socio-economic conditions is considered acceptable and unacceptable to society, stakeholders, researchers and regulators, recognizing when that level is reached through research and effects monitoring, and taking appropriate mitigation action to prevent further harm. Commitments to remove some or all devices from marine waters and to prevent further additions of devices as adverse effects become evident, must be honored. Socio-economic impact assessment will play a key role in the evaluation of public and stakeholder acceptance of change.

The fifth issue focuses on the need for research on the migratory patterns and movements of lobster populations in the Minas Channel, Minas Passage and Minas Basin. This issue relates to the collection of baseline data on the size of the resident population in the Minas Basin area and recruitment from offshore and NB waters. It also relates to the extent of the exclusion zone, access to the fishing in the exclusion area, and lobster movements from the exclusion zone into areas accessible to the fishery. Denial of access to the fishery from the creation of the exclusion zone was considered as a key socio-economic concern. Both lobster fishery and TISEC industry serve valued purposes and in so far as possible, need to find a way to work within the same marine area. Cooperation between the two industries to find appropriate equitable solutions to resolve space-use and resource access issues will go a long way toward ensuring the sustainability of both industries.

The final issue relates to the concern that the results of short term studies on the demonstration project may be used as a basis to decide whether development should proceed immediately to commercial level deployment. Assumptions must not be made that the results of short term turbine demonstrations or even medium scale development can be directly extrapolated to a larger or commercial scale project. Impacts may be incremental (linear) or additive but they may be also synergistic, exponential, or even antagonistic. It was recommended that development proceed cautiously on an incremental basis and that monitoring of each sequential addition of TISEC devices be a regulated requirement and basis for determining whether or not development should proceed further. Only on the basis that additions of TISEC devices show no significant adverse effects to the environment, its resources, and the socio-economic well-being of stakeholders and communities, should further incremental development be permitted.

A conceptual model (adapted from NRC (1990)) was developed to outline steps necessary for the development of an effects monitoring program and the collection of appropriate information for decision purposes. It is recommended that regulatory agencies and the proponent consider this framework as a guide to decision making. Within the context of this conceptual model, further recommendations suggest a series of actions to address key issues pertaining to coastal strategy development, relevant legislation, effects monitoring, cumulative effects, baseline and reference condition, boundary limits, the lobster fishery, coordination of research, and funding for research and monitoring programs, and incremental development.

Recommendations call for the development of a NS ICOM strategy to set the context for ocean renewable energy development. ICOM principles must be incorporated into the coastal policy, ocean renewable energy strategies and applied to TISEC development projects to ensure appropriate development within the coastal marine area. It is important that regulatory agencies prepare a document summarizing legislation, policy, and process requirements relevant to marine renewable energy and TISEC development to clarify roles and responsibilities of the proponent in the EIA process, identify legislative and polity gaps and prioritize issues for discussion. It was also recommended that regulators design and implement a lifecycle effects monitoring program capable of assessing short term, medium and long term cumulative effects of TISEC device operation considering the indicators identified through this study. The monitoring program must have the flexibility to incorporate additional indicators as unanticipated cumulative effects resulting from incremental additions of TISEC devices and other stressors are identified. Sufficient levels of funding must be allocated to support original baseline and impacts assessment research, monitoring of TISEC impacts under natural conditions, and the collection of environmental and socio-economic baseline data on lobster populations, fisheries, and communities in the upper Bay of Fundy. It is also recommended that the developers and regulators agree on cumulative evaluation criteria and an approach to assess cumulative changes and boundary limits for impact assessment. Proponents must be granted the appropriate time to establish the environmental and socioeconomic baseline conditions and to select reference condition sites to separate natural ecosystem variability from change resulting from TISEC development. It is recommended that lobster population and lobster fishery be a major focus of ecological and socio-economic assessment under the EIA process. To this end it is suggested that the Province consider allocating a portion of the $2 million recently granted for marine research and the $300,000 in Ecotrust funding for research and monitoring to collect existing baseline data on lobster populations in the upper Bay of Fundy and to conduct further original research on the impacts of TISEC development.

It is recommended that the 29 recommendations of the OEER (2008) SEA and NSDOE (2008) reports including those specifically related to fisheries be implemented. Fisheries recommendations call for the development of a geo-referenced database of fisheries activities and resources as a planning tool, and a study of exclusion zone requirements, impacts, and mitigation strategies. A further recommendation calls for the development of protocols and procedures to ensure that fishermen and fisheries stakeholders are consulted and informed at each stage of the tidal development project. and the appointment of the OEER and its Advisory Committee to coordinate the design and implementation of a renewable energy research program and agenda. Above all it is important that TISEC development proceed only on an incremental basis with continuous monitoring at each stage of deployment as a condition of operation. Provincial commitments specified in NSDOE (2008) must be honored to remove devices should adverse environmental impacts become evident.

Overall, there are four major recommendations of this study. The effects monitoring program must have an appropriate number and kind of indicators to monitor impacts over the lifecycle of the project. Assumptions must not be made that the results of short term prototype demonstrations or medium scale development can be directly extrapolated to a commercial scale project. TISEC development must proceed as indicted by the Province on an incremental and precautionary basis. Monitoring of impacts must take place with each incremental addition of devices as a condition of operation. Approval to move to the next development increment must be made on the basis that no significant adverse environmental or socio-economic impacts have occurred. Should adverse impacts occur, the Province has indicated that devices will be removed in accordance with permit specifications (NSDOE 2008).

In conclusion, the ability to assess change from TISEC development depends on the appropriate coordination and design of a research and monitoring program to establish the baseline and reference condition, to assess impacts over the lifetime of the project, and respond to management questions. Indicators must have the capacity to monitor cumulative changes in environmental and socio-economic conditions with each incremental addition of TISEC devices. Research and monitoring data and information must be analyzed, interpreted and presented in a way that responds to management issues and is easily understood. The coordinated integration of all relevant data and information into a decision framework is essential to informed decision making. The successful implementation of recommendations made by this study and those specified in the OEER (2008) and NSDOE (2008) reports (particularly those related to fisheries) are considered very important to the future success of the TISEC industry and to lobster fishery sustainability in NS.

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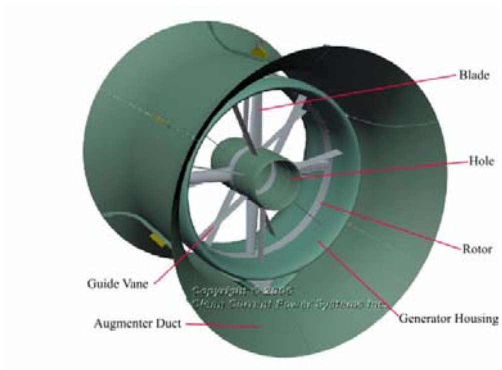
Appendix A. TISEC technologies chosen for demonstration in Nova Scotia (Derived from websites of UEK, Clean Current, and Open Hydro).

1) Clean Current



(Source: http://www.cleancurrent.com/technology/design.htm)

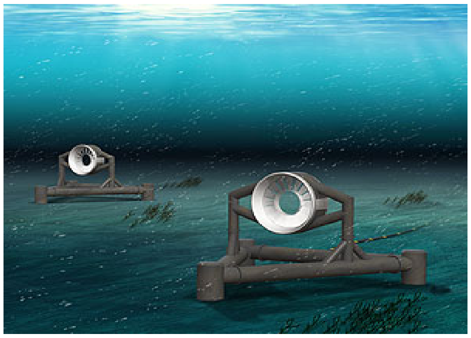
The following information/data is derived from the Clean Current Systems Incorporated website (http://www.cleancurrent.com/media/backgrounderfundy.htm). Clean Current is a fully submerged turbine cylinder containing a bi-directional horizontal rotating blade and a variable speed magnetic generator. The diameter of each blade is 17 meters with an overall device diameter of 20 meters. The generator is mounted on a post that provides a clearance of at least 15 meters to allow commercial shipping to pass above unimpeded. The operation is simplified by the fact that the rotor containing permanent magnets, are only parts that move. There is no gearbox or drive shaft therefore eliminating the need for lubrication using hydrocarbons. The reported efficiency of energy conversion is 92%. All Clean Current size models feature a hole in the center of the rotor unit which in commercial units, is 4 meters in diameter (Clean Current website). This open space is believed to provide an escape route for marine mammals or fish should enter the blade area. Generators emit low frequency noise (<100 Hz) which is below the sensitivity range for cetaceans. Fixed vanes are installed downstream and upstream of the turbine, to guide fish movement and prevent injury to fish from blade rotation. It is anticipated that the device will require a generator overhaul every 10 years and will be in service for ~25-30 years (Clean Current website). Clean current has developed three models of one design each specifically suited to extract energy at a given peak tidal current velocity. The model best suited to the Bay of Fundy, Clean Current 2.2 MW, is designed for peak tidal currents of 4.7m/s (Clean Current website). Each 2.2 MW device can provide 4GW of power/year if situated in currents that peak at 4.5m/s which is enough to power ~400 homes assuming an average residential consumption of 10,000 kW hours per year (CleanCurrent website). A turbine farm of approximately 200 devices, is estimated to be capable of supplying electricity for 80,000 homes (Clean Current website). The estimated commercial scale production cost of electricity is $0.12-0.13 kWh if located in the Minas Passage (Clean Current website).

2) UEK

(Source: http://uekus.com/The_Global_View.html)

The UEK (Underwater Electric Kite) model is a twin cylinder horizontal axis turbine -propeller that contains an augmentor ring to increase the internal water flow velocity in order to improve the efficiency of energy extraction (EPRI 2005). A UEK device is fully submerged but buoyant and secured by an anchor system to the seabed with lateral controls to maintain the unit in the appropriate current stream. The system accommodates current speeds of 4-8 knots or less than 2.5 m/sec tidal velocity (UEK website: http:/uekus.com/UEK%20Specifications.html). The device has an outer augmentor ring diameter of 5.18 meters, and turbine diameter of 4 meters and servicing is required every two years (EPRI 2005). Data on the number of homes served or predicted cost of electricity were not available.

3) OpenHydro



(Source: http://www.openhydro.com/technology.html)

OpenHydro devices similarly is a cylinder horizontal axis turbine with an outer rim that is fixed and an inner rotating disc. The turbine is either directly fixed by a foundation to the seafloor (as depicted above) or is mounted between two pole structures attached to a seabed baseplate. The pole structure allows the turbine be raised or lowered for maintenance. Similar to other devices, an encapsulated generator removes the need for a gearbox and only moving part is the turbine or rotor (EPRI 2005). OpenHydro is also fully submerged and has an open centre which is believed to minimize impacts on marine mammals and fish in providing a means of escape. Electrical output is rated at 1520 kW at water current velocities of 5 knots (2.57m/s) (EPRI 2005). The upper rim of the turbine are at least 15 m below the surface to avoid surface wave influence and interruptions in vessel passage (EPRI 2005).

Appendix B. The TISEC Project Cycle (adapted from Jacques Whitford 2008)

Timelines identified here are for wind energy project phases as this information is not yet available for TISEC development.

Site evaluation involves an assessment of locations suitable for energy development (appropriate energy resource, community support and nearby access to the electrical grid for transmission). Once appropriate sites are found, site permits are acquired, estimates are made of the cost for grid connection, and the tidal resource is validated using a test facility (Joseph and Gunton 2008). Usually for wind projects, this phase takes between 12 and 18 months (Aeolis 2005; Wittholz and Pan 2004; Ball 2002).

The **development** phase involves acquisition of the site., necessary utility license, power purchase agreement, equipment contracts, and financial agreements. It also involves completion of engineering surveys, environmental impact assessments, and obtaining any additional approvals (Joseph and Gunton 2008). For wind projects, development takes between one and three years (Aeolis 2005; Wittholz and Pan 2004; Ball 2002).

During the **construction phase**, the power facility, infrastructure and equipment are built and installed, the facility is tested, and environmental impact monitoring is conducted as required by approvals and permits (Joseph and Gunton 2008). Construction usually takes between 6 and 12 months (Aeolis 2005; Wittholz and Pan 2004; Ball 2002).

During the **operational phase**, energy is generated and the facility continues for as long as permits, leasing, or equipment allow. Monitoring and other activities may be required by permits and approvals (Joseph and Gunton 2008). The lifetime of a wind project is between 20 and 40 years (Aeolis 2005; Wittholz and Pan 2004; Ball 2002).

The last phase involves **site decommissioning** after the life of the project is complete. This usually involves removal of infrastructure and site reclamation (Joseph and Gunton 2008). Decommissioning takes between 1-2 years for wind energy projects (Aeolis 2005; Wittholz and Pan 2004; Ball 2002).

Appendix C. Integrated coastal and ocean management (ICOM) principles relevant to TISEC development stages (adapted from P.R. Hinch, Marine Affairs Program, Dalhousie University, Halifax, NS, unpublished report).

The following provides a summary of principles most relevant to tidal energy development and how they might apply throughout the TISEC project cycle.

1) Sustainable development: This principle emphasizes the importance of ensuring that current resource use(s) do not compromise the availability or quality of resources for use by future generations. Current resource use and development, technology and financial investment support must be in harmony with those of future generations (Cicin-Sain and Knecht 1998). The operation of TISEC devices must demonstrate that there are no significant adverse effects on ecosystem integrity, living resources, or physical processes essential to the long term sustainability of the marine ecosystem. TISEC development must also contribute to the social, economic and cultural well-being of coastal communities and the general populus.

2) Environmental protection and maintenance of ecosystem integrity: These principles focus on the need to prevent environmental degradation to support ecosystem structure, function and capacity to maintain/support life. They call for an understanding of ecosystem assimilative and carrying capacity i.e. the degree to which the environment can withstand and absorb perturbations and change. TISEC device demonstrations must show that there are no significant adverse environmental impacts from their operation and that their installation will not deter or interfere with conservation, protection, resource/land use planning, or restoration initiatives within the area of influence of the project. The development, demonstration and operation of TISEC pilot and commercial scale plants must be consistent with marine protection and conservation policies and regulations that sustain, preserve and protect the biological and physical environment (i.e. maintain biodiversity, habitats), and natural physical processes.

3) Ecosystem-based management: This principle highlights the importance of managing the ecosystem as an integral whole. It emphasizes that management decisions must consider interrelationships among organisms and their relationship with the physical environment. It is important that recommendations for TISEC development take into consideration the appropriate scale of the project impact as environmental effects of TISEC operation may be local, site specific, or extend over a much broader area or ecosystem. Proponents must be prepared to address regulatory requirements should impacts extend beyond the anticipated impact area.

4) Adaptive management: The principle specifies that management approach is flexible and can be occasionally changed to incorporate changes in conditions and new information Cicin-Sain and Knecht 1998). TISEC development should support change in initially proposed locations for pilot demonstration or commercial scale deployment if either environmental impact assessment or monitoring results indicate significant adverse effects of the project on environment or vise versa. Monitoring programs must also have the capacity to accommodate change in indicators to assess the impacts of incremental additions of turbines to coastal waters. The proponent must be willing to accept the possibility that the project could be cancelled and the devices removed if significant negative environmental or socio-economic effects are demonstrated in any project lifecycle stage.

5) Cumulative impact assessment (CIA): Provincial and federal environmental impact assessment reviews require that proponents predict the cumulative effects of a proposed project on the environment and vice versa. This principle could apply to an assessment of the scalability of impact results from the demonstration of a single prototype TISEC device through to the commercial scale deployment of multiple turbines in a turbine array. At the commercial scale, cumulative impact assessment must also consider cumulative changes in the ecosystem from the long term operation of multiple devices and determine whether these effects are merely additive, or synergistic, or antagonistic.

6) Ecological risk assessment (ERA): This principle refers to a method to assess both the likelihood/probability that a negative effect will occur and the severity of its consequences. ERA provides a means to identify and prioritize issues that require immediate attention and assign appropriate resources. Demonstrations of TISEC devices may use this method to assess the probability and acceptability of risks posed by devices on the environment and vice versa. As such, this information could be used to identify significant issues of concern, guide decision making, identify regulatory and monitoring requirements, and inform the environmental impact assessment review process.

7) Precautionary approach: The principle emphasizes that preventative or remedial action is needed to prevent decisions that based on the best available scientific information, have irreversible, and/or negative environmental consequences. In the absence of full information, the burden of proof is placed on the developer to demonstrate that an irreversible impact has not occurred and is not anticipated (Cicin-Sain and Knecht 1998). Developers of TISEC devices would need to show that TISEC device operation would not result in significant irreversible damage environmentally or socio-economically throughout lifecycle phases of the project. Managers/regulators need to be cautious in accepting claims that impacts and costs of prototype devices are scalable to full commercial scale development and in giving approvals for site development on this basis. They must also be careful that an appropriate set of indicators have been selected for the stage of development of TISEC devices as they may require change from one stage to the next.

8) Integrated management and use: Integrated use "implies that multiple use of the ocean space and resources will be managed in a co-ordinated manner so that no single activity is seen outside the context of other users" (Walmsley 2005). DFO (2003) defines integrated management as: "a comprehensive and co-ordinated approach to planning and decision-making for sustainability, based on the balanced consideration of the full range of interests and environmental, social, cultural, economic and institutional objectives for a management area".

Appendix D. Summary of data gaps in baseline information and knowledge of TISEC impacts on environmental and socio-economic conditions and recommendations (Source: Jacques Whitford 2008)

Key Environmental Issue	Data Gap	Recommendation
Critical Physical Processes	▪ Lack of detailed, site specific information on vertical and horizontal current structure and substrates for validation of models. ▪ Inadequate fine-scale hydrodynamic and sediment models relevant to selected sites of tidal energy development. ▪ Limited knowledge of the overall distribution and dynamics of sediments in the Bay of Fundy. ▪ Limited application of hydrodynamic models to assess the impacts of TISEC developments.	▪ Gather site specific information about substrates and sediment movement and currents for proposed development locations using in situ monitoring with ADCP and sediment sensors. ▪ Complete high density multibeam bathymetric studies of the Bay, and complete the analysis of existing data. ▪ Adapt or refine hydrodynamic models to provide adequate small-scale analyses of the potential and effects of energy extraction developments. ▪ Hydrodynamic modeling should be used to assist with the selection of sites for TISEC developments in order to optimize the extractable tidal energy potential and minimize cumulative effects on physical or biological processes.
Fisheries	▪ Absence of information on fish behaviour with respect to TISEC technologies. ▪ Inadequate knowledge on the effects of remobilized sediments on commercially important species of fish and shellfish. ▪ Questions about EMF from sub-sea cables and the effects on demersal fish and shellfish. ▪ More specific information is required regarding the number of fishing operations, vessels and products, and locations of fixed gear fisheries. Present data gathered for fisheries management purposes is insufficient for assessment of tidal power implications. ▪ Assumed existing infrastructure such as wharves would be used to support TISEC development projects—infrastructure status and availability or requirements for tidal power development is not well known. ▪ Lack of clarity on set-back requirements for marine energy developments.	▪ Conduct experimental and field-based monitoring studies of fish behavior and mortality, in the vicinity of tidal power devices. ▪ Conduct experimental studies of fish responses to vibrations or noise generated by TISEC devices. ▪ Conduct experimental studies of effects of high suspended sediments on migratory and commercial fish species. ▪ Work with fishing groups to obtain better fisheries data particularly with respect to activities near proposed development sites. ▪ Determine specific infrastructure requirements (e.g., wharves, supply bases) and necessary upgrades for each proposed project. ▪ Gather detailed information on potential adverse effects on local fisheries, and necessary mitigative measures (including project site selection). ▪ Establish consultative group including fishers and developers to create effective set-back guidelines.
Fish and Fish Habitat	▪ Data on distribution, seasonality and trophic relations of many non-commercial species of fish are not available. ▪ Absence of information on fish	▪ Conduct experimental and field-based monitoring studies of fish behavior and mortality, in the vicinity of tidal power devices. ▪ Conduct experimental studies of fish

Appendix D (continued). Summary of data gaps in baseline information and knowledge of TISEC impacts on environmental and socio-economic conditions and recommendations (Source: Jacques Whitford 2008)

Key Environmental Issue	Data Gap	Recommendation
	behaviour and/or mortality with respect to TISEC technologies, particularly with respect to noise and vibration. ▪ Questions about EMF from sub-sea cables and the effects on demersal fish.	responses to vibrations or noise generated by TISEC devices ▪ Establish an ongoing and updatable database of knowledge about local and migratory fish stocks. ▪ Identify potential mitigative measures for effects on fish populations based on experimental results.
Marine Habitat and Benthic Communities	▪ Available data on existing benthic communities are limited in the Outer Bay. ▪ Available data on existing benthic communities of the Upper Bay are limited, especially in view of some significant changes that have happened in the Bay since the data were obtained. ▪ Little existing data for many areas in the Bay.	▪ Replication of broad benthic surveys that were conducted in the 1970's. ▪ Establishment of long-term survey transects of benthic habitats and communities in priority areas for energy developments, including reference (*i.e.* non-impacted) sites. ▪ Creation of a coordinating agency to ensure consistency and quality of monitoring activities.
Pelagic Communities	▪ Similar to Fisheries and Fish and Fish Habitat issues noted above with respect to pelagic species.	▪ Similar to Fisheries and Fish and Fish Habitat issues noted above with respect to pelagic species.
Marine Mammals	▪ Lack of data on marine mammal behavioural responses to TISEC devices. ▪ Limited data available on the occurrence of marine mammals in the Upper Bay of Fundy.	▪ Study long term effects of health and behavior (*e.g.*, mortality, migration, avoidance, attraction) of tidal power development on marine mammals including monitoring of results from pilot and demonstration projects in the Bay of Fundy and elsewhere. ▪ Establish long term monitoring programs for marine mammals in the Upper Bay of Fundy, incorporating NGO resources. ▪ Identify and assess possible mitigative measures for effects of TISEC development on mammals.
Marine Birds	▪ Lack of data on marine seabird and shorebird activity in the area of priority sites. ▪ Lack of information on the trophic relationships of many marine birds, and their ability to adjust feeding preferences.	▪ Establish long term monitoring programs for marine birds in the Upper Bay of Fundy, incorporating NGO resources. ▪ Surveys to support project-specific environmental assessment prior to deployment. ▪ Identify and assess possible mitigative measures for effects of TISEC development on birds, including the secondary effects associated with changes in prey availability.

Appendix D (continued). Summary of data gaps in baseline information and knowledge of TISEC impacts on environmental and socio-economic conditions and recommendations (Source: Jacques Whitford 2008)

Key Environmental Issue	Data Gap	Recommendation
Species At Risk	▪ Requirement for better site -specific information on species presence (depending on species and location).	▪ Establish an ongoing and updatable database of knowledge about local and migratory species at risk in the Bay of Fundy. ▪ Identify and assess potential mitigative measures for different species at risk. ▪ Work with Species Recovery Teams to develop comprehensive strategies for species at risk that use areas of high priority for energy extraction. ▪ Where necessary, conduct species-specific surveys in high priority areas.
Aquaculture	▪ Similar to Fisheries above (including lack of knowledge concerning appropriate setback distance from TISEC devices).	▪ Similar to Fisheries above.
Marine Transportation	▪ Uncertainty regarding level of interaction with other marine transportation users in the study area.	▪ Stakeholder consultation (other marine users). ▪ Regulatory consultation (*e.g.*, *NWPA* process). ▪ Detailed navigation safety assessments and underkeel clearance surveys in the context of site specific project EA and project site selection.
Tourism and Recreation	▪ Lack of information on informal and unregulated recreational activities.	▪ Project-specific data gathering as part of site specific EA process (including shore-based facilities).
Marine and Coastal Archaeological and Heritage Resources	▪ Uncertainty regarding the location and condition of many potential archeological and heritage resources (marine and shore-based) in the study area.	▪ Detailed site specific bathymetric survey using side-scan sonar as part of project specific EA process. Follow up with ROV survey if sonar shows potential resources. ▪ Detailed archeological survey may be necessary as part of shore-based facility site selection and EA process.
Economic Development	▪ Uncertainty in identification of specific business opportunities for local business. ▪ Local capacity not clear.	▪ Local economic benefits study in context of project specific EA process. ▪ It is recommended that an Energy Sector Capability Study be commissioned for Atlantic Canada to address the barrier to supply-chain deficiencies within Atlantic Canada's Energy Sector, particularly within Nova Scotia and New Brunswick. ▪ Study potential benefit agreements. ▪ Project-specific job fairs.

Appendix D (continued). Summary of data gaps in baseline information and knowledge of TISEC impacts on environmental and socio-economic conditions and recommendations (Source: Jacques Whitford 2008)

Key Environmental Issue	Data Gap	Recommendation
Species At Risk	▪ Requirement for better site -specific information on species presence (depending on species and location).	▪ Establish an ongoing and updatable database of knowledge about local and migratory species at risk in the Bay of Fundy. ▪ Identify and assess potential mitigative measures for different species at risk. ▪ Work with Species Recovery Teams to develop comprehensive strategies for species at risk that use areas of high priority for energy extraction. ▪ Where necessary, conduct species-specific surveys in high priority areas.
Aquaculture	▪ Similar to Fisheries above (including lack of knowledge concerning appropriate setback distance from TISEC devices).	▪ Similar to Fisheries above.
Marine Transportation	▪ Uncertainty regarding level of interaction with other marine transportation users in the study area.	▪ Stakeholder consultation (other marine users). ▪ Regulatory consultation (*e.g.*, *NWPA* process). ▪ Detailed navigation safety assessments and underkeel clearance surveys in the context of site specific project EA and project site selection.
Tourism and Recreation	▪ Lack of information on informal and unregulated recreational activities.	▪ Project-specific data gathering as part of site specific EA process (including shore-based facilities).
Marine and Coastal Archaeological and Heritage Resources	▪ Uncertainty regarding the location and condition of many potential archeological and heritage resources (marine and shore-based) in the study area.	▪ Detailed site specific bathymetric survey using side-scan sonar as part of project specific EA process. Follow up with ROV survey if sonar shows potential resources. ▪ Detailed archeological survey may be necessary as part of shore-based facility site selection and EA process.
Economic Development	▪ Uncertainty in identification of specific business opportunities for local business. ▪ Local capacity not clear.	▪ Local economic benefits study in context of project specific EA process. ▪ It is recommended that an Energy Sector Capability Study be commissioned for Atlantic Canada to address the barrier to supply-chain deficiencies within Atlantic Canada's Energy Sector, particularly within Nova Scotia and New Brunswick. ▪ Study potential benefit agreements. ▪ Project-specific job fairs.

Appendix E. Summary of gaps in knowledge and understanding of TISEC impacts (information derived from OEER 2007; Jacques Whitford 2008; EPRI 2006_b; EPRI 2006_a)

Effects of TISEC devices on the physical environment

Energy extraction:

- short and long term cumulative effects of energy extraction on coastal processes (e.g. changes in erosion, sediment properties (including cohesiveness, organic and toxic contaminant content, grain size, surface weathering), and sediment distribution patterns (including suspension, deposition, remobilization); water movement/circulation (turbulence, turbidity, scouring and vertical mixing, upwelling, stratification) (OEER 2007) (Jacques Whitford 2008); exchange of materials (e.g. oxygen, nutrients, contaminants); light levels; and persistence in ice formation (Jacques Whitford 2008)

Contaminants:

- absorption by sediments of equipment dispersants, biocides, and oils (Jacques Whitford 2008)

Substrate change:

- cumulative effects from disturbance of substrate and underling glacial sediments and marine clays on erosion, water depth, and sediment redistribution (Jacques Whitford 2008)

Effects of TISEC on the biological environment

Benthic communities:

- effect of construction and changes in sediment deposition on benthic organism distribution and productivity (Jacques Whitford 2008)
- susceptibility of benthic organisms from non-weathered particulates generated during

excavation (Jacques Whitford 2008)

- effect of pile driving on fish (swim bladder), benthic and pelagic invertebrates health and behaviour (Jacques Whitford 2008)
- effects of jet plowing on benthic populations (OEER 2007)
- effects of sediment deposition and remobilization on benthic communities (OEER 2007; JacquesWhitford 2008)

Primary and secondary productivity:

- effect of turbine operation on primary and secondary productivity (OEER 2007) (by affecting light and nutrient levels) (Jacques Whitford 2008)

Energy extraction:

- effects of reductions in downstream current velocity on food supply for benthic filter feeders, with consequent effects on bird and fish populations that dependent on them (Jacques Whitford 2008)
- effects of sediment resuspension on filter-feeding organisms and fish (Jacques Whitford 2008)
- effects of turbine operation (reduction in current velocity downstream) on the transport/vertical movement and settlement of larvae within the water column (EPRI 2006_b; Jacques Whitford 2008)
- cumulative temporal and spatial effects of energy extraction on biophysical characteristics (e.g. change in sediment distribution and deposition on benthic organisms with secondary effects on feeding potential and movement of whales, marine birds, and migratory fish) (Jacques Whitford 2008)

Fish and marine mammals:

- potential for physical harm to fish and marine mammal from contact with turbines (EPRI 2006a)
- potential of fish mortalities from TISEC operation and impacts of blade spacing and speed of rotation on ability of fish to avoid contact (Jacques Whitford 2008)
- effects of artificial lighting on fish behaviour (Jacques Whitford 2008)

- effects of operation on migratory fish species, schooling fish, mid-water and bottom Fish (Jacques Whitford 2008)
- impact of device installation and operation (noise, vibrations pollution, electrical and magnetic fields, silt concentrations, changes in current flow, habitat destruction or modification) on behaviour, migration, movement or navigation of marine mammals (OEER 2007), benthic fisheries, migrating fish populations (e.g. striped bass, Atlantic salmon, alewife, herring, sturgeon, smelt), species at risk (e.g. porbeagle, shark, Atlantic salmon, finback whales, harbour porpoise), planktonic larvae, non-fish nekton (e.g. euphausiids and longfin squids), pelagic and demersal fish, lobster, birds (e.g. diving (cormorants), intertidal, and migratory shorebirds (sandpipers, plovers)), (OEER 2007; (Jacques Whitford 2008)
- entrapment of marine mammals by cables (OEER 2007)
- response of fish and marine mammals to device noise, and rotating turbine blades (avoidance or attraction) (OEER 2007)
- benefits of the infrastructure to the fishery (sanctuary or reef effect (OEER 2007; EPRI 2006_b)
- potential for habitat creation by rip-rap or scour protection provided by the structure for fish and benthic organisms (epibenthic and biofouling) (Jacques Whitford 2008)
- potential for species composition shift in the project area resulting in change to marine ecology (EPRI 2006_b)
- effects of TISEC devices on the salinity wedge on which some fish species life stages depend for transport to nursery areas (EPRI 2006b)
- impacts of turbine devices on drifting eggs and schools of migrating Atlantic salmon and herring in the Minas Passage (EPRI 2006 b)

Effects of the physical/biological environment on TISEC projects

Physical processes:

- effect of tidal currents on turbine stability (EPRI 2006a)
- effects of climate change on tidal energy development (potential long term risk of coastal flooding, erosion, sediment deposition and ice damage and changes in

temperatures, salinity, and habitats/ecosystems) (OEER 2007)

- potential for ice damage and effect on engineering requirements (EPRI 2006a)
- effects of ice scouring/damage, sediment souring, coverage by a sandbar, and tidal force on device stability (OEER 2007)
- difficulties in anchoring devices to the seafloor (OEER 2007)

Biological processes:

- bioaccumulation on turbine and support structure (EPRI 2006a)

Effects of TISEC devices on the socio-economic environment

Exclusion zone:

- temporary effects of construction and installation on recreational activities (e.g. visual impacts, aesthetics, access to coastal areas/quality of experience)
- long term effects of an exclusion zone on: fishing industries and/or use of fishing gear; tourism and recreational industries/activities (e.g. sea kayaking, whale watching and coastal water access (Jacques Whitford 2008; OEER 2007)

Economic development:

- cumulative effect of TISEC expansion on existing land-based facilities and infrastructure (Jacques Whitford 2008)
- cumulative effects to the Bay of Fundy resulting from TISEC development, other development activities and ecosystem changes (Jacques Whitford 2008)
- potential competition for investment resources (e.g. displacement of economically marginal or established fisheries by investments in TISEC energy development) (Jacques Whitford 2008)
- potential for lasting economic benefits to Nova Scotia (OEER 2007)
- opportunity for economic growth and business development (e.g. fabrication, installation, maintenance and monitoring activities (OEER 2007)
- potential community involvement in monitoring (OEER 2007)
- opportunity for local investment in the project (OEER 2007)

- potential opportunities to provide support services e.g pre-deployment services (e.g. project management, surveying, resource mapping/modeling, cable laying, utility upgrade, transportation upgrades, technology design, materials research/testing, device transport/assembly;) and deployment and maintenance (e.g. equipment and infrastructure, environmental monitoring, device operation, and maintenance activities) (OEER 2007; Jacques Whitford 2008)
- opportunities for job creation, benefit agreements, generation of provincial revenues, economic spinoffs, capacity development, and expansion in export market (Jacques Whitford 2008)
- opportunities for specialized training of the local workforce (Jacques Whitford 2008)

Fisheries and aquaculture:

- potential impacts on the aquaculture industry (e.g. from resuspension of sediments, noise and vibration or competition for ocean space with aquaculture and TISEC expansion into common waters) (Jacques Whitford 2008)
- potential conflict/competition for shore based infrastructure currently supporting aquaculture and fisheries sectors (e.g. wharves) (Jacques Whitford 2008)
- impacts of device operation (noise, vibration, sediments) in Digby Gut to commercial trawling and gillnet fisheries (e.g scallop, haddock, pollock, herring shad, gaspereau), and in the Minas Passage, the lobster fishery, dragging or handline fisheries (e.g. haddock, spiny dogfish, pollock), drift or gillnet fisheries (e.g. Atlantic herring and American shad), purse seining (e.g. herring), demersal fishery (e.g. winter founder, Atlantic sturgeon), and shellfish fishery (e.g. scallops and soft shelled clams) (Jacques Whitford 2008)
- potential hazard posed by lost fishing gear on the structure (Jacques Whitford 2008)
- impact of anchoring on submerged TISEC cables and equipment (Jacques Whitford 2008)

Research:

- opportunities for collaborative research (Jacques Whitford 2008)

Safety:

- safe deployment of devices (OEER 2007)

Visual impact:

- aesthetics of turbine arrays (EPRI 2006a)

Archaeological resources:

- project impacts of operation on known and potential terrestrial and marine archaeological and heritage sites including shipwrecks (OEER 2007; Jacques Whitford 2008)

Transportation and navigation:

- potential interaction with fishing vessels both in transit and during fishing activities, recreational boating, and restrictions in channel navigation restrictions (aquaculture operations) (Jacques Whitford 2008)
- effects of construction and operation on marine transportation and navigation (involving bulk carriers, tugs, fishing fleets, yacht clubs, gypsum industry (Hantsport), eco-tourism industry, and ferry services (for Digby Gut area)) (Jacques Whitford 2008)

Recreation:

- long term effects of turbine presence on recreational boating (Jacques Whitford 2008)

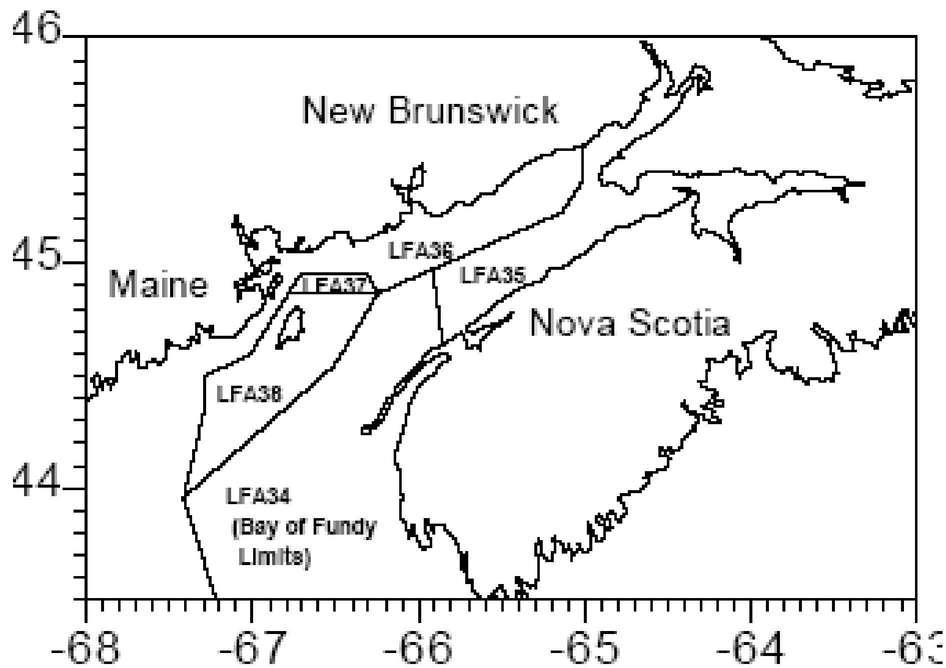
Appendix F. Potential socio-economic interactions between a TISEC project and the lobster population (model adapted from Darce and Bullen 2001 and DTI 2002)

Project lifecycle stages	Lobster Lifecycle stages	Reproduction			Larval			Settlement			Cryptic			Emergent				Adult			
		Spawning & hatching areas	Health /growth	Egg production	Contam. sensitivity	Light sensitivity	Survival /dev't	Substrate /habitat	Contam. & health	Health/disease	Pollution /disease	Recruit. /health	Habitat /substrate	Prey abundance	Predator abund.	Distribution/migr	Abundance/health	Habitat /substrate	Predator/prey abundance	Distrib/migration	Health /growth/ abundance
Construction	Seabed preparation (gravel/cobble removal)	x						x				x	x	x	x	x	x	x	X	x	
	Noise & vibration	x			x					x		x		x	x	x	x		X	x	x
	Site lighting					x							x								
	Sed. mobilization	x						x		x		x		x	x	x	x	x	X	x	
	Pres. of install equip (sanctuary, exclusion)	x						x					x	x	x	x	x		X	x	
	Instal of foundation or pilings	x						x					x	x	x	x	x	x	X	x	
	Drilling fragments		x		x		x	x		x	x			x	x	x	x		X	x	x
	Grouting &cementing	x								x				x	x	x	x		x		
	Install. of turbine	x						x					x	x	x	x	x		x	x	
	Minor oil leaks/spills	x	x		x		x		x	x	x	x		x	x	x	x		x	x	x
	Disposal of dredge spoils		x		x		x		x	x	x	x		x	x	x	x		x	x	x
Operation and Maintenance	Temperature	x	x	x			x			x		x		x	x	x	x		x	x	x
	Alteration in currents/ water flow/circulation	x					x	x		x		x	x	x	x	x	x	x	x	x	x
	Noise, vibration		x							x		x	x	x	x	x	x		x	x	x
	Habitat alteration	x	x				x	x		x		x	x	x	x	x	x	x	x	x	x
	Energy extraction & sediment redistribution	x						x		x		x	x	x	x	x	x	x	x	x	x
	Minor oil leaks/spills	x	x		x		x		x	x	x			x	x	x	x		x	x	x
	Pres. of turbine	x						x					x	x	x	x	x	x	x	x	x

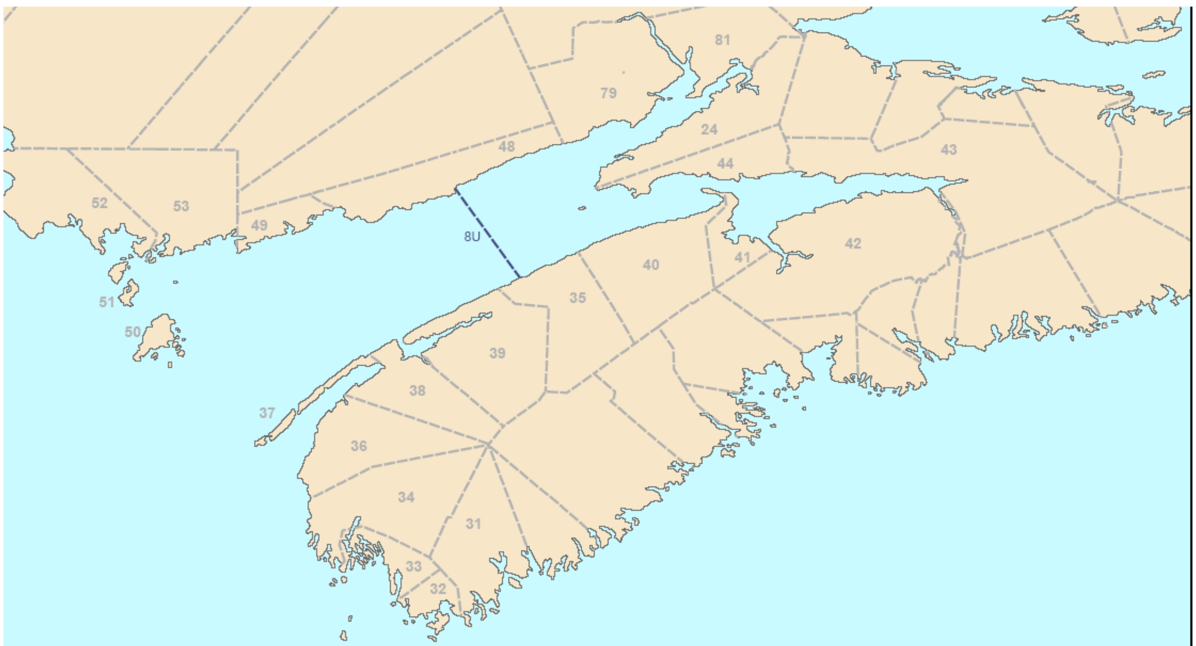
Project lifecycle stages		Reproduction			Larval			Settlement			Cryptic			Emergent				Adult			
	Lobster Lifecycle stages	Spawning & hatching areas	Health /growth	Egg production	Contam. sensitivity	Light sensitivity	Survival /dev't	Substrate /habitat	Contam. & health	Health/disease	Pollution /disease	Recruit. /health	Habitat /substrate	Prey abundance	Predator abund.	Distribution/migr	Abundance/health	Habitat /substrate	Predator/prey abundance	Distrib/migration	Health /growth/ abundance
	Operation of turbine						x							**x**	**x**				x		
	Lobster predator impacts						**x**			**x**		x			x	x	**x**		**x**	**x**	**x**
	Lobster prey impacts						**x**			**x**		x		x		x	**x**		**x**	**x**	**x**
	Water quality	x	**x**				**x**		x	**x**	x	x		x	x	x	**x**		x	x	**x**
	Electrical gen. (EMR)	x	**x**							**x**		x		x	x	x	**x**		x	x	**x**
	Maintenance/repair (activities, pres of equipment, lighting)	x			x	x		x		x	x		x	x	x	x	x		x	x	x
	Upwelling/stratification		x				x			x				x	x	x	x		x	x	x
Decom-missioning	Pres. of equip.	x				x		x					x	x	x				x	x	
	Structure removal	x				x		x					x	x	x			x	x	x	
	Disposal							x					x					x			

Matrix key: ■ Potentially significant interaction

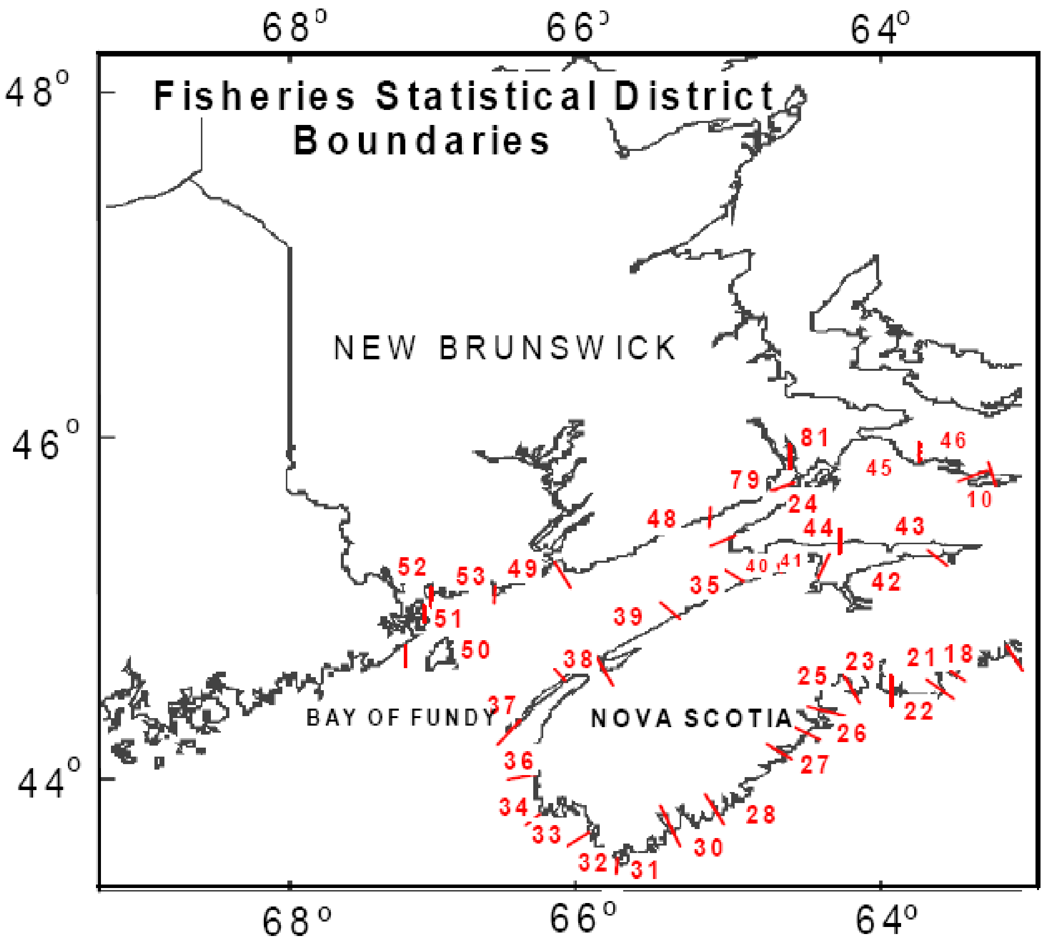
Appendix G. Lobster fishing areas (LFA) in Nova Scotia (Source: DFO 1998)



Appendix H. DFO Fisheries Statistical District Boundaries for the Bay of Fundy (Source: Dyer *et al.* 2005)



Appendix I. Limits of Fisheries Statistical District boundaries for the Bay of Fundy (Source: DFO 2007c)

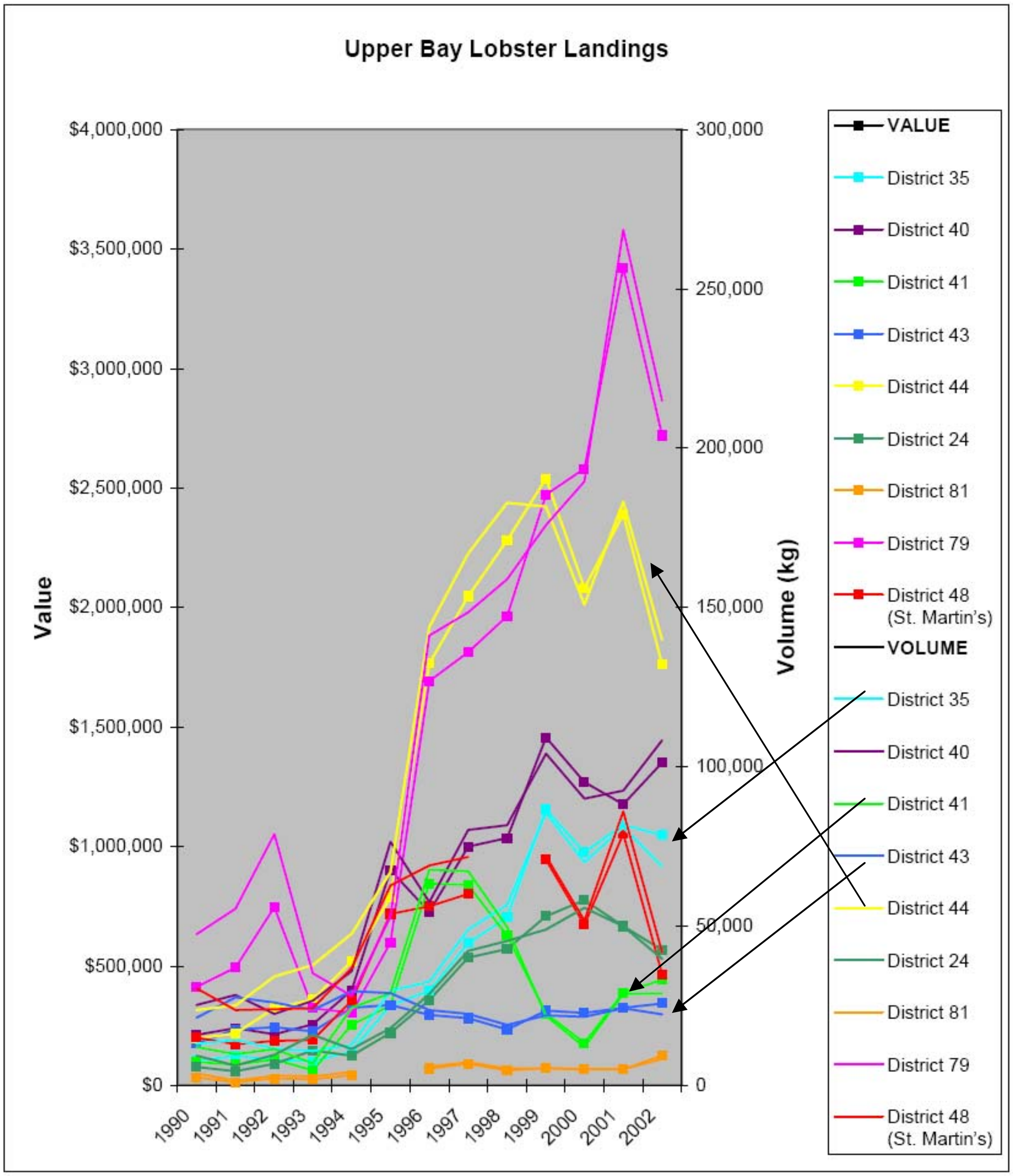


Appendix J. Lobster landings by Statistical District (STD) for LFA 35 (Source: DFO 2007c)

Table 3.1.3a. Lobster landings in MT by Statistical Districts (STD) for LFA 35.

Season	STD79	STD81	STD24	STD44	STD43	STD41	STD40	STD35	STD39	STD38	LFA 35 Total
1983-84	62.0	8.0	10.0	13.0	14.0	9.0	16.0	9.0	20.0	15.0	**176.0**
1984-85	76.0	10.0	13.0	20.0	19.0	8.0	24.0	17.0	28.0	17.0	**232.0**
1985-86	72.0	6.0	7.0	33.0	15.0	15.0	18.0	19.0	50.0	19.0	**254.0**
1986-87	99.0	7.0	11.0	44.0	19.0	15.0	28.0	16.0	78.0	18.0	**335.0**
1987-88	77.0	12.0	13.0	33.0	14.0	19.0	20.0	19.0	55.0	13.0	**275.0**
1988-89	84.0	6.5	15.0	31.3	20.0	20.1	32.7	15.3	41.2	13.0	**279.1**
1989-90	64.0	6.4	10.5	25.5	18.0	14.3	29.8	20.8	45.9	20.6	**255.8**
1990-91	42.1	0.9	4.0	26.9	27.0	9.4	25.9	24.9	52.0	20.2	**233.3**
1991-92	58.0	2.2	10.6	27.6	27.0	12.4	22.7	20.6	50.6	30.7	**262.5**
1992-93	61.5	4.6	10.9	36.1	24.0	7.5	23.7	16.9	32.0	23.7	**240.8**
1993-94	44.8	2.8	8.6	43.2	20.0	14.4	31.7	18.3	40.8	17.2	**241.8**
1994-95	24.8	1.7	19.5	62.4	33.0	29.2	53.4	18.1	45.2	21.9	**309.3**
1995-96	99.5	3.1	24.6	92.9	28.0	42.2	71.9	52.3	113.9	30.7	**559.2**
1996-97	147.4	6.9	32.8	145.4	25.0	66.4	63.5	66.0	153.0	42.4	**748.8**
1997-98	151.4	6.8	47.3	184.8	22.0	67.1	84.9	72.4	163.4	44.2	**844.3**
1998-99	164.5	5.1	48.6	198.6	23.4	37.0	96.6	128.0	184.2	70.1	**956.0**
1999-00	185.7	4.3	54.8	143.4	15.5	19.0	89.4	107.8	236.4	76.2	**932.4**
2000-01	213.8	5.8	47.5	164.6	25.3	15.9	87.6	117.7	290.6	123.4	**1092.2**
2001-02	234.2	5.5	37.0	157.1	19.1	32.5	100.2	153.3	286.5	226.0	**1251.4**
2002-03	179.5	8.8	38.4	128.4	21.9	28.8	99.9	139.6	288.9	281.8	**1215.9**
2003-04	154.7	7.1	33.8	127.0	24.2	27.6	96.0	121.0	308.9	416.0	**1316.3**
2004-05	162.4	7.3	25.0	118.1	23.7	29.8	114.2	105.9	319.1	220.8	**1126.4**
2005-06	141.8	5.9	17.0	112.5	19.3	26.8	92.9	87.2	219.2	250.5	**973.3**

Appendix K. Upper Bay Lobster Landings by STD (Source: Dyer *et al.* 2005)



Appendix L. Lobster licenses by district in the upper Bay of Fundy (Source: Dyer *et al.* 2005)

Licenses 2004	**Lobster**
District 35	5
District 40	8
District 41	4
District 42	2
District 43	12 (Truro – 10)
District 44	12
District 24	3
District 81	1
District 79	18 (Alma – 18)
District 48	11 (St. Martins – 11)
Total	76

Appendix M. Potential socio-economic interactions between a TISEC project and the community (model adapted from Darce and Bullen 2001 and DTI 2002)

Socio-economic components / Project lifecycle stages		Pop. demo.		Economic aspects						Market impacts					Social impact				
		Pop. characteristics	**Pop. trends**	**Employment (short-term)**	**Employment (long -term)**	**Lobster fishery**	**Lobster fishing community**	**Traditional use**	**Coastal dev't char.**	**Revenue generation**	**Housing demand**	**Goods & Services**	**Supply chain cap.**	**Knowledge export**	**Pub. service demand**	**Aesthetic quality**	**Perceived health**	**Equitable opp. & sust. income**	**Attitude on devt & social change**
Construction	Install.equip.transport	x	x	x						x		x	x		x				
	Seabed preparation	x	x	x						x		x	x		x				
	Instal. piling foundations	x	x	x						x		x	x		x				
	Disposal dredge spoils	x	x	x		x				x		x	x		x	x			
	Installation of foundation	x	x	x						x		x	x		x				
	Installation of subsea cables	x	x	x		x				x		x	x		x				
	Installation of turbine	x	x	x		x	x			x		x	x		x				
	Land activities	x	x	x						x		x	x		x	x			
	Grouting and cementing	x	x	x						x		x	x		x				
	Transport to sites	x	x	x			x	x		x		x	x		x				
	Presence of structure (sanctuary effect)					x	x	x									x	x	x
	Exclusion zone					x	x	x									x	x	x
	Env. res.& devt	x	x		x	x	x			x				x	x		x	x	x
	Socio-economic research	x	x		x	x	x			x	x			x	x		x	x	x
	Employment/ educ. opp.	x	x	x			x			x	x						x	x	x
	Grid connection	x	x	x						x		x	x						
	Public involvement						x											x	x

Project lifecycle stages	Socio-economic components	Pop. demo.		Economic aspects						Market impacts					Social impact				
		Pop. characteristics	Pop. trends	Employment (short-term)	Employment (long -term)	Lobster fishery	Lobster fishing community	Traditional use	Coastal dev't char.	Revenue generation	Housing demand	Goods & Services	Supply chain cap.	Knowledge export	Pub. service demand	Aesthetic quality	Perceived health	Equitable opp. & sust. income	Attitude on devt & social change
Operation and Maintenance	Electrical generation (linkage & EMR emissions)			x		x							x		x				
	Turbine operation	x	x		x	x	x	x	x	x	x	x	x		x				
	Tidal energy extraction					x			x				x	x			x		
	Maintenance/repair	x	x		x					x		x	x			x			
	Minor oil leaks/spills	x	x	x		x				x			x		x		x		
	Presence of structure (sanctuary effect)					x	x	x											
	Exclusion zone					x	x	x									x	x	x
	Transport to sites			x			x	x		x		x	x		x				
	Env. res.& dev't	x	x		x	x	x	x		x				x	x		x	x	x
	Socio-economic research	x	x		x	x	x	x		x				x	x		x	x	x
	TISEC development	x	x	x		x	x	x	x	x	x	x	x	x	x				
	Development impact considerations				x	x	x		x						x		x		x
	Employment /educ. opp.	x	x				x				x				x		x	x	x
Decom-mission	Pres. of equip.					x	x	x											
	Structure removal	x	x	x		x	x	x	x	x		x	x		x	x			
	Disposal	x	x	x						x		x	x		x	x			

Matrix Key: Potentially significant interaction

Table 1. Potential TISEC interactions with environment and socio-economic components (model adapted from Darce and Bullen 2001& DTI 2002)

Environmental Components / Project Lifecycle Phases		Physical Environment														Biological Environment									Socio-economic Environment										
		Substrate/seabed	Tidal currents	Ice /scouring	Sedimentation	Climate /atmos.	Water Quality	Water Column	Coastal change	Temperature	Noise, vib /EMR	Suspended seds.	Vertical mixing	Plankton	Pelagic organisms	Demersal orgs.	Benthos	Pinnipeds	Cetaceans	Seabirds	Invertebrates	Marine/coastal plants	Bioaccumulation	Protected areas	Cable ** chnge	Fishing	Shipping	Tourism	Recreation	Other uses	Archaeol. sites	Locall economy	Loclal residents & communities	Research & dev't	Tech. capacity
Installation	Transp of installation equip.					x					x															x	x	x	x	x		x	x	x	x
	Presence of install equip.	x		x			x	x			x				x	x	x	x	x	x	x			x		x	x	x	x	x	x	x	x	x	
	Seabed preparation	x			x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x		x	x	x	x			x
	Instal. piling foundations	x		x	x		x	x	x		x	x			x	x	x	x	x	x	x			x	x	x	x		x	x	x	x			x
	Disposal of dredge spoils	x			x		x	x	x						x	x	x	x	x	x	x			x			x			x	x	x	x	x	x
	Installation of foundation	x		x	x		x	x	x		x	x			x	x	x	x	x	x	x			x	x	x	x		x	x	x	x			x
	Installation of subsea cables	x		x	x		x	x	x		x	x			x	x	x	x	x	x	x			x	x	x	x		x	x	x	x			x
	Installation of turbine	x		x	x		x	x	x		x	x			x	x	x	x	x	x	x			x	x	x	x		x	x	x	x			x
	Land activities				x				x		x									x		x		x				x	x	x	x	x	x	x	x
	Grouting and cementing				x		x	x							x	x	x	x	x	x	x			x		x	x				x	x			x
	Presence of turbine	x	x	x	x				x		x			x	x	x	x	x	x	x	x		x	x		x	x	x	x	x	x	x	x		x
Operation & Maintenance	Minor oil leaks/spills	x			x		x	x	x					x	x	x	x	x	x	x	x	x				x							x	x	x
	Turbine operation	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x		x	x	x	x
	Tidal energy extraction	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x	x	x												x	x
	Maintenance/repair	x			x			x	x		x	x			x	x	x	x	x	x	x					x	x		x	x		x	x	x	x
	Grid connection								x		x											x			x							x	x		x
	Electrical generation					x																			x							x	x		x
Decomm-issioning	Presence of equipment	x					x				x				x	x	x	x	x	x	x					x	x		x	x			x		
	Structure removal	x	x		x	x	x	x			x	x			x	x	x	x	x	x	x	x	x		x	x	x	x	x	x		x	x		x
	Disposal	x					x	x	x	x																						x	x		x

b

Table 2. Significance matrix: Potential project-environment and socio-economic interactions (Model adapted from DTI 2002 and EMEC 2005)

(Adapted from DTI 2002)		Physical Environment														Biological Environment									Socio-economic Environment										
Project Lifecycle Phases	Environmental Components	Substrate/seabed	Tidal currents	Ice /scouring	Sedimentation	Climate /atmos.	Water Quality	Water Column	Coastal change	Temperature	Noise, vib /EMR	Suspended seds.	Vertical mixing	Plankton	Pelagic organisms	Demersal orgs.	Benthos	Pinnipeds	Cetaceans	Seabirds	Invertebrates	Marine /coastal plamts	Bioaccumulation	Protected areas	Cable	Fishing	Shipping	Tourism	Coastal recreation	Other uses	Paleo . & archaeol. sites	Local economy	Communities	Research & dev't	Tech. capacity/training
Installation	Transp of installation equip.					1					1															1	1	1	1	1		1	1		1
	Presence of install equip.	1		1			1	1							1	1	1	1	1	1	1			1		1	1	1	1	1	1	1	1		
	Seabed preparation	1			1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1		1	1	1	1		1	1
	Instal. piling foundations	1		1	1		1	1	1		1	1			1	1	1	1	1	1	1			1	1	1	1		1	1	1	1		1	1
	Disposal of dredge spoils	1			1		1	1	1						1	1	1	1	1	1	1			1			1			1	1	1	1	1	1
	Installation of foundation	1		1	1		1	1	1		1	1			1	1	1	1	1	1	1			1	1	1	1		1	1	1	1		1	1
	Installation of subsea cables	1		1	1		1	1	1		1	1			1	1	1	1	1	1	1			1	1	1	1		1	1	1	1		1	1
	Installation of turbine	1		1	1		1	1	1		1	1			1	1	1	1	1	1	1			1	1	1	1		1	1	1	1		1	1
	Land activities				1				1		1									1		1		1				1	1	1	1	1	1		1
	Grouting and cementing				1		1	1							1	1	1	1	1	1	1			1		1	1				1	1			1
	Presence of turbine	5	5	5	5				5		5			5	5	5	5	5	5	5	5		5	5		5	5	2	5	5	5	5	5	5	5
Operation & Maintenance	Minor oil leaks/spills	1			1		1	1	1					1	1	1	1	1	1	1	1	1				1							1	1	1
	Turbine operation	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	5	5		3		5	5	2	5	5	5	5	5	5	5
	Tidal energy extraction	5	5	5	5	5	5	5	5		5		5	5	5	5	5	5	5	5	5	5									5			5	5
	Maintenance/repair	2			2			2	2		2	2			2	2	2	2	2	2	2					5	5		5	5		2	2	2	2
	Grid connection								5		5											1			1							5	5		5
	Electrical generation					5					5														1							5	5		5
Decomm-issioning	Presence of equipment	1					1				1				1	1	1	1	1	1	1					1	1		1	1			1		
	Structure removal	1	1		1	1	1	1			1	1			1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1
	Disposal	1					1	1	1																							1	1		1

d

Table 3. Interactions Matrix Key

<u>Interaction Frequency (adapted from DTI 2002)</u>

1 One time occurrence within a 6–11 month period
2 Low frequency – 3–5 times a year
3 Minimum frequency – 6 times a year
4 High frequency – 7 or more times a year
5 Ongoing – continuous

<u>Interaction Magnitude</u> (adapted from DTI 2002 and EMEC (2005))

Scale of interaction	**Ecological effects**	**Socio-economic effects**
No interaction	None	None
Minor	Species or habitat change/impact falls within the bounds of natural variability. Change is negligible, difficult but possible to detect, observe and measure. Recovery or mitigation is anticipated within 2 years.	Slight change is noticed in commercial or business activities and opportunities. There are no negative effects on other activities. No negative effects are observed on public or community health or social well-being. There are minor impacts on employment opportunities.
Moderate	Short term change is observed in habitat or species beyond natural variability. Recovery or mitigation is possible within 2 years.	Change occurs in commercial activity with loss of opportunity or employment on a short term temporary basis but within normal commercial variability or risk. Opportunities return in less than 2 years. Unlikely but possible effect on public health or social well-being.
Major (yellow)	Significant but short term change in species health, and availability or quality of habitats. Recovery takes between 2 and 5 years.	Significant changes in commercial activities leading to medium term losses in income and employment opportunities beyond normal levels of commercial risk/variability. Opportunities return in 2-5 years. Potential for short term impact.
Severe (red)	Ongoing interaction results in long term impacts / cumulative change in ecosystems including shifts in species composition & habitat features or characteristics with little hope of recovery/return to former condition/status. This includes impacts which are unknown but are expected to result in permanent change.	Major shifts in commercial activities with permanent loss of opportunity and income. Potential long term effect on public health or social well-being. Possible recovery to former levels of opportunity or employment over the long term. Potential long term impact from the environment on TISEC devices.
Positive (green)	Enhancement in valued ecosystem component/ feature.	Community benefits.