Fisheries and Oceans Canada / Pêches et Océans Canada
Science / Sciences
Maritimes Region
Canadian Science Advisory Secretariat
Science Response 2008/013

POTENTIAL IMPACTS OF, AND MITIGATION STRATEGIES FOR, SMALL-SCALE TIDAL GENERATION PROJECTS ON COASTAL MARINE ECOSYSTEMS IN THE BAY OF FUNDY

Context

In support of the development of alternate sources of renewable energy, the Provinces of Nova Scotia and New Brunswick are exploring the feasibility of offshore tidal power. To guide the development of this new energy sector, the province of Nova Scotia, with the participation of New Brunswick, recently conducted a Strategic Environmental Assessment (SEA) for offshore renewable energy. The SEA process included consultation with the fishing and aquaculture sectors, marine transportation interests, academia, municipalities, and First Nations. The document included a number of recommendations, some of which are within the mandate of DFO. A parallel document is in preparation to summarize the consultation sessions conducted in New Brunswick.

As next steps, Nova Scotia is proposing the implementation of demonstration scale projects, whereas New Brunswick is considering a different approach based on monitoring conditions at candidate sites to understand energy conversion potential and environmental interactions.

In preparation for DFO's possible involvement with the regulatory aspects of tidal power, DFO Maritimes Oceans, Habitat, and Species at Risk Branch requested Science Branch in May, 2007 to provide advice on four areas relating to expected environmental impacts of small-scale tidal power generation projects in the Bay of Fundy. In March 2008, a workshop was held by DFO to review a preliminary document entitled, 'Background Report for the Fundy Tidal Energy SEA', prepared by Jacques Whitford. The Strategic Environmental Assessment (SEA), prepared by the Offshore Energy Environmental Research Association, followed and the Nova Scotia Department of Energy has since responded to its 29 recommendations. In the interim, in response to a request from Oceans, Habitat, and Species at Risk Branch, DFO Maritimes Science has undertaken a Special Science Response Process to provide scientific advice on four issues associated with the potential for environmental impacts from the proposed small-scale tidal power generation projects in the Bay of Fundy.

The specific questions requiring science advice were:

- What are the potential / expected environmental impacts of a small-scale tidal power generation projects in the Bay of Fundy on fish and fish habitat, species-at-risk, and other issues of concern to DFO?

- What mitigation measures could be implemented to help minimize any negative environmental impacts of concern to DFO?

- What type of monitoring approach and design would help to verify any conclusions made above (i.e., to delineate any residual environment effects of the project)?

- What data could be collected prior to and during small-scale tidal power generation projects that would improve science's ability to predict the potential environment impacts of large-scale tidal power generation projects?

A National DFO Workshop to investigate the broader issue of tidal/wave energy is expected later in 2008 or 2009, and that it is possible that the outcomes of this workshop may further inform the conclusions of this science response.

Background

A number of small-scale tidal power project proposals incorporating technology know as Tidal In-Stream Energy Conversion (TISEC) are being considered for the Bay of Fundy in the waters of both Nova Scotia and New Brunswick. As reported above, a Strategic Environmental Assessment (SEA) for tidal power in the Bay of Fundy has been developed by the Province of Nova Scotia. DFO Oceans, Habitat, and Species at Risk Branch will be required to review the SEA, and will be required to make a determination on the requirement for a Fisheries Act Authorization for any tidal power projects proposals that are submitted.

Advice on the potential effects of small-scale tidal projects, proposed mitigation, and potential monitoring design will likely be used to revise the SEA, as well as influence the design of these projects (and potentially whether or not DFO would require a Fisheries Act authorization).

Response

Potential Impacts

At this time, there are insufficient data to state definitively how fish and fish habitat will be impacted by small-scale tidal power projects. Studies in the marine environment are scarce as TISEC represents a new area of development. Based on our knowledge of the Bay of Fundy we can expect that small-scale development will have impacts similar to any other construction project of similar size in the coastal zone. See below for further details:

Physical Benthic Impact – Near Field

In most cases, physical impact from small-scale tidal generation projects will be short-lived and reversible especially as the areas most suitable for tidal power generation will be located where high current flow causes natural disturbance to the sediments. The response of sediment to natural flow obstructions observed in multi-beam images suggests that a drift of sediment will likely occur downstream of the turbine. If present, or if created as a result of altering flow, mobile bedforms would modify the benthic habitat considerably in the vicinity (~1-2 diameters during operations) of an obstruction placed on the bottom. The extent of these modifications depends on the character of the bottom in question; bedrock will have the least effect whereas areas of mobile sediment will respond rapidly to obstructions to the flow. For engineering reasons, TISEC devices will likely be located in areas of exposed bedrock, which could reduce downstream drifting of sediment. Grain size, sediment supply, and the degree to which flow is altered will control the extent of down drift deposition.

Evaluation of the benthos should be part of the environmental assessment (EA) for development and should identify the presence of benthic valued ecosystem components (VECs) that could be impacted.

Note: For a commercial scale project where many turbines would be expected in an area, this "field" of obstacles would likely have intersecting and reinforcing disturbances. Predicting the magnitude of the effect and the area affected would require sophisticated modelling and an understanding of natural sediment movement.

Physical Benthic Impact – Far Field

For small-scale tidal energy extraction, it is unlikely that any far field effect on sediment dynamics will occur. This is especially true for areas where suspended sediment concentrations are low. However, in the likelihood of scale up to commercial sized projects, the cumulative effect of tidal energy removal from the Bay of Fundy system needs to be considered with respect to far field impacts. For example, a potential significant issue for commercial scale extraction of tidal energy in the upper Bay of Fundy is changes in sediment transport and the rates of erosion / deposition in sensitive far-field areas of the Bay (e.g., macrotidal flats). It is important to note that the issue of the interaction between extracting tidal energy and sediment deposition decreases as sediment concentration decreases. A critical factor for the deposition of fine grained sediment is concentration, which largely controls the clearance rate of mud from suspension. For example, the nonlinear response of sediment to the decrease in flow caused by the Windsor, Petitcodiac, and other causeways is due to a feedback mechanism created by the rapid deposition of mud that reduced near bottom turbulence. An asymmetry in tidal energy tends to force sediment upstream, but under normal equilibrium conditions accumulation on the flood tide is balanced by the ebb flow augmented by other forces such as run off and wave action. In the case of the Petitcodiac, the balancing forces were insufficient to break down the density interface created by the depositing mud. A similar response could occur on the macrotidal mud flats well away from the commercial scale tidal power generating site if sufficient power is extracted.

Fish Interactions – Physical Structure

As yet, there are no published data on the interactions between turbines and fish in the marine environment. Unlike turbines located within barrages or dams, fish avoidance of the TISEC installation should be possible, and proponents of the technology suggest that the rotation speed of the turbines will be slow enough to be avoidable by fish. However, evaluation of potential fish interactions is an extremely challenging proposition, and collecting reliable data is still largely in the realm of research. Furthermore, there is no obvious precedent for assessment of this type of fish behaviour. For example, it is not clear whether some species utilize high currents to passively carry them, making avoidance of the TISEC devices more difficult.

The species of fish present in the local areas are well published, but the natural behaviour of many important species in this energetic environment is largely unknown. There is some anecdotal evidence, including commercial fishing and research activity, suggesting that Inner Bay of Fundy salmon swim in the surface waters (Garry Melvin, St. Andrews Biological Station, St. Andrews, NB, *pers. comm*.); however, further investigation of the vertical distribution and movement of salmon is ongoing. If it is found that salmon do spend much of their time in the surface water, the location of the turbines at depth could reduce possible interactions with this species.

One potential approach that could be used to evaluate fish behaviour and potential interactions with the TISEC devices is the use of acoustic sensing in the field. However, some form of testing of the available technologies and equipment to evaluate its effectiveness in the harsh environments, i.e., high energy and suspended loads, of the Bay of Fundy is required. It is advised that such equipment testing be carried out initially to determine its effectiveness prior to installation of the turbines. That way, tailored equipment known to be able to operate in the extreme conditions can be used to quantitatively assess fish behaviour in the vicinity the small-scale TISEC project. This information would be valuable for inferring fish interactions with larger-scale commercial projects.

Unfortunately, laboratory studies are not appropriate in this circumstance due to issues with scaling. For example, turbulence levels and oceanographic characteristics are not easily represented in laboratory situations. Similarly, fish behaviour would be affected by the laboratory setting so the desired response of the fish to the single turbine "prop" would be unlikely to represent actual field observations.

DFO Science is aware of other projects that are evaluating TISEC devices. For example, DFO Science representatives have spoken with the New York State Department of Environmental Conservation (NYSDEC), which is investigating effective environmental monitoring of TISEC devices in the East River. This project, however, has met some difficulties in their ongoing in effort to measure the behaviour of fish (Kevin Kispert, NYSDEC, Stony Brook, NY. *pers. comm.*). The group has expressed their willingness to share the results of their ongoing study with DFO once completed. The major issues they encountered were: (i) the failure of the installation to operate for more than a short period of time; (ii) the underwater cameras were prone to fouling; and (iii) fish species could not be identified unequivocally using the methods they employed. The results analysed so far were generally inconclusive. Moreover, while the East River setting is somewhat uniform (30-40m deep, 5-6 knots current, turbid, noisy), the NYSDEC technologies have yet to be tested under the more difficult conditions of the Bay of Fundy, and the NYSDEC expressed some concern as to how well they would work in the Bay of Fundy environment. There is interest on both sides to continue to communicate as knowledge in this area is developed. DFO Science will continue to explore other projects and initiatives, as appropriate, that are evaluating the ecosystem impacts of TISEC devices.

Fish Interactions – Sound

The degree to which sound transmission from TISEC installations interact with fish behaviour is unknown. It is advised that the propagation and the relative intensity and frequency of sound from these installations in the highly turbulent Bay of Fundy environment be investigated, as well as the subsequent impact on fish behaviour.

Potential Mitigation Measures

Physical Benthic Impact

It is expected that small-scale TISEC installations will have effects on the environment similar to those associated with other construction projects in the coastal zone; thus, normal construction mitigation measures should be appropriate (i.e., siting to avoid interactions, materials, construction methods, scheduling, best management practises for works around the water, etc.). Some additional considerations for these mitigation measures should be the location and proximity of the project(s) relative to Ecologically and Biologically Sensitive Areas (once identified) as well as the potential impacts on identified benthic VECs. This will require an evaluation of the area that might be impacted by downstream deposition of mobile bedforms. Since most of the potential areas for TISEC development occur in areas where natural disturbance of the substrate is likely, benthic species will probably be able to adapt rapidly. The exception would be for hard bottom areas where slow growing sessile species may exist.

Fish Interactions

Since there are insufficient data currently to determine the (i) occurrence and (ii) degree of impact of interactions between TISEC installations and pelagic species, it is difficult to identify or suggest potential mitigation strategies at this time. However, following the principles of risk management and minimising risks, the avoidance of migration routes, nursery areas, and spawning areas would reduce the likelihood of interactions.

Potential Monitoring Approach

Standard monitoring protocols for coastal construction sites, including suspended sediment concentration, should identify short term variations for small-scale tidal generation projects. Monitoring of the environment should be augmented by the development and validation of high resolution biophysical and sediment transport models for forecasting the impacts of full commercial development.

Physical Benthic Impact

A concern that is regularly brought up during construction in the coastal zone is the increase in total suspended sediments (TSS) as a result of bottom disturbance. In areas where TSS is low, monitoring with correctly calibrated optical instruments such as turbidity meters or optical backscatter sensors can be used to identify and delineate sediment plumes. *In situ* water samples should be used to develop calibration curves for optical instruments. In the Bay of Fundy, these measurements could be compromised by the very large natural variation in TSS that occurs on a number of time scales. Collection of *in situ* samples for calibration is also problematical due to the high current speeds in the areas proposed for the small-scale project, which make profiling difficult.

Surveys could be limited to the identification of a plume in the immediate area of the construction and could be used to identify an increase in TSS beyond acceptable limits. In this case baseline surveys could be eliminated. The natural variation in TSS and settled sediment in the Bay of Fundy would make attribution of changes to the activity extremely unlikely outside of the delineation of a distinct plume.

Repeated multi-beam or sidescan surveys of the area around the installation could be used to identify if predictions of down drift alterations of bedforms occur.

No monitoring response is expected for fine-grained sediment in the far field as a result of small-scale TISEC development, since the effect of small-scale TISEC on tidal flat dynamics would be expected to be undetectable against natural variability.

Fish Interactions

Depending on the type of substrate and the organisms inhabiting it, benthic surveys of the area may show if species composition has changed in response to physical alterations (e.g., alterations to flow) due to the TISEC development. For example, it has been suggested by local fish harvesters that the region of the Minas Passage favoured for TISEC development is a migration route for lobsters; thus, it is possible that this migration route may be disrupted due to physical alterations of the benthic environment. However, even if lobster landings decrease, in the absence of appropriate benthic sampling and monitoring, it will be difficult to determine whether a causal link exists between lobster landings and TISEC development in this area.

As stated earlier, it would not be appropriate to conduct initial research in a laboratory setting (i.e., to observe the behaviour of different types and sizes of fishes, including lobsters, to a scale model of a TISEC device) since the behaviour of fishes, lobsters, and other organisms in a laboratory setting would be very difficult to relate to natural field conditions.

One critical area for monitoring is the interactions between pelagic species and TISEC installations. At this time, no proven monitoring strategy can be suggested other than physical observation of surface waters downstream. One possible approach may be through the use of 3D acoustic tools, but the effectiveness of these tools needs to be evaluated in the environments in which TISEC development is proposed.

Similarly, until it is determined that sound propagation from TISEC installations has an impact on fish and fish habitat, an effective monitoring strategy can not be proposed.

Potential Data Collection Prior to and During Small-Scale TISEC Projects to Help Predict Potential Environmental Impacts of Large-Scale TISEC Projects

The extraction of tidal energy using in-stream technologies is a very recent area of research and interactions between TISEC installations and the environment are largely unknown. Only a very few installations exist and most of them are located in areas that are different from the Bay of Fundy in terms of oceanographic conditions and processes as well as ecosystem structure and function. As identified in previous reports, the key areas that need to be investigated so that DFO is more informed to make decisions relating to commercial scale TISEC projects are: (i) changes to sediment dynamics both near and far field, including impacts to benthos; (ii) impacts on the overall tidal forcing as a result of energy extraction; (iii) interactions between pelagic species and the installations; and (iv) impacts of sound.

The natural variability of the Bay of Fundy system makes measuring interactions between TISEC and many of the ecosystem components seen to be critical for understanding environmental interactions extremely difficult. Since it is difficult to extract signal from noise, there will be a heavy dependence on modeling to predict ecosystem impacts. However, there will be certain challenges to developing models in these areas. For example, the high sediment concentrations and the extensive tidal flats will require new implementations of numerical models. Modelling of the Bay of Fundy system also can be used to predict potential changes in tidal amplitude resulting from commercial scale TISEC implementation. In previous studies, distant changes to tidal amplitude were predicted for barrage construction in the Upper Bay of Fundy; thus, similar modelling effort should be undertaken early on in TISEC development.

Physical

Collection of current data from strategic locations will help to validate circulation models, and bathymetry surveys will help to constrain model domains and friction elements, which will lead to a more accurate model. However, collection of these data should be co-ordinated to ensure compatibility and special attention should be paid to datum. In addition, near field measurements of flow disturbance would help to validate models of turbulence generation from the installations, which could be scaled up to development stages, and repeated multi-beam or side scan surveys of the near field would help to validate predictions of bedform response to flow disturbance.

In preparation of commercial scale development and its potential effects on the far field, in particular tidal flats, some effort should be directed to carry out process-based studies of tidal flat sediment dynamics coupled with sophisticated modelling. Further discussions are required to determine the timing, scale, and scope of such studies. As demonstrated by earlier research into the effect of tidal barrages, the complex and delicate ecology of the Bay of Fundy further complicates these studies. Incorrect assumptions about the interaction of mud and flow led to the severe underestimation of the impact of causeway construction.

Biological

The behaviour of marine animals (including species-at-risk) in the vicinity of a moving impediment (e.g., turbine) is unclear. Results of attempts to monitor fish behaviour in the presence of turbines in the East River, New York have not been reported. In preparation for potential scale up of the tidal energy generation project, an experimental program to determine if pelagics can be tracked, and to determine what type of interaction with the turbines occurs and its result should be concurrent with the development of trial installations. DFO Science in the Maritimes Region has acoustics experts who could investigate the problem. The research, however, would have to be carefully planned and executed since the effectiveness of the acoustic tools in the proposed high energy environment is unproven, and it may be difficult to reach an unambiguous conclusion regarding issues of avoidance, mortality, or injury.

Determining the level and effect of sound on fish and fish habitat associated with TISEC will have to be studied. Similar to the interaction between the installation and pelagic species, an experimental protocol will need to be developed.

Baseline Monitoring – Physical Data

Proposed sites for these TISEC projects should be in areas with the least risk to fish and fish habitat, especially spawning, nursery, and migration areas. Under the assumption that the sites proposed for the installations will occur on hard substrate in areas of high current, then water quality issues will be limited to TSS (provided the are no operational losses of contaminants). Variations to TSS are unlikely to occur in the immediate vicinity of TISEC installations except during construction.

Physical environmental data, which would help in providing a baseline for future monitoring, should be collected as part of a proponent's evaluation of site potential. The collection of physical data also will help validate models that will be required to predict environmental interactions. Coordination between DFO and the proponents of data collection and standardization of data formats will be essential to both the immediate utility and ultimate value of these baseline observations.

The minimum physical data that should be collected include current velocities and detailed bathymetry, and could extend to characterisation of the suspended sediment load where it might impact turbine operations. Other environmental parameters that could be collected at a given site include:

- Location (i.e., latitude and longitude);
- Water depth (e.g., as indicated on Canadian Hydrographic Service charts);
- Direction of maximum fetch (degrees) and the associated estimates of maximum wave height (m) and direction of maximum waves (degrees); and
- Annual minimum and maximum salinity values.

In addition, specific details relating to the collection of current velocities include:

- Moor the current meter at the center of the proposed site and configure it to record current speed and direction at a maximum of fifteen minute intervals for a minimum of six weeks;
- The following current statistics should be determined and plotted:
  - Frequency distribution of current speed
  - Maximum, minimum, average, and median frequency distribution of current speeds
  - Frequency of currents with directional bins of fifteen degrees.
- Meter calibration procedures, data calibration sheets, and an electronic copy of the raw data (in ASC II or text format) must be provided;
- Measurements should be taken by an Acoustic Doppler Current Profiler (ADCP) at a one to two meter bin resolution; and
- Measurements also should be taken at a reference-control site (which could be determined following preliminary field observations and examining relevant model predictions).

Furthermore, underwater video or still photography would be an effective way of characterizing the bottom, but it will be limited to areas where visibility allows. Protocols will need to be developed based on the total area of the project. Towed systems would expand the area that could be surveyed, but higher costs potentially could be prohibitive. Drop camera systems would be effective provided a statistically significant number of images were captured. Diver protocols developed for aquaculture could only be applied to regions with a sufficiently long period of slack current and acceptable visibility. The proposed depth for installations (40-50m) will also limit the use of diver surveys. If feasible, a series of transects similar to those carried out for aquaculture would be appropriate.

Sidescan or multi-beam surveys may be required for engineering purposes and could form the basis for evaluation of bedform alteration. The high cost of multi-beam surveys suggests that sidescan surveys should be evaluated as a method to determine the extent of bedform migration.

In the SEA document, the recommendations that proposed the establishment of provincial ecological data standards for all marine renewable energy proponents and their consultants is useful to develop standard protocols for both sample collection and data base construction to which all parties would adhere. Further discussion as to the purpose of the database and the types of data that would be available would need to be carried out among the different parties. DFO databases such as BioChem and the Ocean Sciences Division’s current meter database would be places to start.

Baseline Monitoring – Biological Data

The identification of species will require an evaluation of historical records and benthic surveys. Due to the concern for SARA species and the protection of commercial stocks, surveys of pelagic species along various migration routes will require use of non-intrusive methods, presumably acoustics, validated by strategic sampling. Precedents for the application of these methods exist for species, such as herring, in the outer Bay of Fundy, but the techniques will require modification and evaluation for use in the upper Bay of Fundy and for other specific species.

Conclusions

The extraction of tidal energy using in-stream technologies is a very recent area of research and interactions between TISEC installations and the environment are largely unknown. Only a very few installations exist and most of them are located in areas that are different from the Bay of Fundy in terms of oceanographic conditions and processes as well as ecosystem structure and function. As identified above, the key areas that need to be investigated are: (i) changes to sediment dynamics both near and far field; (ii) impacts on the overall tidal forcing as a result of energy extraction; (iii) interactions between fish species (primarily pelagic species) and the installations; and (iv) impacts of sound. The natural variability of the Bay of Fundy system makes measuring interactions between TISEC and many of the ecosystem components (seen to be critical for understanding environmental interactions) extremely difficult. Because it is difficult to extract signal from noise, there may be a heavy dependence on modeling to predict ecosystem impacts.

Although information is limited, it is expected that small-scale tidal power generation projects will have impacts similar to other construction projects (of comparable size) in the coastal zone. For most small-scale projects, benthic physical impact will be short-lived and reversible. However, in the case of commercial scale projects, excessive extraction of tidal energy in the upper Bay of Fundy may cause changes in sediment transport as well as rates of erosion / deposition in sensitive far-field areas of the Bay (e.g., macrotidal flats). Potential fish interactions with the physical structure is not well understood, thus some form of acoustic sensing in the field would be useful for measuring such interactions.

Appropriate mitigation measures that would help manage potential environmental impacts of concern for the small-scale projects would be similar to those instituted for other construction projects in the coastal zone (i.e., siting to avoid interactions, materials, construction methods, scheduling, best management practises for works around the water, etc.).

Standard monitoring protocols for coastal construction sites, including suspended sediment concentration, should identify short-term variations to ecosystem structure and function. No monitoring response is expected for fine-grained sediment in the far field as a result of small-scale TISEC development, since the effect of small-scale TISEC on tidal flat dynamics would be expected to be undetectable against natural variability. At this time, no definitive monitoring strategy can be suggested for fish interactions with the project other than physical observation of surface waters downstream. 3D acoustic monitoring of fish may prove to be an appropriate monitoring tool, but further evaluation is required.

The key data that could be collected prior to and during small-scale tidal power generation projects to assist in evaluating potential effects of scale up would be physical environmental data including current velocities, detailed bathymetry, and characterization of the suspended sediment load (following appropriate protocols). The behaviour of species in the local area and their interaction with the TISEC devices should be collected; however, due to concern for species at risk; appropriate methodologies need to be developed (e.g., use of acoustics for pelagic species).

Contributors

Gary Bugden	DFO Maritimes Science
Peter Smith	DFO Maritimes Science
Tim Milligan	DFO Maritimes Science
Edward Kennedy	DFO Maritimes Science

Approved by

Tom Sephton
Acting Regional Director, Science
Dartmouth, NS
(902) 244-6080

Date: 4 September 2008

This Report is Available from the:

Center for Science Advice (CSA)
Maritimes Region
Fisheries and Oceans Canada
PO Box 1006, Station B203
Dartmouth, Nova Scotia
Canada B2Y 4A2

Telephone: 902-426-7070
Fax: 902-426-5435
E-Mail: XMARMRAP@mar.dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas

La version française est disponible à l'adresse ci-dessus.

Correct Citation for this Publication:

DFO. 2008. Potential Impacts of, and Mitigation Strategies for, Small-Scale Tidal Generation Projects on Coastal Marine Ecosystems in the Bay of Fundy. DFO Can. Sci. Advis. Sec. Sci. Resp. 2008/013.