ADMIRALTY INLET PILOT TIDAL PROJECT
FERC PROJECT NO. 12690

NEAR-TURBINE MONITORING AND MITIGATION PLAN

Submitted by:

Public Utility District No. 1 of Snohomish County

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1.0 INTRODUCTION

Close range interactions between marine life and tidal turbines are of significant interest to resource agencies. These potential interactions include collision/strike, aggregation, or avoidance and receptors include fish, marine mammals, and diving seabirds. In the case of strike/collision, concerns relate to elevated proximate or ultimate mortality, while in the cases of aggregation and avoidance, concerns center around indirect effects such as altered predator/prey dynamics, reef effects, and increased energetic expenditures that could lead to decreased fitness. These interactions are all hypothetically possible, though considered highly uncertain in terms of significance and frequency (Polagye et al., 2011). While laboratory and field studies conducted to date provide some guidance, field observations of full-scale devices are needed to rigorously address these questions. This plan is focused on fish interactions, though, as discussed in § 6, observations of marine mammals or diving seabirds will trigger adaptive management actions, which could include additional studies focused on these taxonomic groups.

The primary technology that will be used to assess close range interactions between marine life and tidal turbines are optical stereo cameras. As summarized in §5.1, this is likely to be the most effective technology option for characterizing close range interactions and the specific species involved in these interactions. However, the potential disturbances due to artificial lighting and data bandwidths associated with monitoring suggest that a judicious approach to hypothesis testing will be required. Because of the significant uncertainties associated with the effectiveness of near-turbine monitoring (the development of the monitoring technology is an active research project), this plan describes the extent of initial studies, but the District will conduct monitoring studies for the duration of the project. Maintenance and adaptable configuration of the camera systems will be enabled by a recoverable instrumentation module (described in the Monitoring Plan Summary). In the latter stages of the project, the recoverable instrumentation module would also support the use of technologies suitable for studying avoidance behavior over distances on the order of 100 m (e.g., active acoustics).

2.0 PROJECT DESCRIPTION

The demonstration project proposed by Snohomish County Public Utility District consists of two turbines manufactured by OpenHydro, an Irish turbine developer. Each of these turbines has a 6 m diameter outer shroud, as shown in Figure 1. These will be deployed on a gravity tri-frame, with tubular cans contacting the seabed at the vertices. Turbine hub height will be 10 m above the seabed. The OpenHydro turbines are fixed-pitch, high-solidity rotors with an open center. The rotor cassette is the single moving part and is supported by water-lubricated bearings. A permanent magnet generator is contained in the shroud surrounding the blades. Anti-fouling coatings are applied to the interior surface of the shroud, hub, and rotor blades, but the gravity frame (steel, ballasted by concrete and aggregate) is left uncoated. The turbine shown in Figure 1 represents the 6 m version of 4th Generation technology. The turbines deployed in Puget Sound will be 6 m variants of 7th Generation technology – the principle differences being fewer blades and more streamlined central hub.

The turbines will be deployed in northern Admiralty Inlet, Puget Sound, Washington. Admiralty Inlet is a constricted sill separating the deep Main Basin of Puget Sound from the Straits of Juan de Fuca and Straits of Georgia. At the narrowest point, between Admiralty Head and Point Wilson, the channel is approximately 5 km wide and 70 m deep. Excepting a small exchange through Deception Pass, the entire tidal prism of Puget Sound passes through this constriction, giving rise to tidal currents that routinely exceed 3 m/s (6 knots) at mid-water. The project site is approximately 1 km SE of Admiralty Head in 55 m of water (Figure 2). The project location was chosen on the basis of strong tidal currents (intensified by the proximity to the headland), negligible seabed slope (necessary to deploy the gravity foundation), separation from high vessel traffic areas (federal navigation lanes, ferry route), and ease of cable routing back to shore.

Each turbine will be connected to shore by a separate power cable. These cables will also provide power for monitoring instrumentation and fiber optic communication with the turbine and monitoring instrumentation. Turbine monitoring systems are grouped into two categories – instruments that will be deployed for the duration of the demonstration project (fixed) and instruments that will be periodically recovered for maintenance (recoverable). This will be enabled by an Adaptable Monitoring Package (AMP) consisting of a self-aligning frame with instrumentation and a wet-mate power and fiber connector.

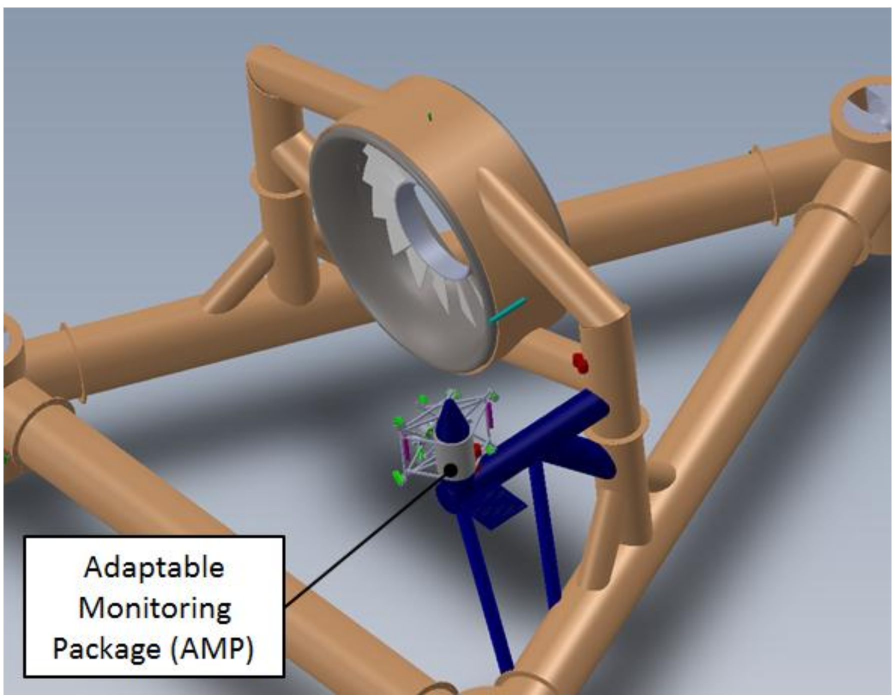


Figure 1 – Conceptual instrumentation layout (fixed and recoverable). Instrumentation shown on a 4th Generation turbine (higher rotor solidity than 7th Generation turbine). The general dimensions of the subsea based and support structure are approximately constant between technology generations for the same rotor size.

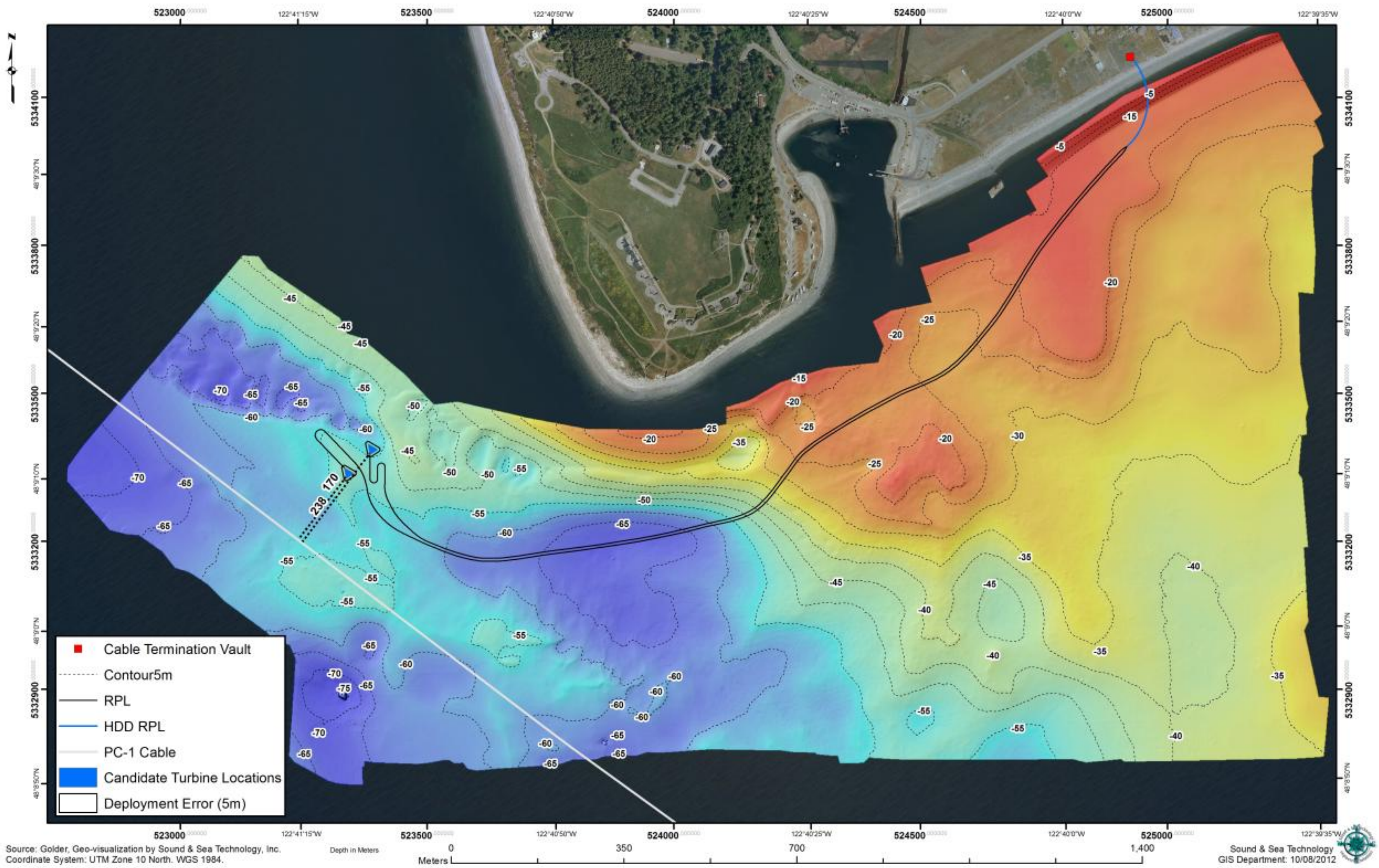


Figure 2 – Turbine deployment location in northern Admiralty Inlet. Blue triangles denote turbines, each of which is connected back to shore via a separate power cable. Dashed red polygon to the east of Keystone Harbor is a marine protected area.

3.0 BACKGROUND INFORMATION

3.1 Near-turbine Monitoring Experience

Near-turbine monitoring programs have been undertaken at several tidal hydrokinetic projects with mixed results. These are described briefly here to provide context for the current plan.

3.1.1 Verdant Power (East River, New York, United States)

Verdant Power operated an array of turbines near Roosevelt Island in the East River of New York from 2005 through 2008. The project used a combination of split beam hydroacoustic transducers (BioSonics) deployed from shore and a vessel-deployed acoustic camera (DIDSON) to monitor for effects on fish. The array of split beam transducers (24 in total) was able to monitor for targets passing through the project area, but could not be used to detect strike or identify species. The cost of the split beam array exceeded the cost of the turbines and the knowledge gained from this activity was not considered proportional to its cost (Polagye et al., 2011). Vessel-based DIDSON observations (3+ days) detected a single fish passing through the vicinity of one turbine during operation (the fish traveled along hydrodynamic stream lines and was not struck by the rotor). Verdant Power concluded that DIDSON could be an effective tool for strike monitoring if used for short-term deployments (2 to 3 weeks) coinciding with periods of peak fish abundance. However, in their opinion, the quantity of data produced, instrument reliability, and high cost precluded long-term deployments. The next stage of project development, planned to begin in the summer of 2012, will utilize split-beam echosounders and acoustic cameras on a targeted, seasonal basis.

3.1.2 Ocean Renewable Power Company (Eastport, Maine, United States)

Ocean Renewable Power Company (ORPC) tested a cross-flow turbine (BETA Turbine Generator Unit) from a barge near Eastport, Maine for two years (2010-2011). Periodically, an acoustic camera (DIDSON) was deployed to monitor fish behavior around the operating rotor. The acoustic camera was deployed from the same barge as the generator in a downward looking orientation across the turbine rotor. These observations are described in Viehman (2012) and are the first observations of natural fish passage around and through a tidal turbine. While the positioning of the sonars did not allow fish to be tracked through the turbine, schools were observed entering the turbine and, having passed through, aggregated in the wake before continuing onwards. 40% of individual fish were observed to interact with the turbine in some way (i.e., passing through the turbine or resting in the wake). Reaction distance and the type of interaction were observed to depend on the turbine state, fish size, and grouping, with schools interacting less than individuals. Avoidance behavior was less apparent at night, suggesting that visual cues play a role in fish avoidance of turbines.

3.1.3 OpenHydro (European Marine Energy Center, Orkney Islands, Scotland, United Kingdom)

OpenHydro used unlighted video to monitor fish interactions with its turbine at the European Marine Energy Center (EMEC). This has been successful at detecting fish aggregation in the turbine wake during periods of relatively low currents (e.g., < 1.5 m/s). No strike of fish or marine mammals has been observed and fish have not been observed to pass through the turbine once it begins rotating. The test turbine at EMEC is deployed within the photic zone and monitoring can be conducted during daylight hours only. A representative image from video observations is presented in Figure 3.

Figure 3 – Unlighted video observation of OpenHydro turbine at EMEC. In this image, fish are aggregating downstream of the turbine. Current velocity is below cut-in speed for the turbine.

3.1.4 OpenHydro (Fundy Ocean Research Centre for Energy, Minas Passage, Nova Scotia, Canada)

In the Bay of Fundy, the Fundy Ocean Research Centre for Energy (FORCE) has responsibility for monitoring environmental effects of deployed devices, including the OpenHydro turbine installed in the fall of 2009. Preliminary investigations of both video and active acoustics suggested that these tools would be ineffective given the physical environment (high turbidity, aeration) in the Bay of Fundy. Additionally, the lack of a power and data cable would have precluded deployment alongside the OpenHydro turbine, regardless of potential effectiveness. Rather than attempt direct monitoring during the OpenHydro test, FORCE deployed an array of Vemco fish tag receivers (8 VR2Ws) around the turbine foundation and another array (8 VR2Ws) in a line across the channel to the east of the turbine. Over the course of the turbine deployment (November 2009 to November 2010), approximately 100 fish were tagged and released in the upper Bay of Fundy. Vemco receivers have been recovered and analysis of collected data is underway. This array may succeed at detecting presence/absence of individuals and providing some tracking capability, but cannot directly monitor for strike.

3.1.5 Marine Current Turbines (Strangford Lough, Northern Ireland, United Kingdom)

The Marine Current Turbine (MCT) deployment in Strangford Lough is the largest prototype deployed to date with twin 16 meter diameter rotors and a rated power output of 1.2 megawatts (MW). Their environmental monitoring framework has no provision for strike monitoring. While this was initially requested by the regulator (Northern Ireland Environmental Agency), the requirement was waived after subsequent determination that strike could not be monitored for in a meaningful way. Emphasis was instead placed on monitoring for behavioral changes among marine mammals (harbor seal, harbor porpoise) in the project area, changes to benthic habitat, and mitigating the risk for harbor seal strike by temporary shutdown.

A comparison of these efforts is presented in Table 1 using the following metrics:

- *Deployment platform*: How was the monitoring technology deployed (shore, seabed, or vessel)?
- *Instrument recovery*: How was the monitoring technology recovered/maintained?
- *Percentage of rotor imaged*: How much of the turbine rotor was imaged during monitoring?
- *Maximum duty cycle*: For the particular technology, what is the upper limit on the duty cycle? (Most data are collected on lower duty cycles or subsampled.)
- *Species identification*: Was it possible to identify observed species?
- *Functional range*: What is the maximum range for monitoring?
- *Cost*: A qualitative assessment of monitoring technology cost.
- *Reliability*: A qualitative assessment of monitoring technology reliability.

Table 1 – Comparison of near-turbine monitoring at worldwide hydrokinetic projects

Turbine (Location)	Verdant Power		OpenHydro (EMEC)	OpenHydro (FORCE)	Marine Current Turbines	ORPC
Turbine Type	Horizontal axis		Horizontal axis	Horizontal axis	Dual horizontal axis	Cross flow
Turbine Size	5 m		6 m	10 m	16 m	2.6 m
Water depth	10 m		15 m	40 m	35 m	-
Monitoring technology	Split-Beam Echosounder	Acoustic Camera	Unlighted Video	Fish Tags	None	Acoustic Camera
Supplier	BioSonics DTX	Sound Metrics DIDSON	GigE vision camera	Vemco VR2W	-	Sound Metrics DIDSON
Deployment platform	Shore	Vessel	Frame attached to turbine	Seabed	-	Vessel
Deployment duration	> 1 year	A few days	3 years[1]	1 year[2]	-	> 1 month
Instrument recovery	Divers	At surface	Integrated lift	Acoustic release[3]	-	At surface
% rotor imaged	0% (beams parallel to turbine rotor)	50-100%	100% of one side	0 %	-	N/A (upstream and downstream monitoring)
Maximum duty cycle	100%[5]	100%	Daylight hours only	100 %	-	100%
Species identification	No	Partial	Yes	Yes	-	Partial
Functional range	> 50 m	10 m	10 m	> 100m	-	10 m
Cost	Very High (exceeded turbine engineering cost)	High (> $100k per camera)	Moderate (low equipment, high processing)	Proportional to tagging effort	-	High (> $100k per camera)
Reliability	High	Poor	High	Moderate	-	High

- [1] Subsampling during this time period
- [2] Turbine damaged within first two weeks of deployment – all blades failed
- [3] Location/orientation of receiver not critical to function (in comparison to video and hydroacoustics)
- [4] Cross-section of turbine imaged
- [5] While sampling was conducted continually, only one of the three hydroacoustic transducers in each of the eight arrays could sample at a time due to acoustic signal interference

3.2 Environmental Risk

Environmental risk is the product of the probability of encounter and the consequence of encounter.

3.2.1 Probability of Encounter

Marine animal abundance in Admiralty Inlet will vary with diel, seasonal, and tidal current cycles. For fish, mobile hydroacoustics transect surveys conducted by Dawson and McClure (2010) found that during some seasons (February 2010), there were order of magnitude differences in target densities when comparing night to day conditions under similar current velocities. The differences in densities between fast versus slow current velocities were particularly evident at night; typically mean target densities were substantially higher under slow current velocities (as compared to fast current velocities) at night, whereas target densities were similar during the day, regardless of current velocity. In contrast, video studies conducted by OpenHydro at a turbine in Ireland suggests that low current velocities during the day may be conducive to high densities of benthopelagic fish species in the presence of the turbine structure but that these fish are absent during periods of stronger currents (Sue Barr, OpenHydro, memo November 2010).

Mobile hydroacoustic transect surveys, ground-truthing trawls, and autonomous, bottom-mounted hydroacoustic surveys were undertaken in May/June 2011 by the University of Washington under a hydroacoustic technology evaluation project funded under the National Oceanographic Partnership Program. Data analysis is ongoing, but preliminary results indicate significant “patchiness” in fish densities and that periods of strong currents may alter diel patterns that are typically observed for certain species (Sandra Parker-Stetter, pers. comm., April 2011).

3.2.2 Consequences of Encounter

Field observations to date, albeit limited in extent, have not observed an incidence of strike, suggesting that strike/collision has been a rare occurrence for deployments to date. These have included the release of tagged fish through small turbine in a riverine environment (Normandeau, 2009), as well as two flume studies overseen by the Electric Power Research Institute. In the first, conducted at Alden Labs, rainbow trout and largemouth bass were released immediately upstream of two turbines (a cross-flow variant and a horizontal axis device). Survival rates ranged for 98-100% and were not statistically significant relative to the control population. Video observations of fish introduced to the cross-flow turbine exhibited strong avoidance behavior, attempting to swim upstream or around the turbine when possible. Those fish that did pass through the turbines and were struck by the rotor, did not exhibit behavior suggestive of stunning or severe injury. Survival rates were much higher than predicted using a model based on strike consequences for conventional hydropower turbines. The second set of experiments was conducted at the Conte Lab, using a vertical axis turbine and involved salmon smolts and American shad. Again, survival for fish exposed to the turbine was not significantly different from survival among control groups.

In summary, experience to date suggests that fish may encounter the turbine in operation, but that the consequences of encounter would be expected to be low. However, given that data from prior experience relate to laboratory studies, different turbines, or different species than are known to be present in Admiralty Inlet, further field study of near-turbine interactions by marine mammals is warranted.

4.0 PLAN OBJECTIVES AND GOALS

The goal of the Near-Turbine Monitoring and Mitigation Plan is to confirm the environmental analyses, including effects on species listed under the Endangered Species Act (ESA) and/or species in the Washington State Priority Habitat and Species (PHS) List and, where possible, their designated critical habitat, and conduct any monitoring required for incidental take. The goal is also to mitigate for proposed effects, based on information gathered through this Plan. In implementing the plan, four hypotheses will be tested:

- *Hypothesis 1*: Strobe illumination may result in a species-specific startle response, avoidance response, or attraction.
- *Hypothesis 2*: The turbines may attract marine animals due to the area of refuge offered by the low-velocity wake.
- *Hypothesis 3*: Marine animals are unlikely to pass through the rotor or open center during turbine operation. Investigation of this hypothesis will test the assumption that although listed and other aquatic species may be shown near the turbine rotor, these aquatic species will not be struck by a moving turbine rotor.
- *Hypothesis 4*: The turbines may attract marine animals due to an artificial reef effect.
- *Hypothesis 5*: Fish may avoid the turbine due to its pressure field or sound (particle velocity or acoustic pressure).

Additionally, in conjunction with the Marine Mammal Monitoring and Mitigation Plan, the plan will also test the assumption that there will be no interaction between marine mammals and the moving turbine rotor beyond that specified in the Project Marine Mammal Protection Act authorization. This information will also inform, as needed, the development and implementation of adequate mitigation measures in consultation with the MARC.

To accomplish these goals, the District will:

1. Develop and test a system capable of identifying species composition and life stage in the direct vicinity of the turbine rotors and assessing the frequency with which targets pass through the turbine rotor;
2. Implement the tested system in conjunction with Project installation;
3. Examine potential for artificial lighting to affect behavior of fish;
4. Collect, manage, and analyze system data relevant to plan objectives;
5. Confer with the MARC to consider modification to this Plan and project operations in response to the collected and analyzed results; and
6. Use information collected by this system to inform, as needed, the development and implementation of adequate mitigation measures in consultation with the MARC and after NMFS' approval, including studies to assess artificial reef effects and avoidance behavior, and determine any necessary project modifications.

5.0 POST-INSTALLATION MONITORING PLAN

Near-turbine monitoring studies will be conducted in sequence on a seasonal basis during the first year of operation. The appropriate sampling structure for each seasonal sequence will be iteratively developed (in consultation with the MARC) from the starting point described in this plan. In other words, as information is developed by the project, study methods and analysis techniques are likely to be refined. The seasonal study sequence will consist of:

- Presence/absence study (§5.2) to evaluate conditions (e.g., time of day, current velocity) for which species presence or absence is likely. A secondary objective of this study will be to determine the effectiveness of the camera system to identify species under different environmental conditions.
- Artificial lighting study (§5.3) to develop guidelines for strobe frequency, duration, and interval that allow for observation of interactions with the turbine rotor (aggregation, strike, passage) without altering marine animal behavior. This study will utilize an acoustic camera with a field of view similar to the optical camera.
- Turbine interaction study (§5.4) to evaluate the frequency and type of interactions between marine animals and the turbine rotor.

The results of each study will inform the next in the sequence. Given the time that will be required to process and interpret collected data, the timing of the plans described in this section may need to be modified, in consultation with the MARC, to avoid prematurely committing resources to studies of unknown effectiveness. For example, if lighting effects have not yet been established, then collecting and analyzing data about turbine interactions may not be advisable. Given the exploratory nature of these studies, closer coordination with the MARC is likely to be required in implementing this plan than other plans, where tools and analysis methodologies are well-established.

In addition to the three seasonal monitoring activities described above, the outline of a plan to study artificial reef behavior is presented in §5.5 and, similarly, avoidance behavior is presented in §5.6. The specific timing and approach to implement these portions of the plan will be strongly influenced by the information gained from preceding studies.

5.1 Imaging System Details

The imaging system that will be utilized for the implementation of this plan is a prototype developed by the Northwest National Marine Renewable Energy Center (NNMREC) on behalf of the District. No off-the-shelf systems were available with the required adaptability and research-grade customized underwater imaging systems are relatively common (Howland et al., 2006; Rosenkranz et al., 2008; Williams et al., 2010). The prototype system is shown in Figure 4. It consists of a pair of high-resolution (2 Mpx) machine vision cameras (AlliedVision Manta G-201) illuminated by a quartet of strobes (Excelitas MVS 5002). Power distribution and communications are routed through a main electronics bottle that steps shore power at 400 V DC down to 12 V DC for the cameras and strobes and converts fiber optic media to copper for the Gigabit Ethernet communications network. Bottle temperature/humidity and power control are monitored over an RS-232 subnet. The system also includes a number of biofouling mitigation measures, including copper rings around the optical ports and mechanical wipers. The field of view (FOV) for each camera is 54^{o} x 42^{o} (horizontal x vertical).

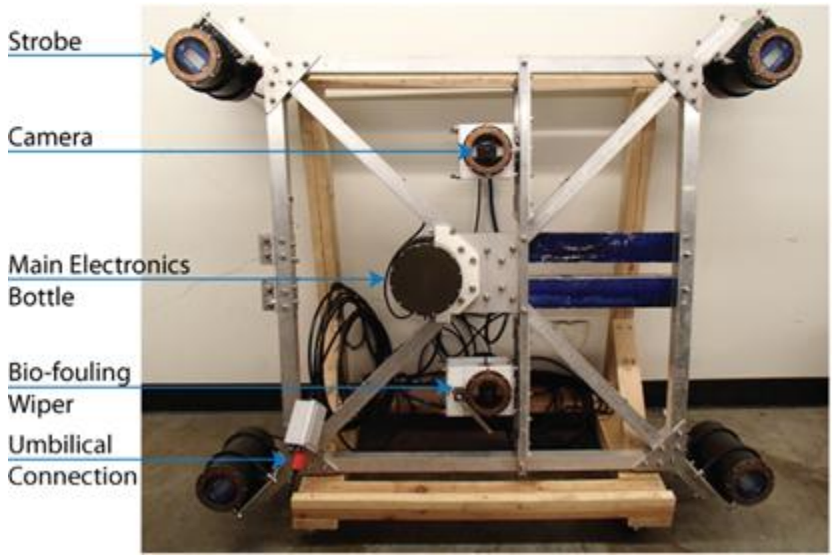


Figure 4 – Camera system assembly

In addition to the optical stereo cameras, an acoustic camera (BlueView P900-2250) will be incorporated in line with the optical cameras to study the effect of artificial illumination on marine animal behavior (not shown in Figure 4). The acoustic camera produces 2D imagery with a 45^{o} horizontal field of view and 20^{o} beam spread in the vertical. The optical camera, in contrast, produces 3D imagery and, through image rectification, the camera pair can provide absolute size, speed, and location of targets.

The field of view for the camera system when deployed on an OpenHydro turbine is shown in Figure 5. The degree of transparency in the fields of view is a qualitative description of system effectiveness. At close range (out to 3 m, least transparent), taxonomic classification will be most likely and target resolution will be highest. At increasing distance (out to 5 m and 7 m), resolution will decrease (same number of pixels over a greater area) and backscatter from naturally occurring flocculent (i.e., biological “snow”) will decrease contrast. These factors will reduce the ability of the camera system to detect targets and capture images suitable for taxonomic classification at these distances.

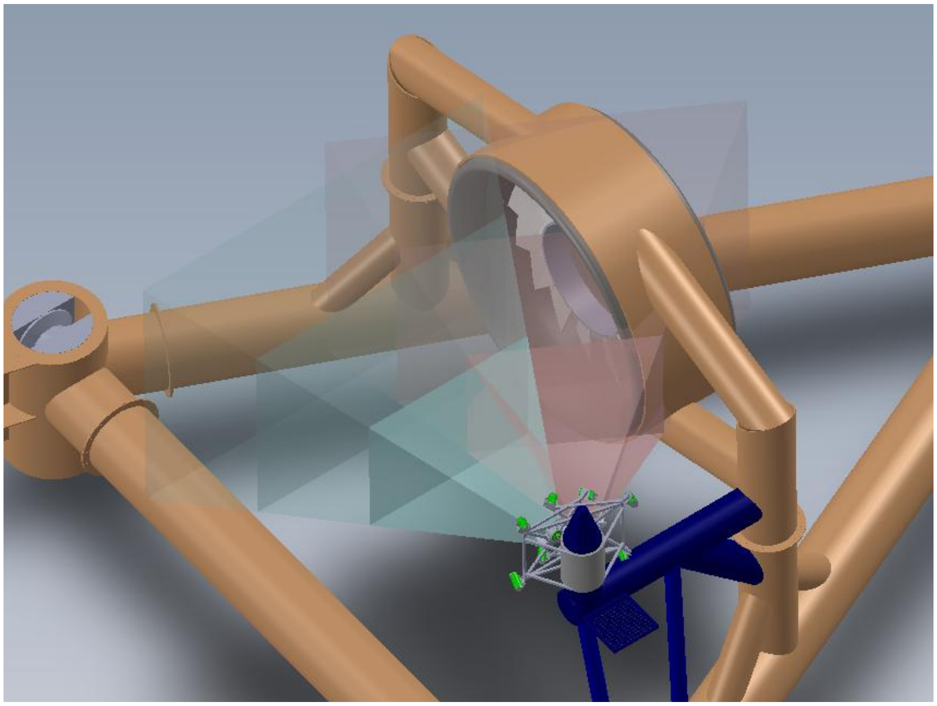


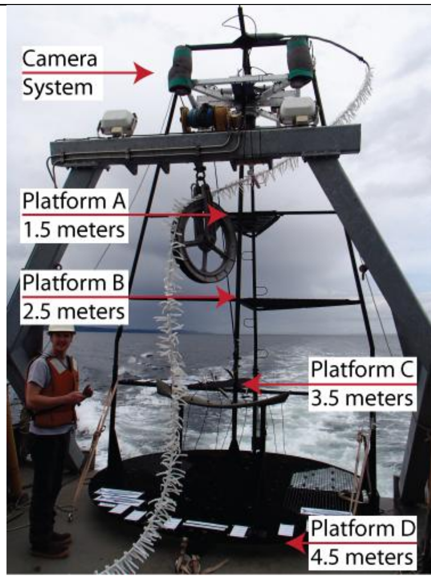
Figure 5 – Optical camera system field of view on the OpenHydro turbines for two configurations: directed across the rotor (green prism) and directed at the rotor (red prism).

It is likely that at least 150 pixels per target will be required for accurate taxonomic classification. This resolution will be possible for large targets (e.g., adult salmonids) at maximum distance and for small targets (e.g., herring) within a few meters of the camera system. Even given high resolution and lighting, some species will be difficult to distinguish. For example, depending on life stage, it can be difficult to accurately identify species of rockfish when they are in hand. Coloring and patterns may provide useful information for taxonomic classification, but length may also be a useful predictor. Determining the length of targets is possible using stereo imaging techniques, but will initially require manual identification and processing of targets and will only be carried out for cases where the additional information is likely to significantly improve taxonomic classification.

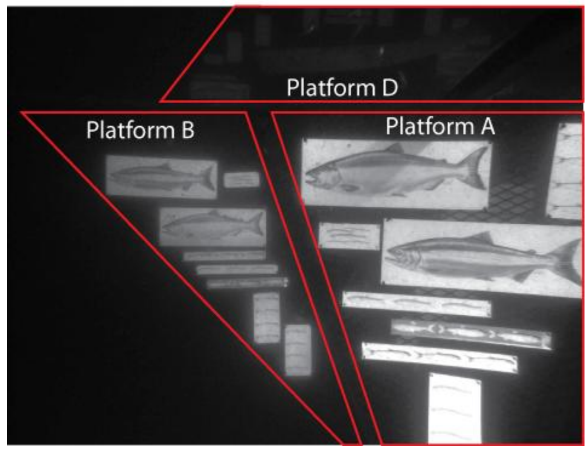
Due to a lack of ambient light, artificial illumination is required for these observations. Infrared or far-red illumination (Widder, 2005; Raymond and Widder, 2007) were considered to reduce behavioral effects. However, the rapid attenuation of red light in water makes observations at distances greater than 1-2 m difficult, even for high intensity red light. §5.3 describes seasonal studies to establish thresholds for full-spectrum strobe illumination that can inform proper use of the camera system for presence/absence, rotor interaction, and artificial reef studies. The camera-light separation shown in Figure 5 is 1 m. This was chosen to balance improvements in effective range associated with greater camera-light separation (Jaffe, 1988) against maintaining a reasonable footprint for the system.

The successful implementation of this plan is dependent upon being able to adapt instrumentation as new information about near-turbine interaction is discovered. In addition, even with biofouling mitigation measures, optical ports are unlikely to remain clear for periods longer than 3-6 months. Consequently, the imaging system will be incorporated into the Adaptable Monitoring Package (AMP) described in the Monitoring Plan Summary (grey frame in Figure 1 and Figure 5). With a maintenance cycle of 3-6 months, this will provide a logical checkpoint for discussions with MARC to modify camera orientation on a seasonal basis.

The camera system has been progressing through a development cycle since mid-2011. Field trials conducted in Puget Sound in April using printed targets attached to a rigid target frame indicate that an effective range of greater than 5 m is possible, as shown in Figure 6.



(a) Test frame



(b) Acquired image

Figure 6 – Camera system field testing

In July, 2012, the system will undergo trials in Admiralty Inlet to further investigate the system range and assess the accuracy of stereo measurements. During this test, the acoustic camera will also be deployed for opportunistic studies of the effects of strobe illumination of marine life. Following these tests, a long-term (3-6 month) endurance test from a dock in Sequim Bay is planned.

Each turbine would be equipped with an imaging system for the proposed project. As described in the Monitoring Plan Summary, cameras cannot be deployed to both sides of the rotor, as this would interfere with turbine recovery operations, but by deploying one turbine frame 180^{o} rotated relative to the other, “upstream” and “downstream” observations will be possible on ebb and flood (albeit not for the same turbine).

5.2 Presence and Absence of Marine Animals

5.2.1 Objective

Observations of the OpenHydro turbine at EMEC have shown that fish (specifically, pollock) aggregate in the turbine wake during low-velocity conditions because this offers an energetically preferable area of refuge. As water velocity increases, fish are observed to leave the area.

The objective of this study is to determine the likely conditions for presence and absence of marine animals at close range (i.e., within the camera system field of view) of the turbine rotor. In other words, under what conditions are specific marine animals likely to be present or absent? The sub-objectives are:

- Determine if the ability of the camera system to make species identification of marine animals is dependent upon environmental conditions.
- Evaluate the extent to which marine animal presence/absence is dependent upon environmental conditions.
- Evaluate the extent to which marine animal density is dependent upon environmental conditions.

An additional objective of this study is to inform a decision whether, based on the information gathered by the study, project operations should be modified to ensure resource protection.

5.2.2 Data Collection

Equipment Description

The primary systems to be used in this test are the optical cameras described in §5.1. Current velocity will be monitored using Doppler profilers on the subsea base. The cameras will be oriented towards the turbine rotor, for subsequent studies of interactions between marine animals and the turbine rotor (§5.4).

Survey Procedure

During a survey, individual stereo camera frames will be captured by the optical camera system at a rate of one frame every 15 minutes. At this lighting interval and duration, the effect of the strobe should not confound observations (i.e., absence in a captured frame would not be correlated with avoidance of the strobe flash from the prior frame, particularly at moderate current velocities). For example, O'Driscoll et al. (2012) used a long duration light for observations and determined, based on active sonar observations, that behavior returned to normal within 30 minutes. The time for resumption of normal behavioral following strobe illumination will be verified by the testing described in §5.3 and, if necessary, strobe intervals could be increased to reduce the potential for bias. Similarly, if the time for resumption of normal behavior is determined to be less than 15 minutes, observations could be made at a higher duty cycle to increase statistical power.

Surveys will be conducted four times during the first year to address seasonal variations. Of these four surveys, two will be chosen to coincide with likely presence of migratory species. Survey duration will be fifteen days to encompass a complete neap-spring cycle and, therefore, the full range of hub-height currents. At a sample rate of one frame every fifteen minutes captured by the camera systems on each turbine, this will produce 2880 images for review and analysis for each seasonal survey.

5.2.3 Data Analysis

Captured frames will be classified by:

- Time of day (6 hour blocks) (4 bins)
- Mean hub-height current velocity (0 to 3.5 m/s in 0.5 m/s increments) (6 bins) – as measured by a five minute average of Doppler measurements centered on the time of image acquisition.
- Current direction (ebb or flood) (2 bins) – as measured by a five minute average of Doppler measurements center on the time of image acquisition.
- Turbine being observed (2 bins)
- Season (1 bin – repeated applications of this methodology will enable comparison between seasons and years)

This yields 96 possible case combinations. If uniformly distributed, there would be approximately 30 images for each of these combinations. In practice, some combinations, particularly observations during the strongest currents, will have fewer samples since these conditions occur less frequently.

All frames will be initially screened to identify potential fish targets. Those with possible targets will be passed on to expert review to qualitatively rank the identification capability of the camera system. Expert input to the development of this plan suggests that species-level identification may be *very* challenging, even for high-resolution optical images. Multiple experts, with progressive levels of expertise, will be used to achieve the lowest level of taxonomic classification possible. Since the length of a target may be a discriminator, determination of target length using stereo imaging may be required. It may also be helpful to describe distance of target from camera. Evaluating either of these parameters will, initially, require manual processing of stereo image pairs and will only be undertaken for images in which this additional information would be useful. Each frame will be assigned a qualitative ranking:

- *Rank 1*: Species classification of at least 75% of targets (species noted, with qualitative certainty probability – low, med, high).
- *Rank 2*: Genus classification of at least 75% of targets (genus noted, with qualitative certainty probability).
- *Rank 3*: Family classification of at least 75% of targets (family noted, with qualitative certainty probability).
- *Rank 4*: Unable to differentiate aquatic species from debris for at least 75% targets.
- *Rank 5*: Insufficient image quality to detect targets.

The number of targets in the field of view will also be qualitatively ranked:

- *Rank 1*: High animal density (>50 animals in FOV)
- *Rank 2*: Moderate animal density (10 - 50 in FOV)
- *Rank 3*: Low animal density (1 - 10 in FOV)
- *Rank 4*: No animals present in FOV

Animal density and classification potential for each of the 96 case combinations described previously will be evaluated. Results will be interpreted by taxonomic groups. The highest level groups will be:

- Resident fish – fish with small home ranges relative to the scale of the project (e.g., rockfish)
- Migratory fish – fish with large home ranges relative to the scale of the project (e.g., ratfish, salmon)
- Marine mammals
- Diving seabirds

Each of these groups will be further sub-divided into listed and unlisted species, as possible based on expert identification.

Analysis will be undertaken to identify conditions (e.g., time of day, current velocity) that are likely to result in biologically significant presence of a species group near the turbine. For a listed resident fish, this might be an individual, while for the most common species, this might be a large school. Similarly, conditions that are likely to result in no members of a species group near the turbine will also be identified. In combination, these factors will be used to establish an order of magnitude estimate for the frequency of occurrence (probability of encounter) of species groups. This will serve to inform resource protection measures, as well as structure illumination (§5.3), close range interaction (§5.4), and artificial reef (§5.5) studies.

Finally, in consultation with the MARC, results from the initial study will be used to determine a minimum statistically valid sampling rate for further studies of taxonomic groups (e.g., listed resident fish) using potential power analysis, including an evaluation of how much data review will be required to evaluate interactions with potentially rare, but important, taxonomic groups.

5.2.4 Reporting and Adaptive Management

A preliminary, oral report will be made to the MARC within 15 days of study initiation to provide informal feedback on observations. Interim written and oral reports will be made to the MARC within 90 days of each survey completion. A final report will be made to the MARC within 120 days of the first year of operation, summarizing presence/absence trends.

Based on reported results, the MARC will determine an appropriate sampling and analysis approach for remainder of project to ensure resource protection.

While some species may not be observed near the turbine, if *no* species of fish are detected near the turbine (i.e., common species such as ratfish or dogfish) then it is likely that the turbine is causing avoidance (provided that avoidance from the strobes can be eliminated as a plausible hypothesis by the study described in §5.3). This result would suggest a need to understand the range over which avoidance is occurring, rather than proceeding to studies of rotor interactions. In conjunction with the MARC and with NMFS approval, as provided in section 6.0, this information will be used to inform project modifications, where necessary, to provide mitigation and resource protection.

5.3 Optimized Strobe Illumination

5.3.1 Objective

Artificial illumination is necessary for optical image capture at the depth of the project. Pre-installation monitoring of light levels using a photosynthetically active radiation (PAR) sensor at hub height for a 90 day period confirmed light levels are likely below camera sensitivity. Additionally, in order to "freeze" motion and produce a crisp image of objects moving at velocities on the order of several meters per second an exposure time of 2-50 μs is recommended (Gallager et al., 2004). This cannot be achieved with a mechanical shutter, but is within the capabilities of machine vision strobes in dark environments (i.e., strobe acts as a virtual shutter). However, the use of strobe illumination may affect behavior of marine animals in a manner that depends upon a number of factors including strobe rate and duration of illumination, organism or fish species and life stage, and hydrodynamic conditions.

Fish behavior in response to strobe lights may be complex; based on studies at dams on the Columbia River (Johnson et al. 2003, Johnson et al. 2005, Simmons et al. 2006), there was a wide range of attraction and avoidance behaviors that varied with time of day and species. Johnson et al. (2005) also found some complexity in the reaction to the strobe light; fish appeared to be attracted to the strobe lights from further distances, yet tended to stay >10 m from the strobe lights (a close-range avoidance response). Lab experiments showed that Chinook salmon tended to avoid strobe lights even after an hour of exposure, on average moving about 7.3 m away from the light source (Richards et al. 2007). However, the aforementioned studies were conducted in freshwater and may not necessarily be applicable to marine settings. Marine fish behavior in response to lighting appears to be similarly complex, with great variation among different species and life stages, from avoidance to attraction, or no reaction to lights (Marchesan et al. 2005, Stoner et al. 2008, Ryer et al. 2009).

The objective of this study is to establish species- and season-specific thresholds for fish responsiveness to the strobes (duration and strobe frequency) that will inform appropriate use of the camera system for studies of presence/absence (§5.2), interaction with the moving rotor (§5.4), and artificial reef effects (§5.5). In other words, this study will develop operating guidelines for the strobes that minimize behavioral changes associated with its operation. It is unlikely that these thresholds will be absolute and close consultation with the MARC will be required to develop these guidelines.

5.3.2 Data Collection

Equipment Description

The primary systems to be used in this test are the optical and acoustic cameras described in §5.1. The cameras will be oriented towards the turbine rotor, for subsequent studies of interactions between marine animals and the turbine rotor (§5.4). Current velocity will be monitored using Doppler profilers on the subsea base.

Survey Procedure

During the first year of turbine operation, the illumination study described here will be conducted four times in order to establish seasonal variation in strobe responsiveness. This is necessary because ambient lighting levels and species presence are also expected to vary with season. Illumination studies would follow presence/absence studies (§5.2) and would precede seasonal observations of interactions with the turbine rotor (§5.4). Each seasonal illumination period would occur within a two week period, in order to obtain information about lighting effects over a range of hub-height current velocities.

Rotor interaction studies (§5.4) could involve image capture with a strobe rates up to 10 Hz and durations of up to 60 seconds. Longer duration observations are technically possible, but with stereo camera data rates > 100 MB/s at 10 Hz, data archiving and processing for longer duration observations is not likely to be initially feasible. Three aspects of the lighting duty cycle are controllable: strobe frequency (up to 10 Hz), duration of lighting (up to 60 seconds, as explained above), and the time between successive lighting periods. Because it will be time-intensive to collect and post-process data for illumination studies (manual triggering and review of stereo camera and acoustic camera imagery), these will be undertaken for a limited subset of possible strobe configurations. The list of configurations may be refined in consultation with the MARC, but will likely include:

- *Configuration 1*: Single frame by the optical camera system and strobes. This corresponds to the proposed configuration for presence/absence studies.

The next three configurations correspond to potential configurations for rotor interaction studies.

- *Configuration 2*: 10 Hz strobe frequency for 10 seconds.
- *Configuration 3*: 10 Hz strobe frequency for 30 seconds.
- *Configuration 4*: 10 Hz strobe frequency for 60 seconds.

The number of data sets captured for each case will be determined in consultation with the MARC, but will likely be on the order of 5-10.

Each strobe configuration will be tested for a similar set of stratifying covariates as is determined to be appropriate for the presence/absence study (§5.2). However, because the primary concern for close-range interaction is rotor strike, illumination effects will only be studied for velocities greater than 1 m/s. In each test, acoustic camera imagery will collected continuously for 5 minutes prior to strobe activation and 15 minutes after deactivation to enable a before and after comparison without lighting stimulus. Information from the acoustic camera will serve to detect strong startle responses, avoidance responses, and the “cool down” time required for behavior to return to normal once the strobe is “off”. If normal behavior does not resume within 15 minutes for a particular environmental condition (e.g., quiescent water), the observation window will be sequentially increased until the time constant for resumption of normal behavior is identified.

Data collection will be manually triggered by an operator when targets are within the acoustic camera’s field of view. The timing of observations will be informed by conditions when marine animal presence is likely, based on preliminary results from §5.2, and structured to provide observations over a range of current velocities. No more than 30 hours of observer time will be devoted to collecting these data during a single seasonal study. If species presence is determined to be very sparse from the results of §5.2, to the extent that very few observations are anticipated with 30 hours of observer time, the MARC will be convened to develop an alternative study methodology.

5.3.3 Data Analysis

The optical and acoustic camera imagery will be analyzed to evaluate attraction and avoidance in response to strobe illumination. Because the field of view for the acoustic camera is somewhat smaller than the optical camera, the optical camera field of view will be truncated in post-processing such that viewed area is equivalent for the two types of cameras. The range of the acoustic camera is, however, greater than the optical camera (10+ m versus 5+ m). To the extent possible, the species of fish present in the field of view will be noted, using the same progressive, expert review approach outlined in §5.2. Given the limited number of data sets that are likely feasible to collect for this type of study, the taxonomic groups outlined in § 5.2 may need to be aggregated to achieve sufficient statistical power to detect change.

Qualitative Analysis of Avoidance: A startle response would be indicated by fish leaving the area observed by the acoustic camera when the strobe is turned “on”. Avoidance would be indicated by sustained absence of fish within the field of view while the strobe is “on”.

The acoustic camera imagery would be evaluated before, during and after the optical camera imagery is collected to evaluate the time after the strobe is turned “off” for fish to resume pre-strobe behavior within the camera field of view. While this will likely be a subjective judgment initially, it will provide guidance for evaluating the minimum cool down time (i.e., illumination interval) to avoid affecting species behavior during different conditions. For example, it is likely that illumination intervals could be shorter during periods of strong currents since fish would be unlikely to hold position near the turbine for extended periods of time.

A combination of responses (similar to those described by other researchers, as noted above) may also be indicated. For instance, fish could come into the field of the acoustic camera during the lighted period, staying out of range of the optical camera, but subsequently come into range of the optical camera once the lighted period has ended. This, more subtle, avoidance could be evaluated in follow-on studies by evaluating fish density at specific ranges to the camera systems, but is not a focus of initial studies.

Quantitative Analysis of Attraction: For the optical camera imagery, the observers will estimate the maximum number of fish for a given species (to the extent possible) within the field of view as a function of time (*Max N*, a commonly used metric, e.g., Merritt et al. 2011; Cappo et al. 2004; Cappo et al. 2007; Harvey et al. 2007) and note observed behavior. If attraction occurs, the number of fish observed over the time period that the strobe is “on” should increase. Similarly to avoidance/startle analysis, the time required for the number of fish to return to pre-strobe levels will serve to bound the possible illumination interval.

5.3.4 Reporting and Adaptive Management

A preliminary oral report will be made to MARC within 15 days of study initiation to provide informal feedback on the effect of the camera. Interim oral and written reports will be provided to the MARC within 90 days of each seasonal survey completion.

Results of the study will inform the operation of the camera system for sequential studies (e.g., interaction with the turbine rotor). If particularly strong avoidance or attraction is observed for some combinations of conditions (e.g., time of day, current velocity), regardless of strobe configuration, alternative approaches to studying marine animal interaction with the turbine rotor may be required.

If species presence is determined to be very sparse from the results of §5.2, to the extent that very few observations are anticipated with 30 hours of observer time, the MARC will be convened to develop an alternative study methodology to establish strobe illumination thresholds.

5.4 Interaction with the Turbine Rotor

5.4.1 Objective

Optical camera observations of the OpenHydro turbine at EMEC have not shown aquatic species (fish or marine mammals) to pass through the rotor or open center during turbine operation. Passage through the turbine during operation poses a risk of blade strike. Active acoustic observations of the Ocean Renewable Power Company turbine in Eastport, Maine indicate that smaller fish may swim through the turbine during all operating states. The differences between these observations may be associated with the species involved or type of device. Certainly, concern over potential injury or mortality associated with blade strike represents a critical uncertainty associated with potential environmental impacts of tidal energy development.

The objective of this study is to characterize how marine animals interact with the turbine rotor, and to inform a decision whether, based on the information gathered by the study, project operations should be modified to ensure resource protection. This study will occur seasonally after the strobe illumination study (§5.3) and the presence/absence study (§5.2).

5.4.2 Data Collection

Equipment Description

The primary systems to be used in this test are the optical cameras described in §5.1. Current velocity will be monitored using Doppler profilers on the subsea base. The cameras will be oriented towards the turbine rotor to maximize the portion of the turbine within the field of view.

Survey Procedure

Studies of interactions with the turbine rotor will require high frame rates (i.e., up to 10 Hz) for moderate durations (up to 60 s). The maximum possible frame rate and duration found to not likely cause a significant behavioral disturbance (§5.3) will be utilized. The camera system will operate on a randomized duty-cycle to avoid "training" fish with the strobe (pers. comm., Kurt Fresh, NWFSC). Observations will target conditions during which species of particular interest (i.e., listed species) or large aggregations are likely to be present at close range to the turbine rotor, based on preliminary results from the presence/absence study (§5.2). The number of instances for which images are captured will be determined, in consultation with the MARC, based on the results of the power analysis (§5.2) and the feasibility of data archiving and review. During the first year of operation, studies will be conducted seasonally within a two week window on the same schedule as presence/absence studies. In addition to limiting the volume of data collected to that which is feasible for analysis, this will result in relatively long (e.g., fortnightly) periods in which the strobe will not be activated. "Dark" periods of this duration are recommended to avoid training of fish and marine mammals (pers. comm., Kurt Fresh, NWFSC).

5.4.3 Data Analysis

Observations will be stratified based on the results of the identified factors influencing presence/absence (§5.2). As for the strobe illumination study, only velocities exceeding 1 m/s will be studied as interactions with a stationary or slowly rotating turbine are of lesser interest (strobe illumination would also be expected to have a greater effect on behavior during quiescent periods). Identification of taxonomic groupings for marine animals involved in rotor interactions will utilize a similar progressive, expert review.

The qualitative strike/collision risk will be assessed for each observation as:

- *Rank 1*: Targets observed passing through the turbine blades. Number of targets also noted. Unless the number of targets in the field of view is very high, with targets in the near-field masking those closer to the rotor, it should be possible to determine if passage has occurred.
- *Rank 2*: Targets observed passing through the open center of the turbine. Number of targets also noted.
- *Rank 3*: Targets observed in field of view, but not passing through turbine rotor
- *Rank 4*: No targets observed in the field of view

5.4.4 Reporting and Adaptive Management

A preliminary, oral report will be made to the MARC within 15 days of study initiation to provide informal feedback on observations. An interim oral and written report will be provided to the MARC within 90 days of each seasonal study. Based on report results and analytical effort, the MARC will determine an appropriate sampling and analysis approach for remainder of project to ensure resource protection, and will determine whether project modifications are necessary.

5.5 Artificial Reef Effect

5.5.1 Objective

It is likely that the turbine support structure will act as an artificial reef and attract fish that associate with complex habitat. This may have positive or negative effects, depending on the attracted species.

The objective of this study is to characterize how marine animals are using the turbine support structure over all stages of the tide, and to ensure resource protection based on the results of the study. This will be correlated with information about the colonization of the subsea base and turbine support structure collected by the Benthic Habitat Monitoring and Mitigation Plan.

Since reef effects are a lower priority than strike/collision, this study will be conducted after the seasonal presence/absence, artificial illumination, and rotor interaction studies planned for the first year of operation.

5.5.2 Data Collection

Equipment Description

The primary systems to be used in this test are the optical and acoustic cameras described in §5.1. Current velocity will be monitored using Doppler profilers on the subsea base. The cameras will be oriented towards the support frame (upright section, including junction with subsea base). Because maintenance cycles to recover, clean, and reconfigure the camera system will occur three times each year, this study will not begin until at least the second year of project operation (i.e., seasonal rotor interaction studies require that the camera system be oriented towards the turbine rotor). Consequently, this study plan is less defined than the preceding plans, as its implementation will depend upon the lessons learned from preceding studies and any further rotor interaction monitoring determined to be necessary by the MARC. For example, depending upon results from the first year of operation, the camera on one turbine foundation might be re-tasked for an artificial reef study, while the other remains oriented at the turbine rotor to assess annual trends in presence/absence.

Survey Procedure

The general survey structure will mirror that of the presence/absence study described previously. Depending on the effect of strobe illumination during weak currents, a subset of observations could be complimented by acoustic camera imagery (e.g., 30 seconds observation prior to single frame capture by the strobes). This would enable behavioral observations using the acoustic cameras and species identification using optical camera imagery during periods of weak currents. The duration and intensity of the study will be determined, in consultation with the MARC, based on the results of the other studies described in this plan.

5.5.3 Data Analysis

Data analysis will also mirror that of the previously described presence/absence study. Approaches to data analysis will be developed in consultation with the MARC based on the effectiveness of the preceding studies during the first year of operation.

5.5.4 Reporting and Adaptive Management

Reporting and adaptive management triggers for artificial reef studies will be developed in consultation with the MARC.

5.6 Turbine Avoidance

5.6.1 Objective

In addition to direct interaction and attraction/aggregation, fish may avoid the turbines. This could occur at relatively close range (within a few rotor diameters) as they detect hydrodynamic pressure changes upstream of the turbine on their lateral line system. Detection of acoustic particle velocity may be possible for some fish species at similar distances by the same biological mechanism. At greater distances, up to several hundred meters, fish may exhibit avoidance behavior in response to acoustic pressure (i.e., turbine sound), though fish behavioral responses to sound are not well understood (Hawkins and Popper, 2012). Avoidance at close range, if preventing strike or collision, could be beneficial. However, avoidance at greater range would be undesirable, since a large array could create a barrier to migratory species.

Since avoidance of the pilot-scale turbines is a lower priority than strike/collision, this study will be conducted after the seasonal presence/absence, artificial illumination, and rotor interaction studies planned for the first year of operation.

5.6.2 Data Collection

The effective range of the optical camera system is expected to be no greater than 7 m for target detection and will be more limited for taxonomic identification. Consequently, the optical cameras may be effective at studying fish avoidance to the turbines caused by hydrodynamic pressure or acoustic particle velocity, as these would be expected no more than 1-2 diameters upstream of the turbine rotor (i.e., 6-12 m). Studies of avoidance at greater distances in response to sound (e.g., 100 meters) would likely require active sonar (split beam or multi beam). Sonars operating at 900 kHz, for example, would be suitable for this application. However, sonar side bands may be audible to mid- and high-frequency cetaceans in the project area and the operation of such sonars would require study plans to be developed in consultation with resource agencies to avoid unacceptable incidental harassment of marine mammals.

For an avoidance study, the Adaptable Monitoring Package would be oriented away from the turbine rotor to detect targets upstream of the turbine. The acoustic camera (BlueView P900-2250) has a 900 kHz setting and could be used for investigation of avoidance behavior. If a higher resolution scientific echosounder is required (e.g., Simrad EK 60), a sonar of this type could be readily integrated into the Adaptable Monitoring Package given power and communications capabilities (pers. comm. John Horne, University of Washington). Current velocity upstream of the turbine would be monitored by the outward looking Doppler profilers.

Duty cycles and operating states for optical cameras and sonars will be developed in consultation with the MARC based on the results from first year of observations for presence/absence, strobe effect, and turbine interaction studies as well as information about fish avoidance of turbines developed by other tidal energy demonstration projects.

5.6.3 Data Analysis

Approaches to data analysis and interpretation will be developed in consultation with the MARC. For example, to evaluate close-range avoidance, one option could be to operate the cameras in the same manner as the presence/absence studies (§5.2) and determine if there are statistically significant differences in presence/absence under given tidal, diel, and seasonal conditions for observations 1-2 diameters upstream of the turbine, compared to close-in to the turbine rotor. If presence is more likely upstream of the turbine under equivalent conditions, this could suggest avoidance. The use of an active sonar to evaluate avoidance behavior at greater distances would require that metrics be developed, in consultation with the MARC, to describe behavioral changes and estimate species composition of acoustic targets.

5.6.4 Reporting and Adaptive Management

Reporting and adaptive management triggers for avoidance studies will be developed in consultation with the MARC.

6.0 APPROACH TO ADAPTIVE MANAGEMENT AND MITIGATION

In implementing this plan, the District will consult with the MARC as appropriate on the technical issues described above and data interpretation associated with the monitoring. Such consultation will include consideration of results from the monitoring system test plan, subsequent adjustments to monitoring methods and, as needed, the development and implementation of adequate mitigation measures to avoid adverse impacts to aquatic resources. In particular, the District will adopt the triggers and subsequent actions described below.

The District will follow the procedures described in the Adaptive Management Framework when conferring with the MARC on implementation of the Acoustic Monitoring and Mitigation Plan and considering how to address the results of the monitoring.

Adaptive Management Trigger 1: If monitoring suggests injury or mortality to any ESA-listed species beyond that specified in the Project’s Take Authorization, the turbine brake will be applied and the Project shut down. The District will notify the MARC within one week and coordinate with the MARC to determine if modifications to the Plan or project operations are necessary and if Project operations can be restarted.

Adaptive Management Trigger 2: If monitoring shows any aquatic species passing through the turbine rotor (within the limits specified in the Project’s Take Authorization), the District will notify the MARC within two weeks and coordinate with the MARC to determine if modifications to the Plan or project operations are necessary.

Adaptive Management Trigger 3: If monitoring detects any marine mammals in the camera field of view, the District will notify the MARC within two weeks and coordinate with the MARC to determine if modifications to this Plan, the Marine Mammal Monitoring and Mitigation Plan, or project operations are necessary.

Adaptive Management Trigger 4: If monitoring detects any diving seabirds in the camera field of view, the District will notify the MARC within two weeks and coordinate with the MARC to determine if modifications to the Plan or project operations are necessary.

Adaptive Management Trigger 5: In the event of a monitoring system outage, the significance and immediacy of repair will depend on when the outage occurs within the life of the project and the information about environmental interactions that has been gathered to that time. The significance of an outage at an early stage of the project will also depend on whether endangered species, such as Southern Resident killer whales, are likely to be present in the project area during the outage[1]. As an example, if a monitoring system became inoperative within the first week of the turbine deployment and Southern Residents were frequently in the project area, this would be much more significant in terms of ensuring marine resource protection than if such an outage were to occur after four years of operation and monitoring. If the near-turbine monitoring package becomes inoperative, the default response of the District will be to mobilize a spare package and conduct an unscheduled maintenance intervention, changing out the inoperative package. The entire monitoring package (near-turbine monitoring, passive acoustic monitoring, etc.) is designed to be recovered to the surface, serviced, and reconnected to turbine power and data systems, as described in the Project Safeguard Plan. The District will change out the monitoring package as quickly as possible and appropriate, depending on the factors such as when the outage occurs, the availability of a vessel, and ocean conditions. Given the broad availability of vessels in Puget Sound that could support this type operation and the required met-ocean condition window, an unscheduled maintenance intervention would likely be completed within one week of the outage being detected[2]. Simultaneously, the District will notify the MARC of the outage and unscheduled maintenance intervention. In the unlikely event that the fault is determined to be on the shore side of the wet-mate connection (i.e., not a fault in the recoverable monitoring package, but a component of the system between the wet-mate and

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[1] As an example, if the monitoring systems on one turbine was to become inoperative within the first week of the turbine deployment and Southern Residents were frequently in the project area, this would be much more significant in terms of ensuring marine resource protection than if such an outage were to occur after four years of operation and monitoring. As part of this example, if the outage occurs during a significant time, the District will conduct the repair as soon as possible, within the constraints of ocean conditions. As described in the project Safeguard Plan, marine resource protection can be ensured with a single, functional monitoring package. In this specific example (an outage of one monitoring package, including near-turbine and passive acoustic systems during a period of Southern Resident killer whale activity in Admiralty Inlet), the passive acoustic package on the other turbine would continue to provide coverage of the entire project area and rapid-response shoreline observers would be unaffected. The likelihood of the monitoring packages on both turbines simultaneously failing is extremely low, particularly in the early stages of the project, since both turbines will be deployed with the monitoring packages connected.

[2] The initial specifications for the AMP is for operations to be completed within a met-ocean window of 30 minutes with the currents fully set in one direction throughout the water column, a mean velocity less than 0.7 m/s, and a Sea State less than 3 on the Beaufort Scale. Based on analysis of current data collected within the project area, there is a 75% chance of at least one maintenance window occurring within 7 days of a fault notification and a 90% chance of at least one maintenance window occurring within 14 days of a fault notification.

shore station), then the affected turbine may need to be recovered to the surface to conduct repairs, as described in the Project Safeguard Plan. The decision as to whether immediate recovery of the turbine is necessary will depend on many factors, including the status of the instrumentation package on the other turbine, stage in the project, presence/absence of species of concern, and information collected to date about environmental interactions. In the interim, the District may continue to operate the turbines unless NMFS requests that turbine operations cease. If immediate recovery is necessary, it will be accomplished as soon as vessel mobilization and met-ocean conditions allow.

By June 30 of each year, the District will develop and file an annual report to FERC fully describing its implementation of the plan during the previous calendar year and a list of the proposed activities during the current calendar year. The MARC will have at least 30 days to review and comment on a draft report prior to the District finalizing and filing the report with FERC. The annual report will provide the following:

- A summary of the monitoring results.
- A summary of any issues or concerns identified by members of the MARC during the year regarding implementation of the plan.
- A list of any changes to the Plan or project proposed by consensus of the MARC during the year.
- A list of plan activities planned for the current year.

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