XODUS DEVELOP

Brims Tidal Array

Collision Risk Modelling - Atlantic Salmon

Brims Tidal Array Ltd

Assignment Number: A100242-S02
Document Number: A-100242-S02-TECH-001

Xodus Group
Cheapside House, 138 Cheapside
London, UK, EC2V 6BJ

T +44 (0)207 246 2990
E info@xodusgroup.com
www.xodusgroup.com

xodus GROUP

Collision Risk Modelling - Atlantic Salmon

A100242-S02

Client: Brims Tidal Array Ltd
Document Type: Technical Note
Document Number: A-100242-S02-TECH-001

A01	03/03/2016	Issued for Use	AS	LF	LF	
R01	22/02/2016	Issued for Review	AS	KC	LF	-
Rev	**Date**	**Description**	**Issued By**	**Checked By**	**Approved By**	**Client Approval**

CONTENTS

1 INTRODUCTION

There is a concern that submerged tidal energy devices placed within a tidal current will present an obstacle to wildlife within the tidal channel and there is a risk of collision as a result. Although concerns are primarily for cetaceans and pinnipeds there is also some concern of the risk to fish, particularly Atlantic salmon (*Salmo salar*). Due to the risks posed, Marine Scotland has recommended that an assessment of collision risk to fish is informed by project specific collision risk modelling (CRM).

CRM is used to assess this risk for Atlantic salmon and it uses a physical model of a rotor and the body size and swimming activity of Atlantic salmon to estimate the potential collision rate. It focuses on the number of animal transits through a rotating rotor and the collision risk during each transit. Following the calculation of the collision risk, likely avoidance behaviours can be applied and a realistic collision rate can be determined (Band, 2015).

This technical note discusses the collision risks associated with various scenarios at the Brims Tidal Array, located in the Pentland Firth to the south of the island of Hoy, Orkney.

2 COLLISION RISK MODELLING

2.1 Model input

2.1.1 Brims development scenarios

Four scenarios were modelled for the Atlantic salmon CRM, detailed in Table 2.1. These were based on the two Project Stages (I and I&II) and two different types of tidal turbine device that are being considered for use for the project.

Table 2.1 Summary of scenarios modelled for Brims CRM

Scenario number	Scenario variables
1	Stage I (30 turbines) utilising 3 bladed turbines
2	Stage I (30 turbines) utilising 10 bladed turbines
3	Stage I&II (200 turbines) utilising 3 bladed turbines
4	Stage I&II (200 turbines) utilising 10 bladed turbines

2.1.2 Salmon population and apportioning

Salmon population numbers are detailed in Table 2.2. The most up to date source on Atlantic salmon migration patterns around Scotland is Malcolm *et al*., (2010). This study details the likelihood of Atlantic salmon from rivers on the east coast of Scotland migrating north and east towards the Faroe Islands and west Greenland. Fish returning to Scotland are most likely to come from a north westerly direction and the lack of Atlantic salmon fisheries in Orkney and Shetland suggest the Pentland Firth as the most likely migration route. The use of the Pentland Firth as a key migratory route is supported by an Atlantic salmon tagging study (Godfrey *et al*., 2014). This study focusses on depth ranges of migrating salmon but highlights the difficulty in predicting the proportion of Atlantic salmon passing though the Pentland Firth. As a result the assumptions, relevant to salmon populations that were adopted for the MeyGen CRM are considered relevant here as they have been reviewed and approved by Marine Scotland (Marine Scotland, 2013).The key assumptions which have been made for this CRM modelling are:

- Total returning salmon population numbers have been taken from ICES (2015) with the 10 year average figure being selected;
- 88% of the total returning population is assumed to head towards east coast waters (Marine Scotland 2013); and
- 90% of the east coast returning population is assumed to pass through the Pentland Firth with 10% returning via Orkney waters (Marine Scotland, 2013).

Total smolt population has been taken from the CRM carried out for MeyGen. This analysis quantified the number of smolts using smolt density in Scottish rivers and the area of suitable habitat available (Xodus Group, 2012). These data are considered relevant here as ongoing studies in the River Esk (where the original smolt density value was based) show that the smolt population has remained relatively stable since the 1960's (Scottish Government, 2016). It is therefore unlikely that the smolt population has changed significantly since the analysis for MeyGen was carried out. As for grilse and adult salmon it is assumed that 88% of the smolt population originate from east coast rivers and 90% of these migrate through the Pentland Firth per year (Marine Scotland, 2013).

Table 2.2 Salmon population numbers

Assumptions		Outputs (1SW)[1]	Outputs (MSW)[2]	Smolts	Comment
Returning salmon population (1SW)	315,284	-	-	-	ICES 2015, 10 year average.
Returning salmon population (MSW)	237,844	-	-	-	ICES 2015, 10 year average.
Migrating smolt population	8,342,569	-	-		Xodus Group(2012)
Proportion from/to east coast	88%	277,450	209,303	7,341461	Xodus Group (2012)
East coast proportion returning via Pentland Firth	90%	249,705	188,372	6,607,314	% of east coast returning population assumed to go through Pentland Firth.
East coast proportion returning via Orkney waters	10%	27,745	20,930	834,257	% of east coast returning population assumed to go through Orkney waters.

[1] 1SW refers to grisle, or salmon that have spent one winter at sea
[2] MSW refers to adults, or salmon that have spent multiple winters at sea

2.1.3 Brims technology and operational parameters for CRM

The parameters used for the Brims collision risk model are detailed in Table 2.3.

Table 2.3 Project parameters for Brims tidal array

Parameter	Notes from model worksheet	Model input values				Notes / assumptions
		Stage I (3 bladed)	Stage I (10 bladed)	Stage II (3 bladed)	Stage II (10 bladed)	
Min Clearance between blade tip and sea surface at LAT		30	30	30	30	
Water / channel depth (m)	Mean depth of channel in area where animals are foraging / transiting	70	70	70	70	The average depth in the area in which the turbines will be located.
Time in period	Normally this calculation will be done for a period of 1 year. However it can be done for a month or breeding season e.g. 3.5 months or a number of weeks, as required. Enter the period required, choosing weeks, months or years in cell D43 and the appropriate number in cell E43. The spreadsheet will convert to seconds in sheet E44	1 year	1 year	1 year	1 year	One year has been used due to the limited understanding of the seasonal behaviour of salmon.
Number of rotors		30	30	200	200	
Rotor diameter (c/f)		23	12.8	23	12.8	12.8 m is the maximum rotor diameter for the 10 bladed turbine. 23 m is the maximum diameter for the 3-blade turbine.
Rotor radius	This is a calculated field	11.5 m (as	6.4 m (as calculated	11.5 m (as calculated	6.4 m (as calculated	

Parameter	Notes from model worksheet	Model input values				Notes / assumptions
		Stage I (3 bladed)	Stage I (10 bladed)	Stage II (3 bladed)	Stage II (10 bladed)	
		calculated by the model)	by the model	by the model)	by the model)	
Number of blades		3	10	3	10	
Maximum blade width	The width of the blade across its widest point, sometimes called the chord width	1.8 m	1.9 m	1.8 m	1.9 m	
Blade pitch at blade tip	The angle that the blade makes at the rotor plane, in degree: a blade at 0 degrees would lie in the plane of the rotor and at 90 degrees would be fully feathered. Blades are twisted, meaning that the pitch varies along the blade length, increasing from a few degrees at the tip to a large angle close to the hub. The worksheet calculates the blade pitch at different radii	0 degrees	30 degrees	0 degrees	30 degrees	A range of 0-10 degrees is expected for 3 bladed turbines and 20-30 degrees for the 10 bladed turbine. • Based on the model0 degrees is the worst case (in terms of highest encounter rate) for the Scenario 1; and • 3 and 30 degrees is the worst case (in terms of highest encounter rate) for Scenario 2 and 4.
Blade profile	The table to the right lists the blade width c, as a proportion of the maximum blade width, at different radii r from r/R=0 to r/R=1, in steps of r/R=0.05. Accurate data is often difficult to obtain because of commercial sensitivities over blade design. The spreadsheet includes a generic profile based on a wind turbine blade	Provided in model	Provided in model	Provided in model	Provided in model	The profile in the model assumes a typical turbine that is at its widest at approximately 25% along the length of the blade (measured from the rotor). If this is not correct, we will need to know the width of the face of the blade at approximately 5% intervals (although we could fill in some of the gaps if fewer measurements were available).
Rotation speed	The mean operational rotation speed of the rotors, in rpm (revolutions per minute). The spreadsheet converts this to radians per second by multiplying by 2π/60. Periods when the turbine is non-operational because of too weak or over-strong currents, or down-time for	10 rpm	8 rpm	10 rpm	8 rpm	

Parameter	Notes from model worksheet	Model input values				Notes / assumptions
		Stage I (3 bladed)	Stage I (10 bladed)	Stage II (3 bladed)	Stage II (10 bladed)	
	maintenance, should be excluded. This is the mean rotation speed when operational					
% time not operational	This allows for the proportion of time when the turbine is not operational because the current speed is below the cut-in speed for the turbine or above the cut-out speed when the current speed is excessive. The 'current speed' worksheet provides a calculator for this. Allowance may also be included for downtime for maintenance and repair	14.4%	14.4%	14.4%	14.4%	
Mean current speed	This is the tidal current speed (in m s-1) at the turbine site, averaged over the time during which the turbine is in operation, i.e. excluding slack tides or excessive tides when the turbine may be closed down. When averaging, both ebb and flow tides should be given the same sign (otherwise the tidal flow will average to near-zero)	1.82	1.82	1.82	1.82	
Channel width		13,180 m	13,180 m	13,180 m	13,180 m	Distance from point at Brims to point at East Mey on mainland Scotland

2.2 Model output

Using the parameters outlined in Section 2.1.3 as inputs, a total of four scenarios were modelled for smolts, 1SW and MSW fish and a range of avoidance figures applied to the outputs. The results are shown in Table 2.4. The results indicate that the worst case potential collision risk is from the 10 bladed turbine. The level of avoidance by Atlantic salmon is unknown but are expected to be high and avoidance of 95% is considered precautionary (Band, 2015). Assuming 95% avoidance, up to 32 salmon (1SW + MSW) and 211 smolts would potentially collide with the maximum development scenario of 200 turbines (Scenario 4) per year, as highlighted by the cells shaded in the table. This represents 0.007% of the annual number of grilse and adult fish passing through the Pentland Firth and 0.003% of the smolts.

Table 2.4 CRM output and percentage of Pentland Firth fish

Avoidance rates	Smolt (smolt per year)	Salmon 1SW (fish per year)	Salmon MSW (fish per year)
Scenario 1 (3 bladed turbine, 30 devices)			
0%	458	36	30
50%	229	18	15
90%	46	4	3
95%	23	2	2
98%	9	1	1
99%	5	0	0
Scenario 2 (10 bladed turbine, 30 devices)			
0%	632	52	44
50%	316	26	22
90%	63	5	4
95%	32	3	2
98%	13	1	1
99%	6	1	0
Scenario 3 (3 bladed turbine, 200 devices)			
0%	3056	237	201
50%	1528	119	100
90%	306	24	20
95%	153	12	10
98%	61	5	4
99%	31	2	2
Scenario 4 (10 bladed turbine, 200 devices)			
0%	4212	346	291
50%	2106	173	145
90%	421	35	29
95%	211	17	15
98%	84	7	6
99%	42	3	3

3 REFERENCES

Band, W.T. (2015) Assessing collision risk between tidal turbines and marine wildlife (draft) *Scottish Natural Heritage Guidance Note Series.*

Godfrey, J., Stewart, D., Middlemas, S. and Armstrong, J. (2014) Depth use and migratory behaviour of homing Atlantic salmon (*Salmo salar*) in Scottish coastal waters *ICES Journal of Marine Science*

ICES (2015) Report of the Working Group on North Atlantic Salmon (WGNAS), 17–26 March, Moncton, Canada. ICES CM 2015/ACOM:09. 332 pp.

Malcolm, I., Godfrey, J. and Youngson, A. (2010) Review of migratory routes and behaviour of Atlantic salmon, sea trout and European eel in Scotland's coastal environment: implications for the development of marine renewables *Scottish Marine and Freshwater Science* **Volume 1 No 14**

Marine Scotland (2013) Marine Renewables Consideration of Atlantic salmon Collision Modelling – MeyGen – Inner Sound; Pentland Firth

Scottish Government (2016) North Esk River Research available online here http://www.gov.scot/Topics/marine/Salmon-Trout-Coarse/Freshwater/Monitoring/Esk [Accessed 01/03/2016; last updated 23/04/2014]

Xodus Group (2012) Estimating the encounter rate for Atlantic salmon for the MeyGen Tidal Energy Project, Phase 1 and potential population effects