Wave resource assessment for Lord's Cove, Newfoundland: 2012 survey

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SUMMARY

The wave energy resource outside Lord's Cove, Newfoundland, has been characterized using wave buoy data to inform the design of a wave pump for the College of the North Atlantic. This resource characterization is based on wave probe data that was pre-processed and transmitted from a wave buoy outside Lord's Cove for 10 months during 2012 (excluding March and April, when the wave probe was not on station). The data is limited to pre-processed parameters from spectral analysis provided by an Axys Technologies Ltd. Triaxys Directional Wave Buoy; raw data has also been downloaded from the buoy after it was retrieved. The results include seasonal probability densities for wave height, period and direction, omnidirectional mean wave power and wave energy flux per unit wave crest. The monthly wave statistics for the theoretical wave power and energy are estimated and presented. Future work is suggested to be tailored to wave pump design.

ADDRESS

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Abstract

The wave energy resource outside Lord's Cove, Newfoundland, has been characterized using wave buoy data to inform the design of a wave pump for the College of the North Atlantic. This resource characterization is based on wave probe data that was pre-processed and transmitted from a wave buoy outside Lord's Cove for 10 months during 2012 (excluding March and April, when the wave probe was not on station). The data is limited to pre-processed parameters from spectral analysis provided by an Axys Technologies Ltd. Triaxys Directional Wave Buoy; raw data has also been downloaded from the buoy after it was retrieved. The results include seasonal probability densities for wave height, period and direction, omnidirectional mean wave power and wave energy flux per unit wave crest. The monthly wave statistics for the theoretical wave power and energy are estimated and presented. Future work is suggested to be tailored to wave pump design.

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Glossary

ATI	Axys Technologies Inc.
CNA	College of the North Atlantic
GPS	global positioning system
H_{mo}	significant wave height as the mean of the one-third highest waves
NRC	National Research Council Canada
T_e	energy period, a mean wave period with respect to the spectral distribution of wave energy transport or wave power level (usually a fraction of peak period)
T_P	peak wave period
UTC	coordinated universal time

1 Introduction

The College of the North Atlantic (CNA) solicited collaboration from National Research Council Canada (NRC) in the design of a wave pump to supply water to the CNA on-shore aquaculture centre at Lord's Cove. To characterize the wave resource outside Lord's Cove, wave data has been measured by a wave buoy at a proposed wave pump location; the wave buoy was on station for most of 2012, excluding March and April after its mooring failed. This wave buoy data has been analysed by NRC to assess the theoretical (omnidirectional) power and total energy available for operating a wave pump. Maximum conditions have also been noted to inform the preliminary design process.

The area under investigation is a site along the southern coast of Newfoundland outside the entrance to Lord's Cove on the Burin peninsula.

1.1 Location

An Axys Technologies Inc. (ATI) wave buoy was deployed twice at 46.86°N latitude, 55.667°W longitude, a point approximately one kilometre outside Lord's Cove. This location, shown in Figure 1, was selected for proximity to the on-shore aquaculture centre and for good exposure to ocean sea states with minimal interference from local bathymetry. The buoy was moored in 30 metres* of water.

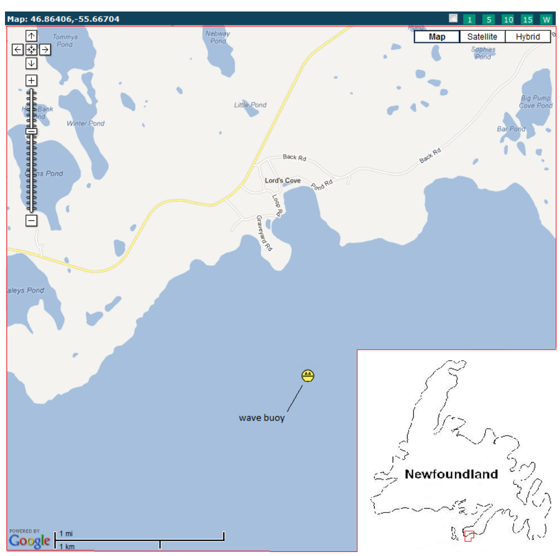


Figure 1: Map of wave buoy location

*all units SI unless otherwise noted

1.2 Data acquisition date range

The wave buoy was first deployed on January 10, 2012. Data was collected from January 10 to February 26, when the buoy moved off-station after breaking its mooring. The buoy was re-deployed on May 1 within 100 metres of its original position. The buoy was retrieved finally in December after it broke its mooring again on December 24. The results presented here include only data for the dates in Table 1.

Table 1: Data acquisition dates

start date	end date	note	samples (days)
Jan. 10, 2012	Feb. 26, 2012	mooring failure @16:30UTC*	2,226 (48)
May 2, 2012	Dec. 24, 2012	mooring failure @07:00UTC	10,871 (232)
			*coordinated universal time (UTC)

This report describes the method used to collect and process data and a preliminary analysis of the wave environment at Lord's Cove, Newfoundland in 2012. It is important to note that the results presented here are based strictly on pre-processed wave buoy data.

Assumptions and methods for analysing wave data were explained in detail in the interim report [1]; here, the relation between these assumptions and test conditions are presented in Section 2. The wave buoy instruments and pre-processing method are described in the Section 3, along with time series of the full data set for channels used in the analysis. Section 4 presents analysed data as recommended by Saulnier and Pontes [2]. Estimates for average theoretical power and energy for one year are summarized and discussed in Section 5. Suggestions for future work relevant to the wave pump design are discussed in Section 6

2 Assumptions and test conditions

This analysis of the wave data at Lord's Cove relies on assumptions that the sea surface behaves as a stationary, ergodic, Gaussian random process.

Stationarity requires that the sea surface behaviour remain constant in time and space, ie. within the sample time period and the range of the wave buoy mooring swing. In the 9-minute sample time, we expect that the wave spectrum did not change dramatically, except possibly for transient effects (eg. boat wakes). In the space of the swing about its mooring, the buoy was restricted to a radius of less than 100 metres during each of the deployments, which were centred within approximately 60 metres of each other. Soundings indicated a flat bottom in the area of the buoy, so it is reasonable to assume the wave spectrum remains constant in space, as well as time. The buoy location data for both deployments is plotted in Figure 2 relative to the centre of the data.

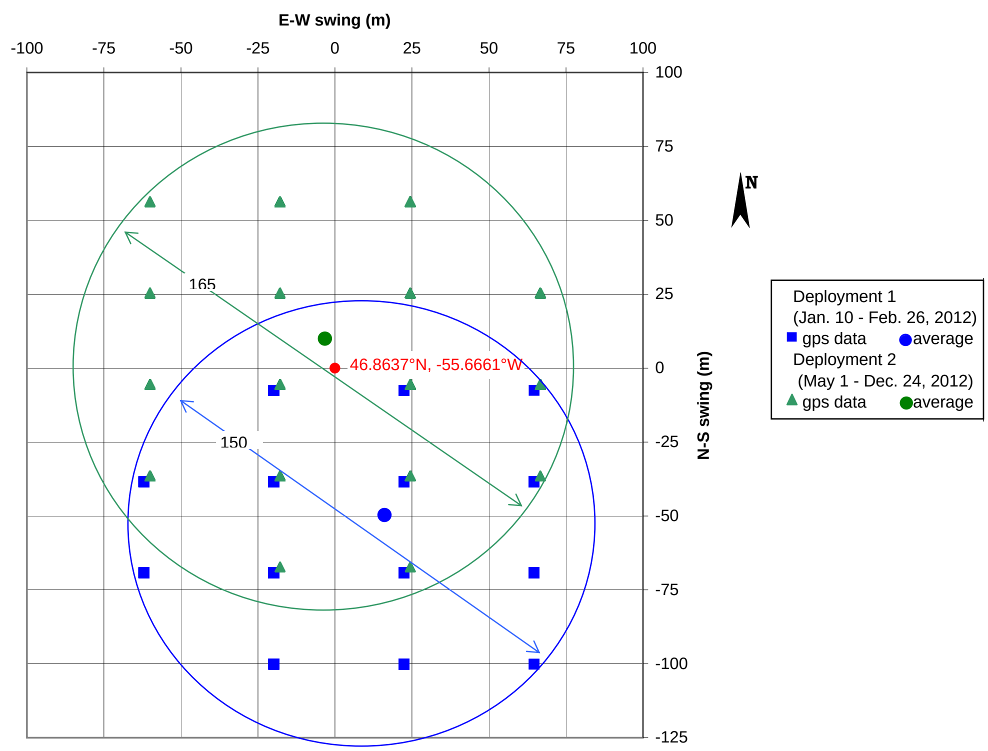
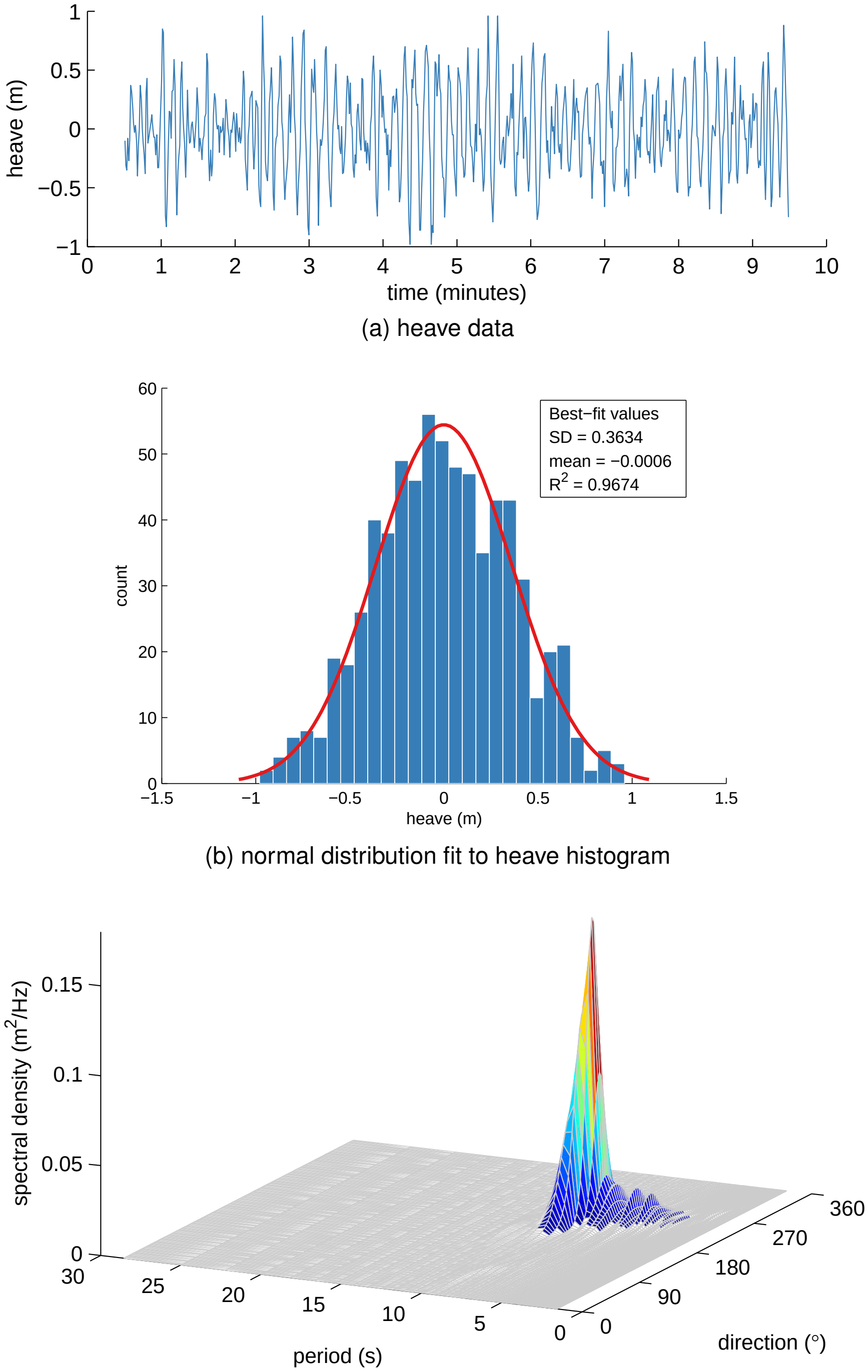


Figure 2: Mooring swing for wave buoy deployments at Lord's Cove (2012)

Ergodicity requires that the sample time is sufficiently long for a reasonable statistical uncertainty. Wave data is strictly speaking not symmetric (ie. non-Gaussian), according to Tayfun[3]. However, given a narrow band wave spectrum, linear theory is appropriate. Figure 3 shows (a) a 9-minute heave data sample representing the sea surface, which correlates well to (b) a Gaussian fit line; the associated spectral density (c) shows sharply-defined peaks typical of the frequency bands in this data.



(a) heave data

(b) normal distribution fit to heave histogram

(c) directional spectrum (pre-processed by wave buoy)

Figure 3: Sample sea surface data (Feb. 1, 2012 07:00)

3 Measurement and pre-processing

Wave data was collected and pre-processed using an ATI *Triaxys*™ Directional Wave Buoy. The buoy instruments measure heave and direction and internal device temperature, and wave height and period are extracted from the spectra. The accuracies for the instruments and the reporting resolutions are given in Table 2.

The ATI buoy collects time traces for sensor data and global positioning system (GPS) location and stores these data on board. It pre-processes the data by performing spectral analysis for transmission by satellite. For these deployments, the buoy was set to sample data at approximately 1.3 Hertz for 9 minutes, pre-process and transmit the results at half-hour intervals via InmarsatD satellite, which are then downloaded via the internet. Only this pre-processed data is used for the analysis in this report.

Table 2: ATI Triaxys wave buoy instrument ranges and resolution[4]

Data	Range	Resolution	Accuracy
Heave	20 m	0.01 m	better than 2%
Direction	0 to $360°$	$1°$	$\pm 1°$
Temperature	not stated	$1°$C	not stated
Height	20 m	0.01 m	(calculated)
Period	1.6 s to 33.3 s	0.5 s	(calculated)

Selection of data is based on inspection and graphing of the complete data set; mooring failures are immediately identified by excursions of the GPS data from the usual mooring swing. Out of 13,358 samples, only two anomalies (one sudden change in period, another in latitude) were identified and removed before analysis. (GPS altitude and internal temperature data were also checked. A few anomalies in the altitude data did not seem to affect other data and so these data are included in the analysis.)

The time series data exhibit smooth changes in sea states as storms wax and wane. Inspection of wave spectra from a few raw data samples confirm narrow frequency bands. Of particular note is the arrival of Hurricane Leslie on Sept. 11, 2012 (shown in Figure 4). As the storm approached, peak period oscillated between 5 s and 15 s from sample to sample; significant wave height grew relatively smoothly from 3 m to 6.5 m in a mere 4 hours (8 samples). The oscillation is an effect of a sea state with two strong periods – Figure 5 shows how the wave spectra peaks combat each other for dominance in a confused sea state. Short, frequent samples ultimately provide data on multiple periods in storm conditions like this.

The significant wave height (H_{mo}), peak period (T_P) and mean wave direction reported by the wave buoy in 2012 are shown in Figures 6 to 8. The pre-processed data is presented as time series, as recommended by Saulnier and Pontes [2].

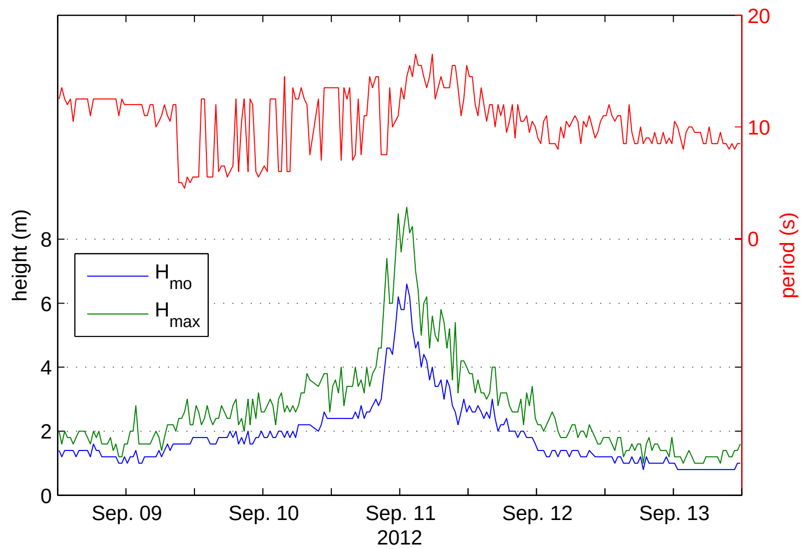


Figure 4: Wave buoy data for Hurricane Leslie

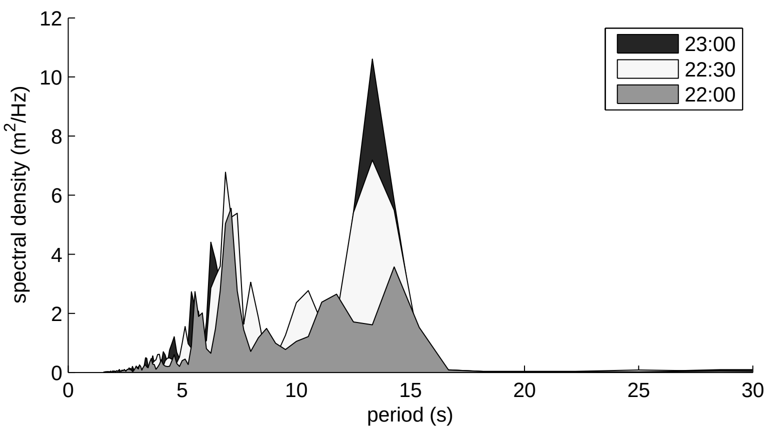


Figure 5: Shifting dual wave period spectra (Sept. 10, 2012)

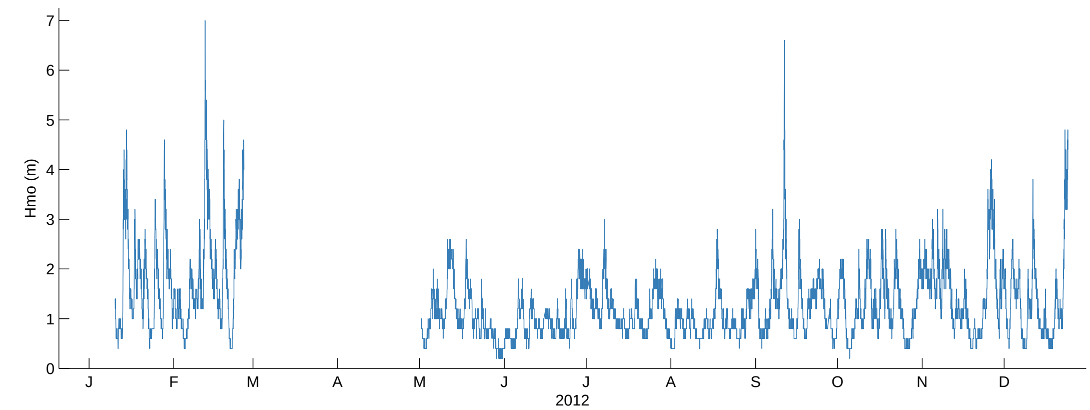


Figure 6: Time series for significant wave height (30-minute intervals)

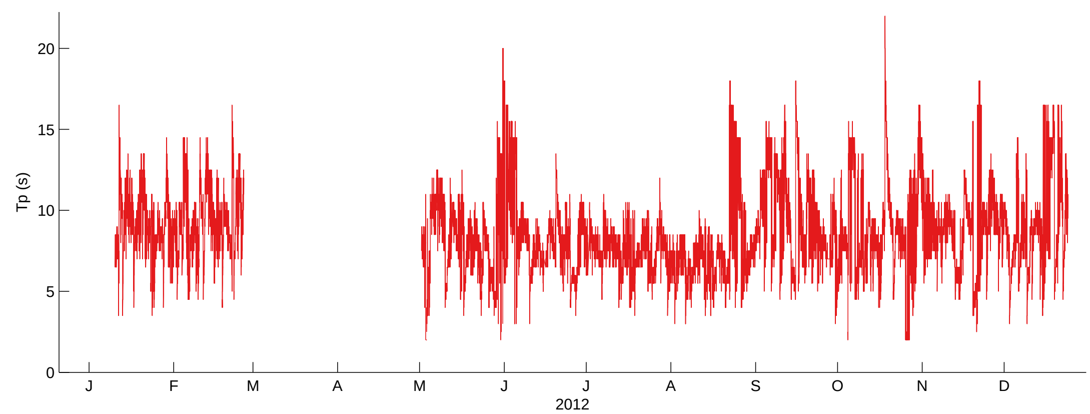


Figure 7: Time series for peak period (30-minute intervals)

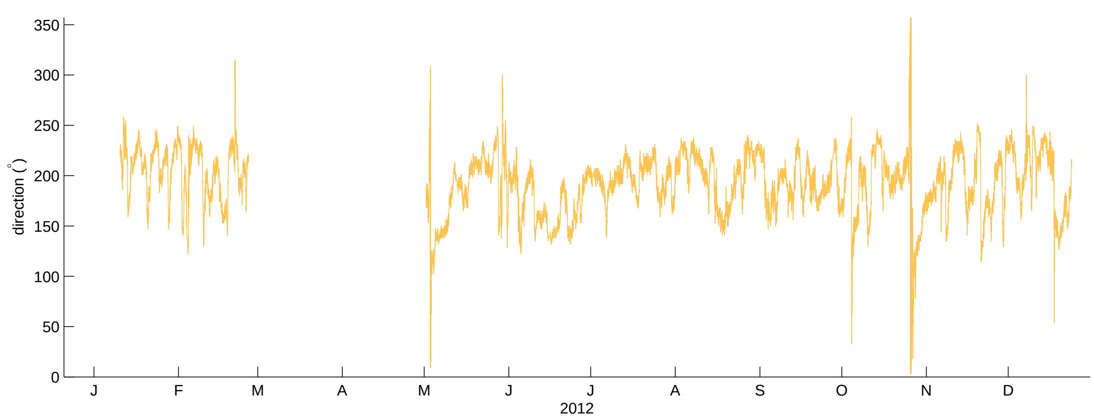


Figure 8: Time series for wave direction (30-minute intervals)

4 Results

All calculations and results in this report are based on the ATI spectral calculations for significant wave height, peak period and mean direction only. Water density is assumed to be 1027 kg/m^3 (average sea surface density) for comparison with Cornett [5].

The pre-processed time series data are post-processed in Mathworks *Matlab*™ using scripts to produce the wave scatter tables and histograms of the probability densities for height and period for each season (see [2], [5]). The average wave power for each sea state is tabulated and the total wave energy is calculated per unit crest length. These results and the methods for generating them are provided in the following sub-sections.

4.1 Wave environment

The wave environment is described by seasonal wave scatter diagrams, probability densities and wave direction roses per Saulnier and Pontes' Guidelines [2].

The wave scatter diagram is a joint histogram of significant wave height and energy (mean) period. The significant wave height is the pre-processed H_{mo}. In this analysis, the energy period, T_e, is estimated from the pre-processed peak period T_P using a conservative value recommended by Cornett [5]:

$$T_e = 0.9 \cdot T_p \qquad \text{energy period} \tag{1}$$

The wave scatter diagram is presented in Tables 3 to 6 as relative (percent) occurrences for each season. The information in the wave scatter diagram is further summarized in the probability densities for height and period (Figures 9 and 10).

Wave direction is presented as a polar histogram of mean direction data binned by 30° increments in a wave direction rose for each season (Figure 11). Each rose shows the direction of wave approach *to* the buoy.

Table 3: Wave Scatter Diagram (%) for Lord's Cove – Winter 2012

$T_e(s)$	0 - 3	3 - 6	6 - 9	9 - 12	12 - 15	15 - 18	18 - 21	21 - 24	24 - 27	27 - 30	>30	**sum**
$H_{mo}(m)$												
>10												
9 - 10												
8 - 9												
7 - 8												
6 - 7				0.1								**0.1**
5 - 6				0.5								**0.6**
4 - 5			0.7	1.3	0.5							**2.6**
3 - 4		0.1	4.7	6.3	0.5							**11.7**
2 - 3		1.9	11.0	10.2	0.5							**23.5**
1 - 2		6.4	25.0	10.1	0.9							**42.4**
0 - 1		2.2	9.7	5.1	2.0							**19.0**
sum		**10.7**	**51.1**	**33.6**	**4.5**							**100.0**
												2226 samples (48 days)

Table 4: Wave Scatter Diagram (%) for Lord's Cove – Spring 2012

$T_e(s)$	0 - 3	3 - 6	6 - 9	9 - 12	12 - 15	15 - 18	18 - 21	21 - 24	24 - 27	27 - 30	>30	**sum**
$H_{mo}(m)$												
>10												
9 - 10												
8 - 9												
7 - 8												
6 - 7												
5 - 6												
4 - 5												
3 - 4												
2 - 3		1.0	2.7	1.1								**4.8**
1 - 2		8.9	23.2	12.2								**44.4**
0 - 1	1.0	10.8	27.9	5.7	4.5	0.2	0.2		0.5	0.1		**50.8**
sum	**1.0**	**20.7**	**53.9**	**19.0**	**4.5**	**0.2**	**0.2**		**0.5**	**0.1**		**100.0**
												2388 samples (52 days)

Table 5: Wave Scatter Diagram (%) for Lord’s Cove – Summer 2012

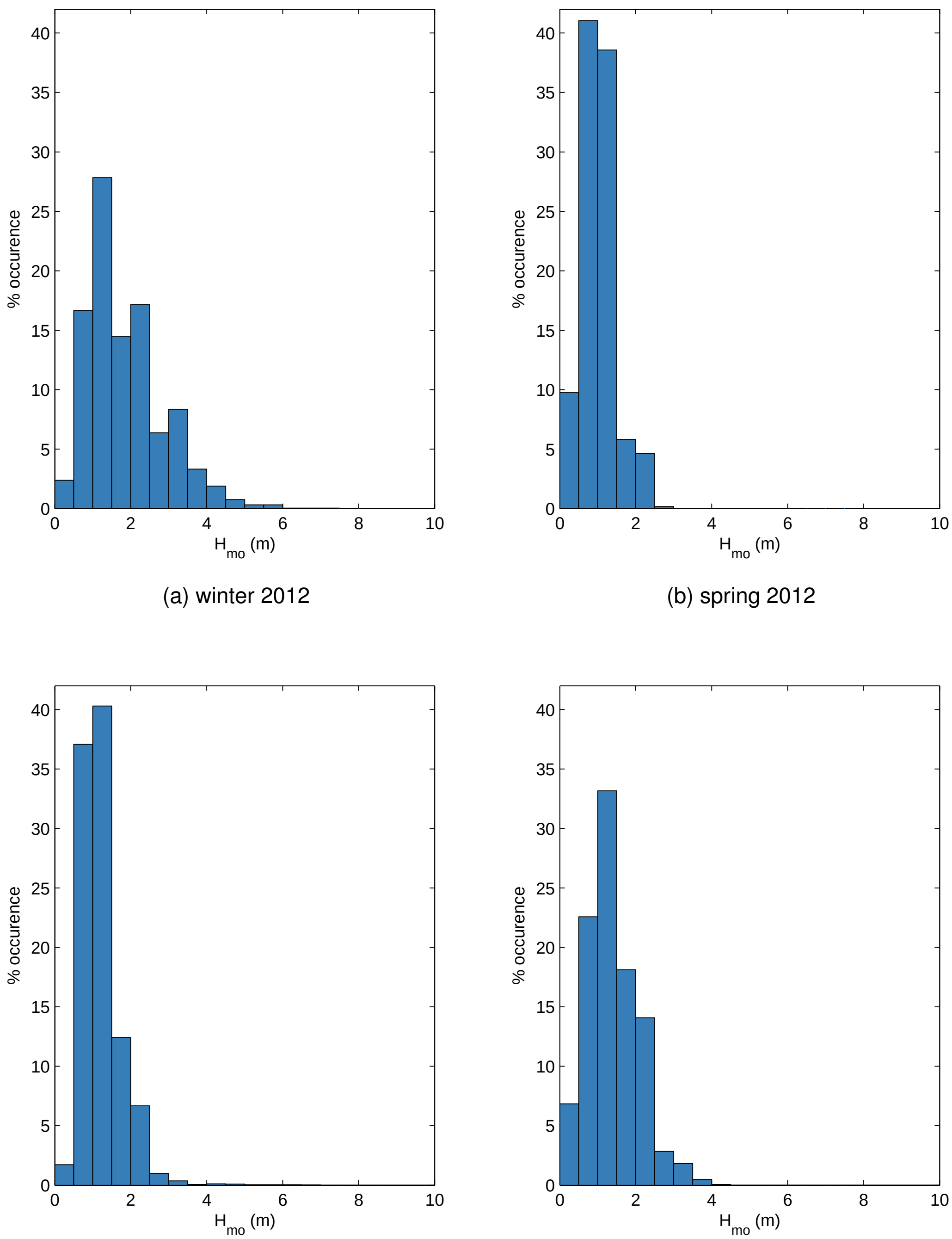
$T_e(s)$	0 - 3	3 - 6	6 - 9	9 - 12	12 - 15	15 - 18	18 - 21	21 - 24	24 - 27	27 - 30	>30	**sum**
$H_{mo}(m)$												
>10												
9 - 10												
8 - 9												
7 - 8												
6 - 7												**0.1**
5 - 6												**0.1**
4 - 5					0.2							**0.2**
3 - 4			0.2	0.1	0.2							**0.4**
2 - 3		1.2	4.1	1.8	0.5							**7.7**
1 - 2		16.5	28.0	6.5	1.8							**52.7**
0 - 1		13.2	18.6	3.6	3.2	0.1						**38.8**
sum		**31.0**	**50.8**	**12.1**	**6.0**	**0.1**						**100.0**

4345 samples (92 days)

Table 6: Wave Scatter Diagram (%) for Lord’s Cove – Fall 2012

$T_e(s)$	0 - 3	3 - 6	6 - 9	9 - 12	12 - 15	15 - 18	18 - 21	21 - 24	24 - 27	27 - 30	>30	**sum**
$H_{mo}(m)$												
>10												
9 - 10												
8 - 9												
7 - 8												
6 - 7												
5 - 6												
4 - 5												**0.1**
3 - 4			1.0	1.3								**2.3**
2 - 3		2.4	9.1	4.4	0.8	0.1						**16.9**
1 - 2		10.9	27.5	11.1	1.7		0.1					**51.3**
0 - 1	1.2	4.7	13.0	4.6	5.7	0.2						**29.4**
sum	**1.2**	**18.0**	**50.6**	**21.5**	**8.3**	**0.3**	**0.1**					**100.0**

4284 samples (91 days)



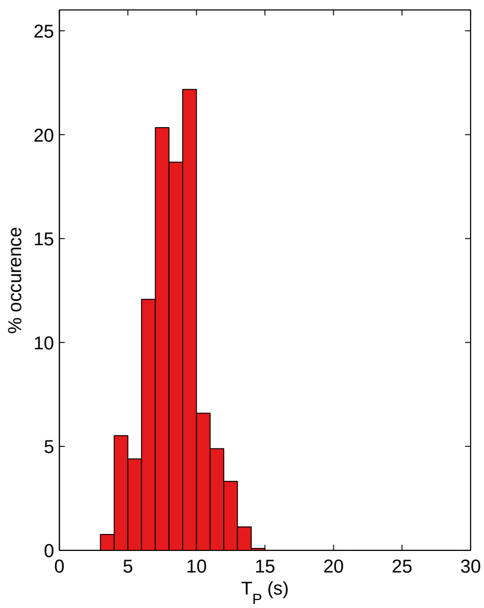
(a) winter 2012

(b) spring 2012

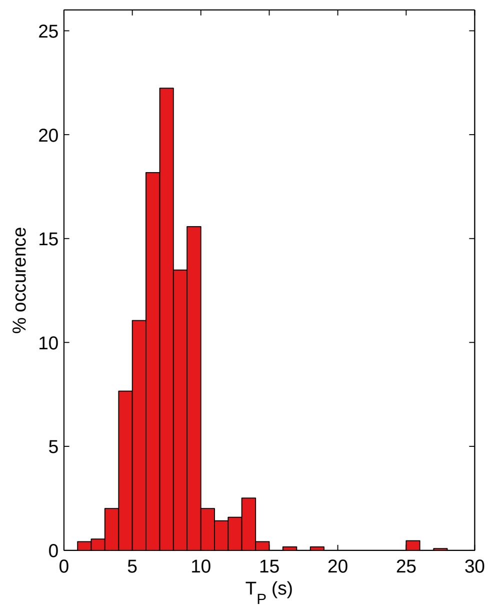
(c) summer 2012

(d) fall 2012

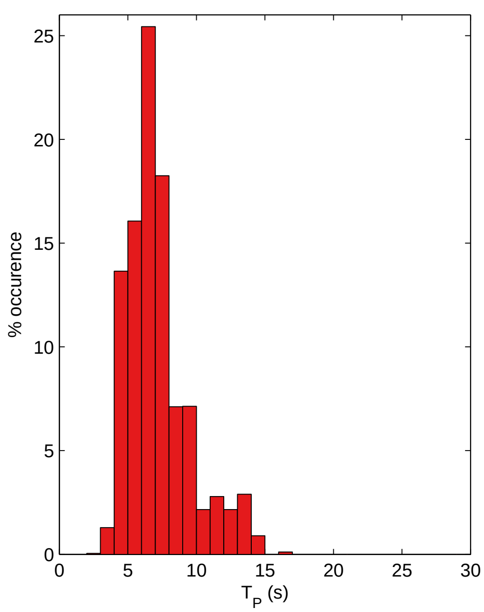
Figure 9: Seasonal probability densities of significant wave height



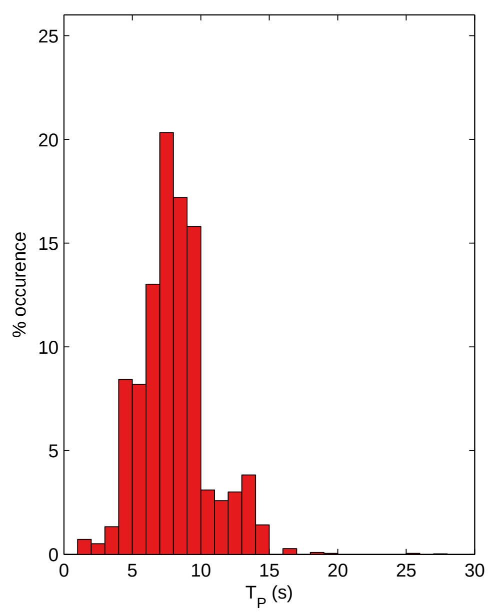
(a) winter 2012



(b) spring 2012

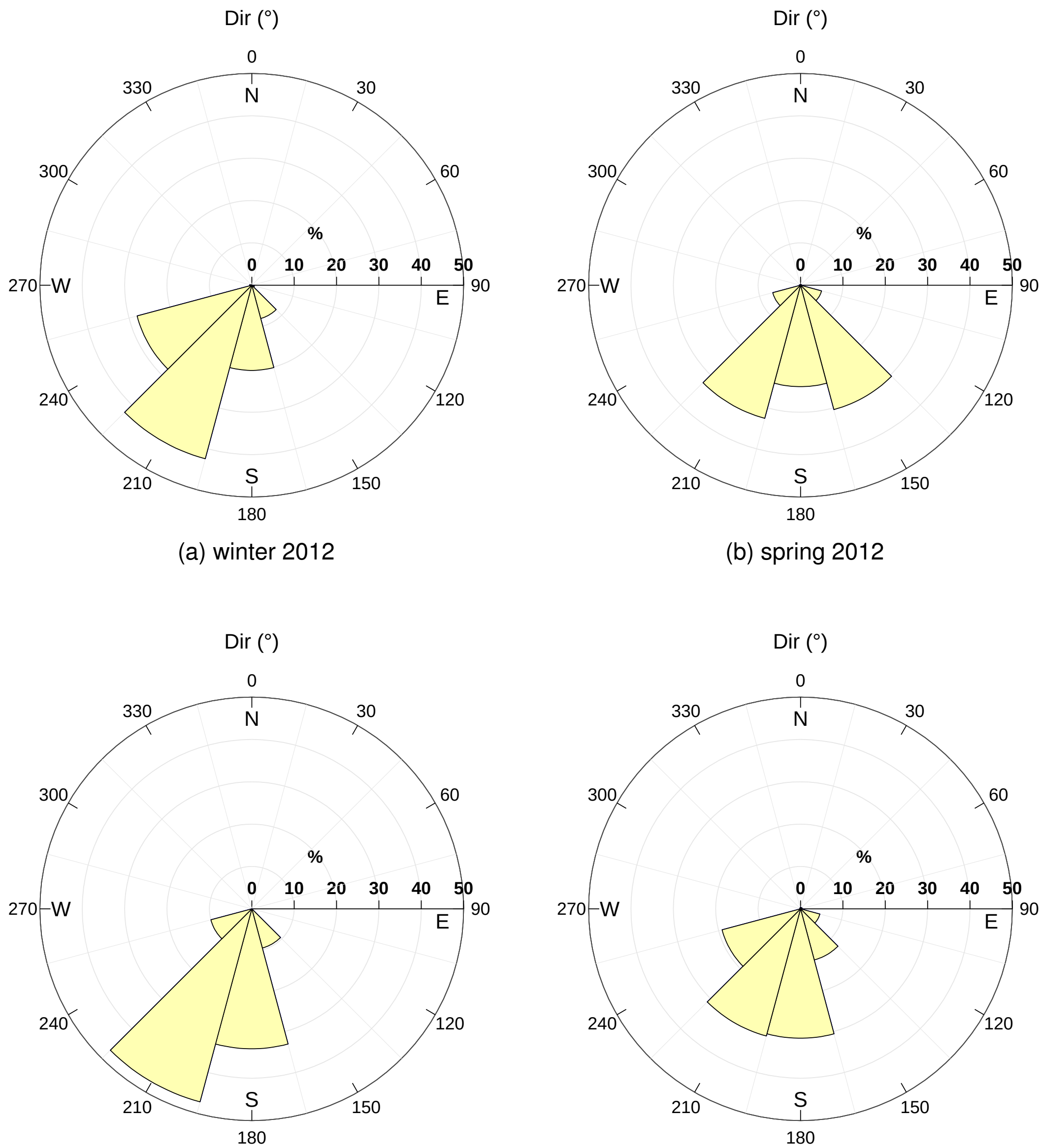


(c) summer 2012



(d) fall 2012

Figure 10: Seasonal probability densities of peak period



(a) winter 2012

(b) spring 2012

(c) summer 2012

(d) fall 2012

Figure 11: Seasonal wave direction roses

4.2 Wave power

For a wave at a given period and height, theoretical omni-directional power in a sea state can be calculated based on the general equation [5]:

$$P \simeq \frac{\rho g}{16} H_s^2 C_g \left(\frac{1}{T_e}, h \right) \qquad \text{power} \tag{2}$$

where ρ is density, g is the gravitational constant, H_s is significant wave height, C_g is group velocity and h is water depth.

For an arbitrary depth, the wave length must be solved using the implicit relation:

$$L = T\sqrt{\frac{g}{k} tanh(kh)} \qquad \text{wave length} \tag{3}$$

where $k = 2\pi/L$ is the wave number, from which group velocity can be calculated using:

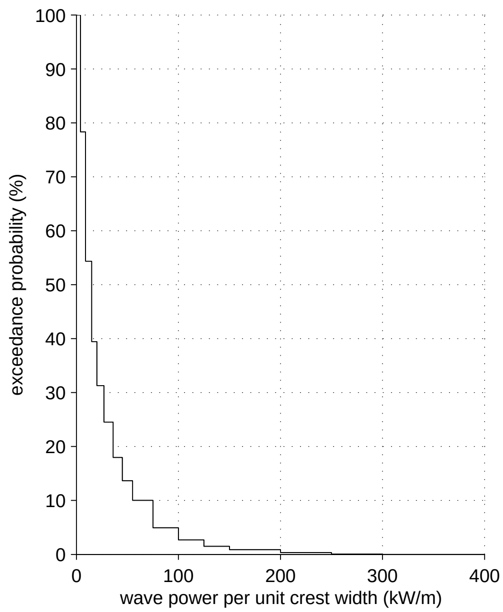
$$C_g = \left(1 + \frac{2kh}{sinh(2kh)}\right) \frac{L}{2T} \qquad \text{group velocity} \tag{4}$$

The average theoretical power is calculated for each sea state in the range of observed typical wave height ($0\ \mathtt{m} < H_s < 7\ \mathtt{m}$) and period ($0\ \mathtt{s} < T_P < 15\ \mathtt{s}$) for Lord's Cove in 2012, as shown in Table 7. Power increases with the square of wave height and, although it is not obvious in the implicit general power equation, in the limits it can be shown that power is also proportional to period.

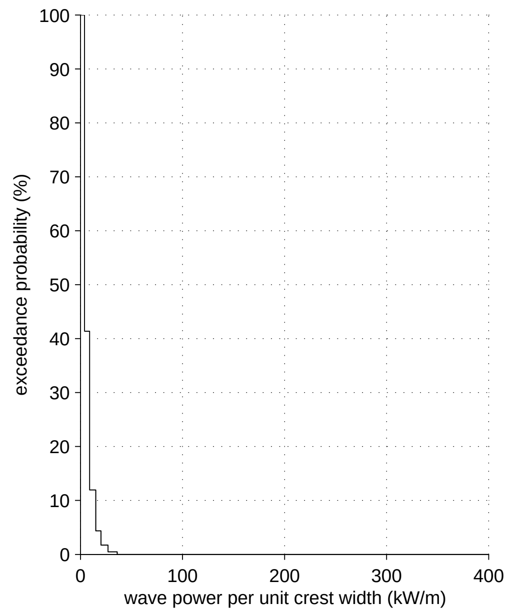
Table 7: Variation in power per unit wave crest width with peak period and significant wave height for Lord's Cove wave buoy site in 30-m water (kW/m)

$T_e(s)$	0 - 3	3 - 6	6 - 9	9 - 12	12 - 15
H_{mo}					
6 - 7	28	84	146	231	300
5 - 6	20	60	104	165	215
4 - 5	13	40	70	111	144
3 - 4	8	24	42	67	87
2 - 3	4	12	22	34	44
1 - 2	1	4	8	12	16
0 - 1	*negl.*	*negl.*	1	1	2

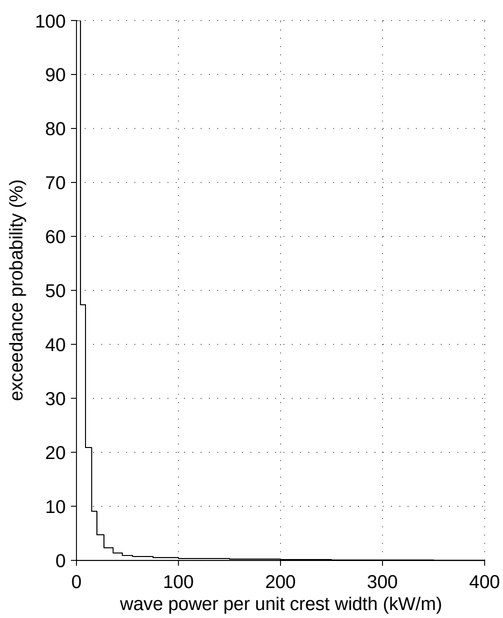
This table represents power at the selected sea states, *not the likelihood* of achieving any particular power. The probability that the available power is above a certain threshold is described in the seasonal exceedance graphs in Figure 12.



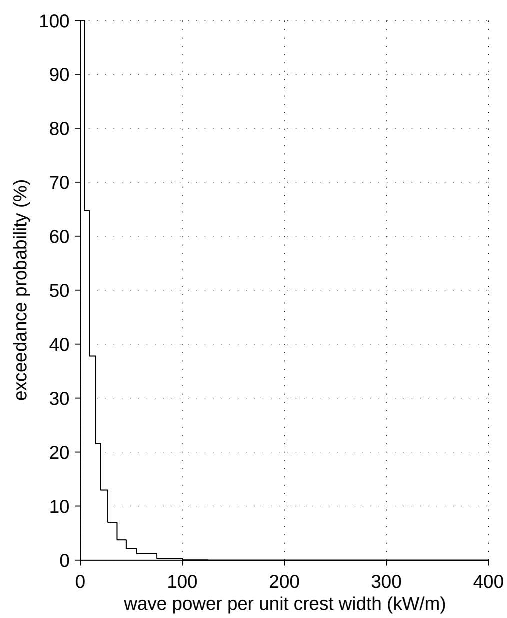
(a) winter 2012



(b) spring 2012



(c) summer 2012



(d) fall 2012

Figure 12: Seasonal power exceedance probabilities

4.3 Wave energy

Total wave energy for a period of time t is calculated for each sea state and duration observed in 2012 from the average theoretical wave power:

$$E = P_{avg} \cdot t \qquad \text{total energy} \tag{5}$$

Since we don't have a complete data set for each season, relative (percent) energy is calculated for each sea state in the available data, as shown in Tables 8 to 11.

Table 8: Wave energy distribution (%) – Winter 2012

T_e (s)	0 - 3	3 - 6	6 - 9	9 - 12	12 - 15	> 15	**sum**
H_{mo} (m)							
> 8							
7 - 8			0.4				**0.4**
6 - 7				1.0			**1.0**
5 - 6			0.2	4.3	0.5		**4.9**
4 - 5			2.4	7.4	3.7		**13.4**
3 - 4		0.2	9.5	20.1	2.2		**32.0**
2 - 3		1.1	11.3	16.6	1.0		**30.1**
1 - 2		1.4	9.3	5.9	0.7		**17.2**
0 - 1		0.1	0.4	0.3	0.2		**1.0**
sum		**2.7**	**33.5**	**55.5**	**8.3**		**100.0**
					2227 samples (48 days)		

Table 9: Wave energy distribution (%) – Spring 2012

T_e (s)	0 - 3	3 - 6	6 - 9	9 - 12	12 - 15	> 15	**sum**
H_{mo} (m)							
> 3							
2 - 3		2.4	11.2	7.1			**20.6**
1 - 2		7.6	34.3	28.5			**70.4**
0 - 1		1.0	4.6	1.5	1.5	0.4	**9.0**
sum		**11.0**	**50.0**	**37.1**	**1.5**	**0.4**	**100.0**
					2388 samples (52 days)		

Table 10: Wave energy distribution (%) – Summer 2012

T_e (s)	0 - 3	3 - 6	6 - 9	9 - 12	12 - 15	> 15	**sum**
H_{mo} (m)							
> 7							
6 - 7				0.7	1.9		**2.7**
5 - 6				1.1	1.4		**2.5**
4 - 5			0.2	0.4	3.3		**3.8**
3 - 4		0.1	1.0	0.9	2.0		**3.9**
2 - 3		2.2	12.4	8.6	3.3		**26.5**
1 - 2		10.4	30.5	11.2	4.0		**56.0**
0 - 1		0.9	2.2	0.7	0.8		**4.7**
sum		**13.5**	**46.3**	**23.5**	**16.6**		**100.0**
					4345 samples (92 days)		

Table 11: Wave energy distribution (%) – Fall 2012

T_e (s)	0 - 3	3 - 6	6 - 9	9 - 12	12 - 15	> 15	**sum**
H_{mo} (m)							
> 5							
4 - 5			0.2	0.5			**0.7**
3 - 4			4.2	8.4	0.2		**12.8**
2 - 3		3.0	19.2	14.9	3.7	0.9	**41.5**
1 - 2		4.8	21.0	13.4	2.7	0.2	**42.0**
0 - 1		0.2	1.1	0.6	1.0		**3.0**
sum		**8.0**	**45.6**	**37.8**	**7.5**	**1.0**	**100.0**
					4284 samples (91 days)		

5 Summary results and discussion

The wave resource at Lord's Cove has been roughly characterized using statistics based on only 10 months of data collected in 2012. Since waves are strongly weather-dependent and thus chaotic, these results are only representative of this data set and what *may* occur given the same set of weather and tides, not for forecasting future conditions. These results only include omnidirectional power, which is typically used as a base measure for a wave resource. Wave pump design for continuous minimum flow requires data reflecting the minimum and typical wave conditions, as well as extreme conditions for ensuring survivability of the pump and its mooring.

The average unit wave power and total unit wave energy extrapolated from relative occurrence for each month are summarized in Table 12 with the size of the data sample.

Table 12: Monthly wave statistics for Lord's Cove (2012)

	Jan	Feb	Mar	Apr	May	Jun
mean power (kW/m)	17.96	24.10	-	-	5.41	4.65
total energy* (kWh/m)	13,359	16,773	-	-	4,029	3,347
data (days)	22	26	0	0	31	30
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
mean power (kW/m)	5.46	3.62	11.55	8.90	14.40	10.88
total energy* (kWh/m)	4 060	2 693	8 314	6 619	10 366	8 097
data (days)	31	31	30	31	30	24

**extrapolated from relative occurrence for the month*

Without data for March and April, omnidirectional power was highest on average in February, a five-fold increase over May to August. Likewise, waves theoretically carried over 16MWh/m in February, compared with less than 3MWh/m in August.

Most common sea states: In total, 77% of the 2012 data fell between 0.5–2 m significant wave height and 5–10 s peak periods, ranging between 0.6–20.5 kW/m. The seasonal wave scatter diagrams (Tables 3–6) show that the dominant sea states were consistently concentrated (approx. 25% of data) in the range 1–2 m at 6–9 s, with the majority (50.9%) of spring data included in a range below 2 m. The wave direction roses (Figure 11) show that waves approached from the south-southwest in winter, backing to south in spring and veering again south-southwest in summer and fall, with the least spread in summer, but in any case ranging between south-southeast to west-southwest (ie. 135°–255°).

Maximum energy: The seasonal wave energy distributions (Figures 8–11) show that the sea states that were observed to contribute the most energy based on highest relative occurrence and average omnidirectional power were 3–4 m, 9–12 s in winter (20.1%) and consistently 1–2 m, 6–9 s in spring, summer and fall (21.0–34.3%).

Minimum continuous power: While the sea states that contributed the most energy varied between seasons, continuous availability of power is of more interest for the design of a wave pump with a specification for minimum flow rate. The seasonal power exceedance plots in Figure 12 are useful for estimating minimum output for a given percentage of time.

If, say, a wave pump needed to continuously supply 10 L/s with a 20 m head, and assuming 50% efficiency, 4 kW is needed based on the following calculation:

$$P = \frac{q \rho g h}{\eta} \qquad \text{pump power} \tag{6}$$

where q is the flow rate.

For this example, power exceedance plots (Figure 12) for 2012 indicate that there is at least 4 kW *per metre* for 78% of the time (winter), but only 41% in spring, so a pump would need to extract the power from more than a metre of wave crest to assure 10 L/s. (Note: the minimum power is not necessarily provided by a single sea state, so the pump design would need to consider a range of input heights and periods.)

Table 13: Sample power exceedance at 4 kW/m

season	exceedance
winter	78%
spring	41%
summer	47%
fall	65%

Extreme sea states: Survivability of the wave pump and its mooring is compromised by fatigue and shock loading. The seasonal probability densities for 2012 (Figures 9 and 10) show wave heights at Lord's Cove were typically below 3 m in spring and summer, below 4 m in fall, but occasionally exceeded 6 m in winter. The highest wave reported by the wave buoy was 10.6 m on Feb. 12, 2012. The shortest periods (choppiest sea states, min. 3.5 s) and also the longest (swells, max. 31 s) occurred in spring and fall.

Of note for survivability is the most powerful event (two data samples) from Sept. 11, 2012 during Hurricane Leslie, when the significant wave heights exceeding 6 m combined with long periods (14.5–15.5 s). Omnidirectional power averaged **315** kW/m for 1 hour.

These results are based on the assumptions given in [1]. The limitation of data to one year *does not allow for large variation in weather between years*. Historically, there is a large seasonal variation in weather in this region and, therefore, a large variation in sea states. To this report date, data representing the four seasons have been analysed (although winter and spring are limited to less than 2 months each).

6 Future work

This presentation of wave data for Lord's Cove follows recommended guidelines [2], and previous work on a national wave atlas [5], so that these data may be compared with other sites and used as a baseline for designing a device to use this resource, namely a wave pump delivering a minimum continuous flow rate.

Further spectral analysis may be required of the raw data recovered with the buoy, if other parameters are needed for pump design.

While only omnidirectional power was considered, the design of a particular device may require the extraction of directional power depending on its mooring configuration and principle of operation. Further regrouping of time series data may be of more importance in the design of a wave pump to ensure flow with fewer or shorter interruptions. Additional analysis of peak events, especially the probability of maximum wave heights, will be useful for designing for survivability. These would only require minor modifications to existing analysis scripts. Changes to the spectral analysis itself, if needed, would require more effort.

7 Acknowledgements

Appreciation is due to Lord's Cove fishermen Bob and Rich Hennebury who rescued the wave buoy after the first mooring failure and the NRC field trials team led by Craig Kirby for retrieving it over the holidays and for providing the mooring diagram.

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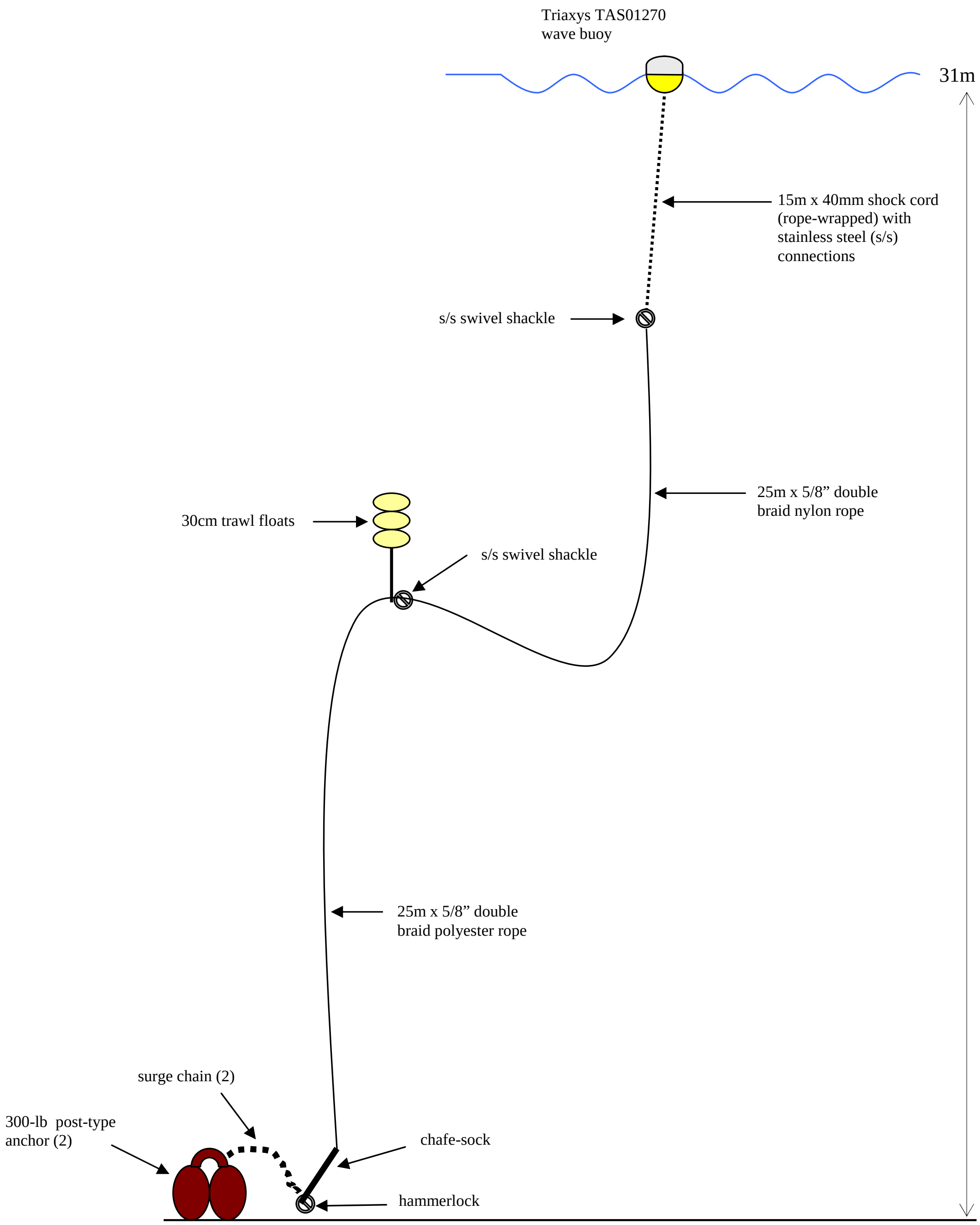
Appendix: Wave buoy details

A list of the ATI pre-processed data parameters are given in the table below. The diagram on the following page shows the mooring arrangement used for the ATI buoy at Lord's Cove.

ATI spectral analysis parameters

parameter	description
DateTimeStamp	data acquisition period end time
Hmax (m)	maximum wave height in metres (m)
Hmo (m)	significant wave height as mean of highest third of the waves calculated using $4\sqrt{m_0}$, where $m_0 = \int_{F1}^{F2} S(f)df$
Hav (m)	mean wave height (m)
TP (s)	peak period in seconds *a.k.a.* dominant period – the period of the highest spectral frequency band F_p from a Fast Fourier analysis. $T_p = 1/F_p$ (s)
T13 (s)	significant period based on the average of the highest third of the waves.
Tave (s)	average zero down-crossing period (s)
MeanDirection (degrees)	mean wave direction (°)
Spread (degrees)	range of directions during acquisition period (°)



Lord's Cove wave buoy mooring arrangement (May–Dec., 2012)