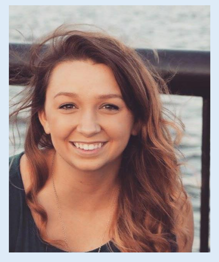
Geomorphological Analysis of Sand Waves at Lucifer Shoals, Ireland



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ABSTRACT

During July and August of 2009, hydrographers with the Geological Survey of Ireland and Marine Institute of Ireland sailed aboard the R/V *Celtic Voyager* on the southeast coast of Ireland approximately 7 km east of Wexford Harbour. A complex suite of large sand bodies with depths ranging 12 to 30 m, Lucifer Shoals was surveyed using a Kongsberg EM3002 multibeam echosounder. CARIS HIPS 9.1 was used to process the bathymetric data, which revealed a convoluted system of sand waves measuring ~14 km along their east-west crests, with crest to crest wavelengths ranging from ~ 100 to 250 m. The purpose of this study is to determine sand wave geomorphology, including their length, width, height, and specific orientation in order to approximate the current water velocity and direction in this area. Analysis shows that the east side of Lucifer Bank has opposing tidal currents traveling generally northward and southward, whereas on Lucifer Bank's west side, there is a dominant northwest current. On the east side of Long Bank, there is an opposite southeast current. Using average wavelength data, sites range in predicted current velocity from approximately 0.1 to 1.6 m/sec.

BACKGROUND

Lucifer Shoals is located off the Southeast coast of Ireland near Wexford Harbour. The areas being studied surround Lucifer Bank along the east side of Long Bank (Figure 1), where the normal tidal current direction on the Southeast coast of Ireland is from the South to the North (Kinahan,1875). The purpose of this study is to discover the direction of current based on the sand wave orientation, symmetry, and peakedness of the primary (i.e., first order) sand waves. Each site is strikingly different in sand wave size and symmetry, which give clues to the current velocity and direction in the area. Based on data collected from the Army Corp of Engineers (Levin and Lillycrop, 1992), velocities in the Irish Sea range from 0.3 to 1.0 m/sec. Current velocities are directly related to sand wave wavelength, whereas sand wave symmetry and peakedness are estimated to be indicative of current direction and velocity, respectively.

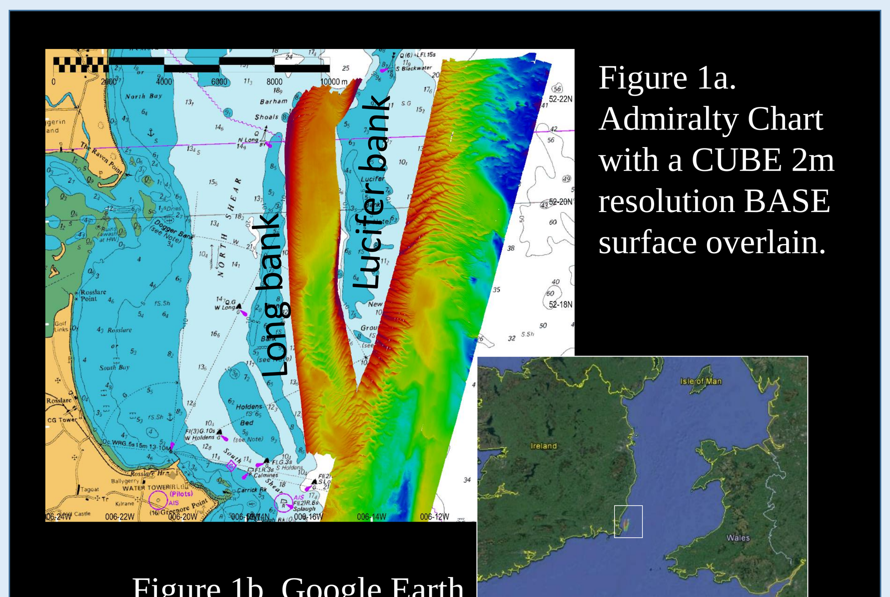


Figure 1a. Admiralty Chart with a CUBE 2m resolution BASE surface overlain.

Figure 1b. Google Earth image of Lucifer Shoals off the East coast of Ireland

METHODS

- As part of the INFOMAR program, the Geological Survey of Ireland and Marine Institute of Ireland sponsored the *R/V Celtic Voyager* cruise in 2009 and collected multibeam sonar data using a Kongsberg EM3002 multibeam echosounder.
- CARIS 9.1 was used to create a CUBE BASE surface with a 2 m resolution.
- Six Sites (A-E) were identified based on the difference in sand wave characteristics surrounding the Lucifer Bank and Long Bank (Fig. 2).
- Measurements were made from south-to-north profiles to determine the crest to crest wavelengths. Individual sand waves were measured for their base length (on both the north and south sides), and height (Fig. 4).
- **Symmetry** was determined by dividing the South base length by the North base length, where a value of 1.0 indicates sand wave symmetry. Values greater than 1.0 indicate asymmetry with a current flowing northward, whereas values less than 1.0 indicate asymmetry with a southward-flowing current.
- **Peakedness** was calculated by dividing height by total base length (Figure 4). Values greater than 0.05 and above represent higher peakedness.
- **Velocity** was estimated from the US Army Corp of Engineers from the Irish Sea (Levin and Lillycrop, 1992). Based on this data, a scale was created to determine the velocities correlating with the data in this study.

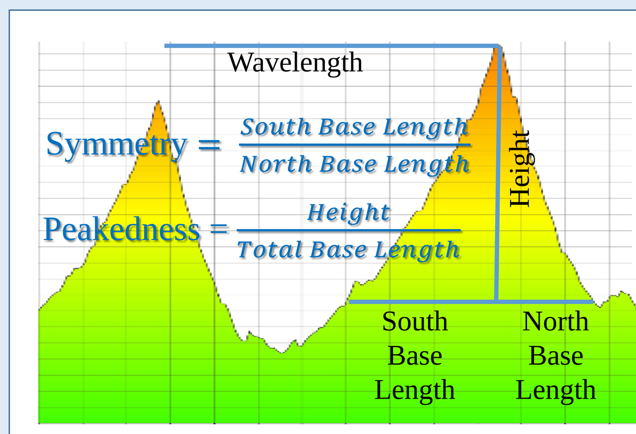


Figure 4: Measurements used to calculate Symmetry and Peakedness.

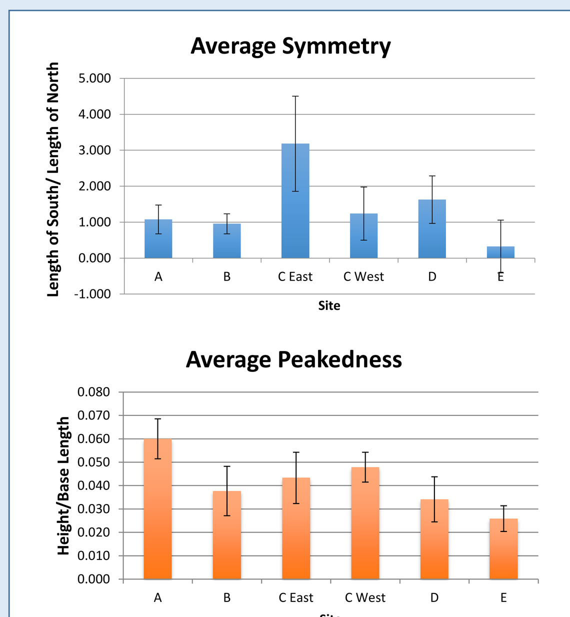
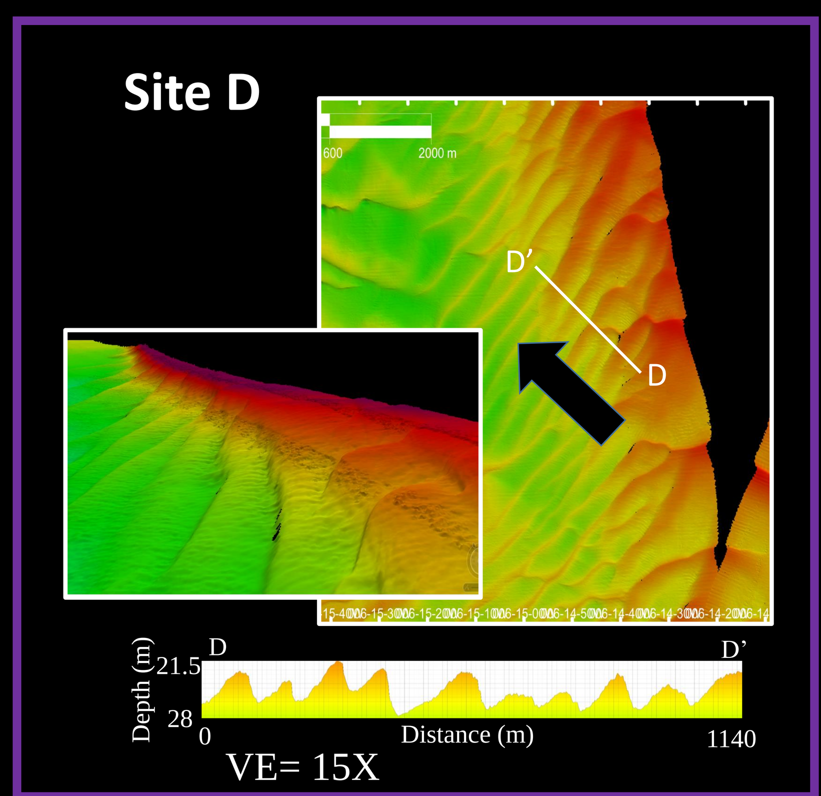


Figure 6: Average symmetry and average peakedness for sand waves at each site, measured along profiles.

Table 1: Average wavelength, symmetry, height, peakedness, and average velocity for sand waves at each site.

Site	Average Wavelength (m)	Average Symmetry	Average Height (m)	Average Peakedness	Predicted Average Velocity (m/sec)
A	252.68	1.075	6.500	0.060	1.6
B	148.09	0.952	3.500	0.038	0.5
C East	105.626	3.181	6.486	0.043	0.1
C West	215.09	1.239	4.429	0.048	1.2
D	92.08	1.626	2.500	0.034	0.5
E	153.4	0.322	3.091	0.026	0.6



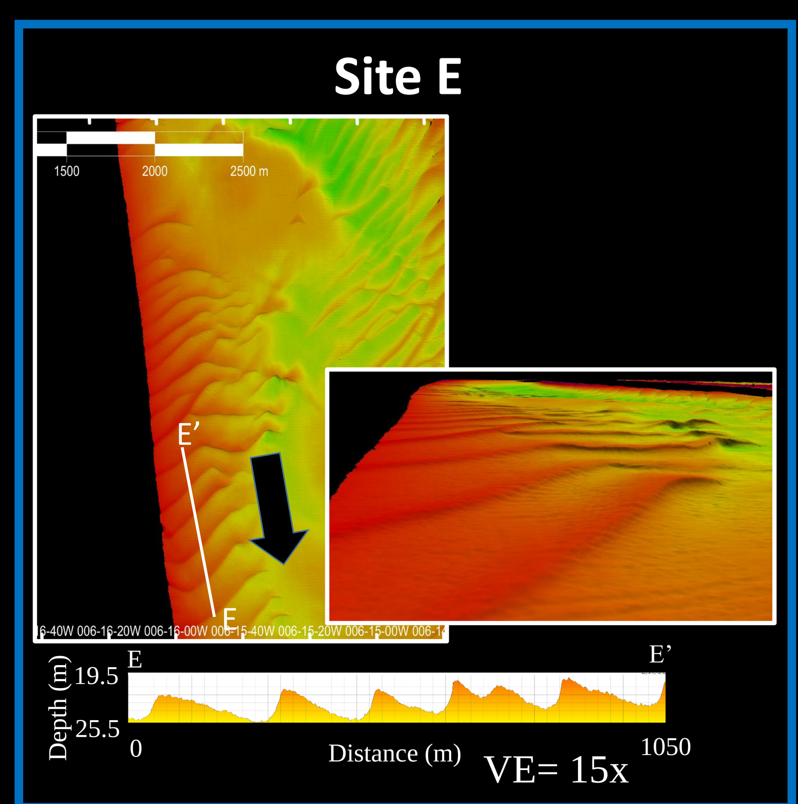


Figure 3A-E and Profiles A-E. - 2D and 3D surface with profiles drawn to show the primary sand waves. As seen in Figure 2, the current direction and relative strength for each site is shown by the large black arrows on each 2D surface.

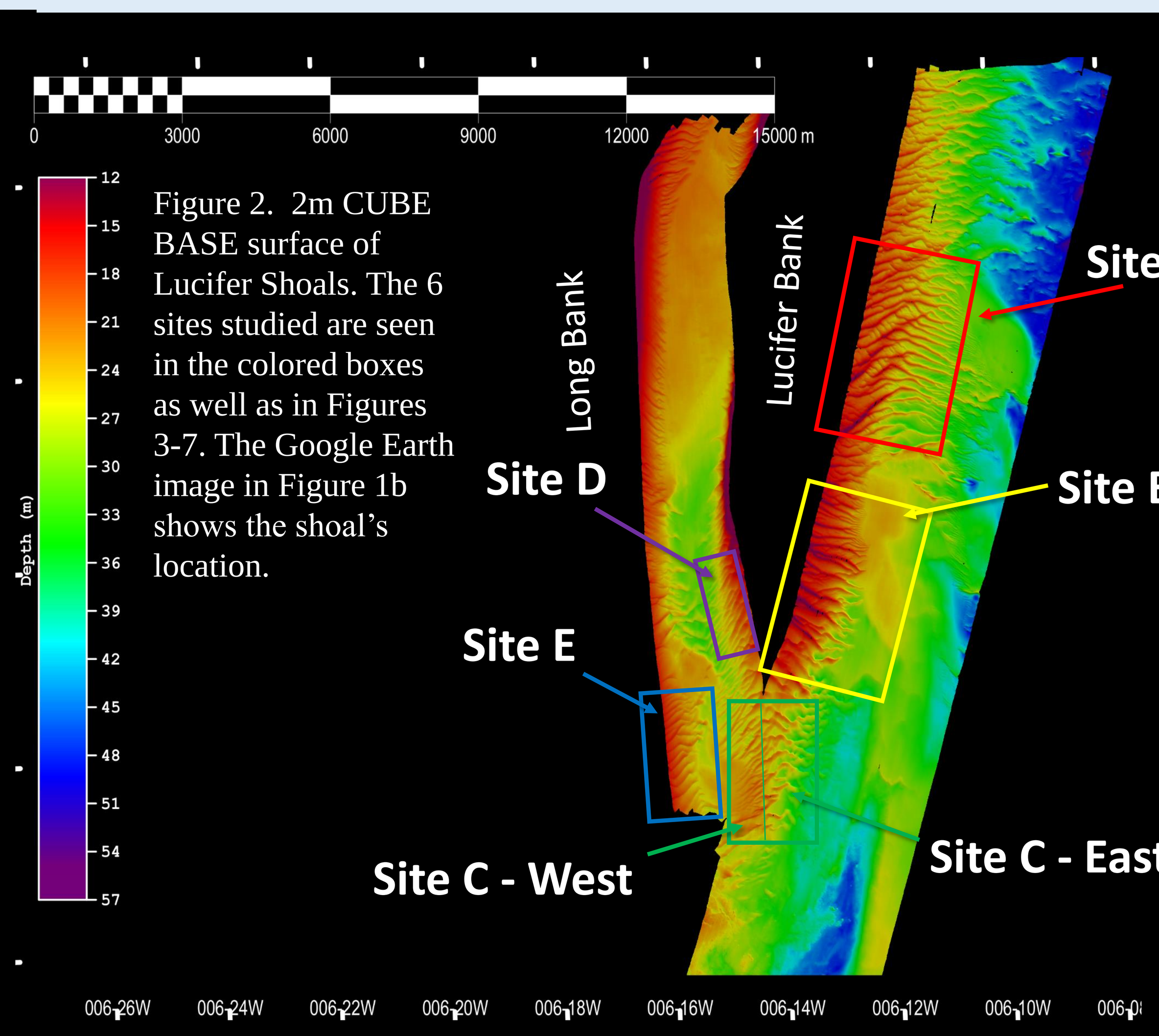
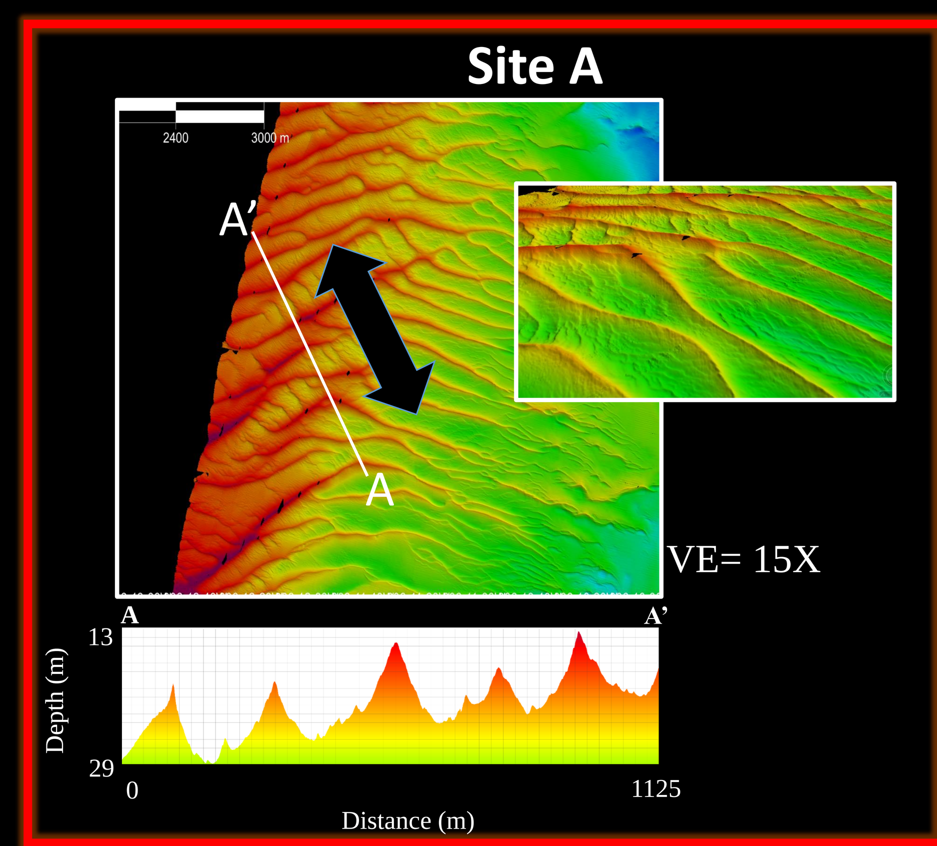
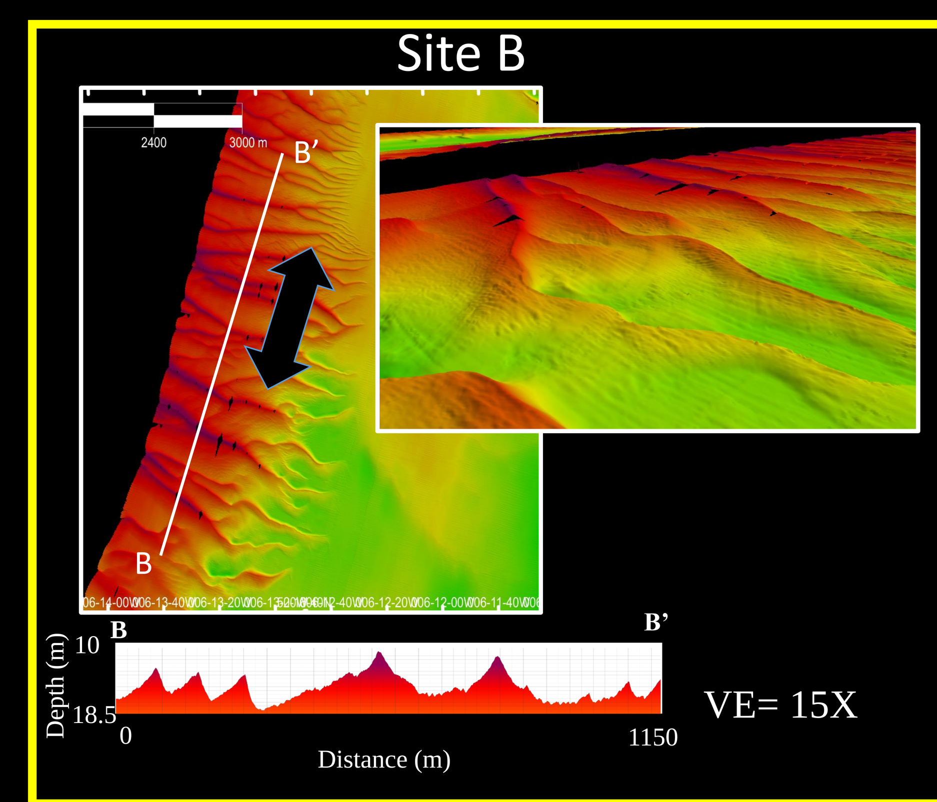
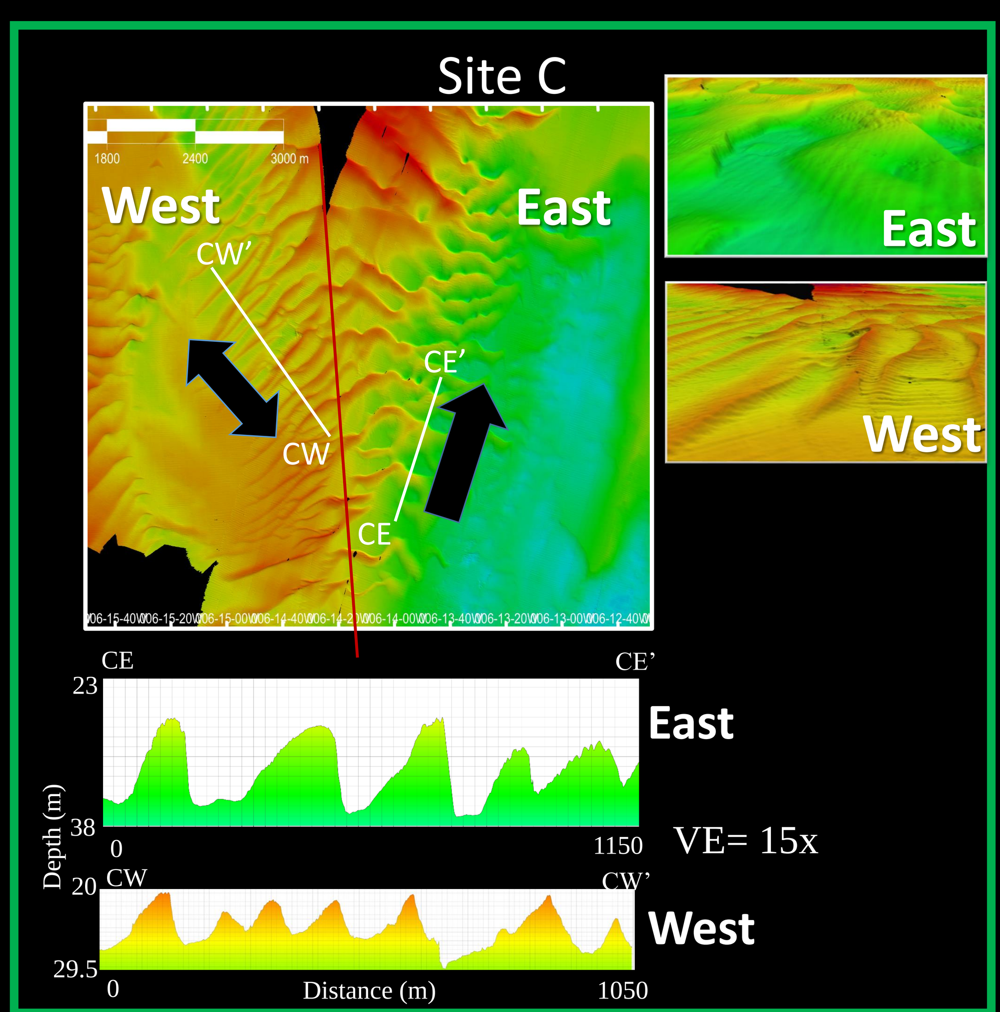


Figure 2. 2m CUBE BASE surface of Lucifer Shoals. The 6 sites studied are seen in the colored boxes as well as in Figures 3-7. The Google Earth image in Figure 1b shows the shoal's location.







RESULTS

(Figs. 5 and 6)

Site A - Sand waves in this area are close to symmetrical indicating a Northwest-Southeast current. Average wavelength (~252 m) indicates that the velocity of the current in this area is 1.6 m/sec. Peakedness is 0.060 m.

Site B - These sand waves are close to being symmetric, indicating a dual current direction flowing Northeast-Southwest. An average wavelength of 148 m indicates velocity is approximately 0.5 m/sec. The average peakedness is 0.038 m.

Site C - East – Nearly all sand waves show strong asymmetry with a Northeast current direction. Approximate velocity in this area is 0.1 m/sec (wavelength average ~106 m) with a peakedness of 6.486 m.

Site C - West – These sand waves are symmetric, indicating dual current directions flowing Northwest-Southeast. The approximate velocity is 1.2 m/sec (wavelength average ~215 m) with peakedness at 0.048 m.

Site D – Sand waves in this area are nearly symmetric, but with a slight trend northward, indicating a dominant current flows Northwest and a secondary current Southeast. The estimated velocity is 0.5 m/sec (wavelength average ~92 m) with a peakedness of 0.034 m.

Site E - Sand waves for this site are very asymmetric and have a dominant current direction towards the Southeast, an average peakedness and 0.026 m, and an estimated velocity of 0.6 m/sec (wavelength average ~153 m) .

DISCUSSION

The differences in current directions and velocities at each site explain the area's name of Lucifer Shoals. The reason this project site was chosen was due to the symmetry of the sand waves at Sites A and B (Figure 3A, 3B).

Symmetric sand waves indicate dual directional currents with similar velocities. Tidal range in this area is ~1.5 m (Wexford Harbour Tide Times) and provides significant ebb and flood current energy. Additional symmetry measurements showed that a dominant current is present at Sites C-East (Northeast), Site D (Northwest), and Site E (Southeast) (Figure 5), suggesting that the velocities in those areas are stronger than the secondary current.

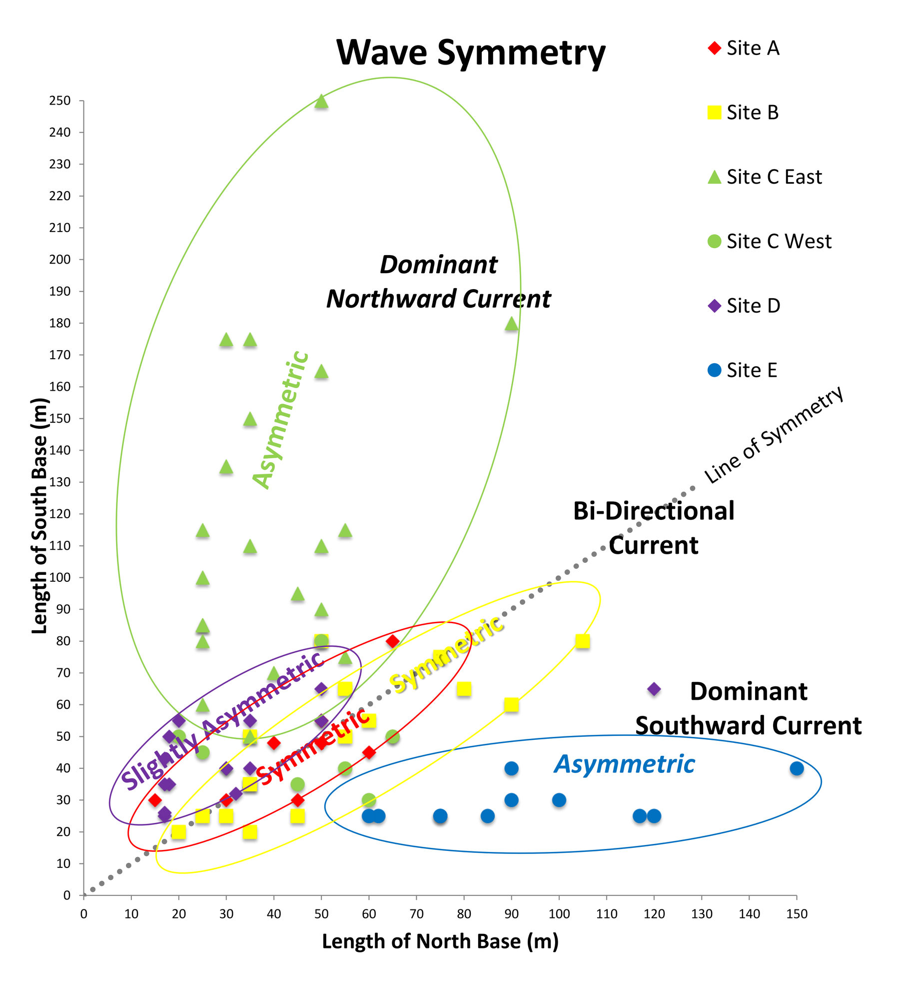
Opposing currents observed at Sites D and E are likely due to the close proximity of Lucifer Bank and Long Bank to one another and the possible restriction of tidal flow (Figs. 1 and 2).

The dominant flow in the Irish Sea is to the north (Kinahan, 1875), which explains the northward asymmetry at Site C East, which is southeast of Lucifer Bank in deeper water.

Peakedness may be a function of current velocity, but requires additional research.

Quantitative analyses of sand wave geomorphology using multi-beam sonar is useful for determining current strength and direction in shallow waters where safe navigation is key.

Figure 5: Sand wave symmetry for the six study sites. Every point above the black symmetry line is asymmetrical with a current travelling Northwest, North, or Northeast. Point clusters below the line show a Southeast, South, or Southwestward current.



ACKNOWLEDGEMENTS

We would like to thank the School of Science and Mathematics and the Department of Geology at the College of Charleston, CARIS for Academic, the R/V *Celtic Voyager*, the Marine Institute of Ireland, and the Geological Survey of Ireland for the INFOMAR collection of bathymetric data.

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