Autonomous Benthic Monitoring Downunder

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Integrated Marine Observing System
Sirius AUV

- Flexible, mobile, high resolution data collection
- Sensors include
  - DVL
  - Attitude
  - Pressure depth
  - fwd obstacle avoidance
  - GPS (surface)
  - USBL
  - Vision (stereo)
  - Multibeam sonar
  - Water Column

Dense Grid

\[ \begin{align*}
  \text{\raisebox{0.5em}{25 m}} \\
  \text{\raisebox{0.5em}{1 m}}
\end{align*} \]
SLAM: Visually Augmented Navigation
Underwater robot survey path

3D reconstructions from stereo

Accurate loop closures kilometers apart (SLAM)
IMOS benthic monitoring program

Scott Reef (2009, 2011)


SA Sir Joseph Banks MPA (2008)
SA Whyalla (2008)

GBR Myrmidon Reef (2011, 2012)
GBR Viper Reef (2007)
GBR Ribbon Reefs (2007)
GBR Noggin Reef (2007)
GBR Inshore Reefs (2013)
GBR Hydrographers Passage (2007)

GBR Myrmidon Reef (2011, 2012)
GBR Viper Reef (2007)

Solitary Islands (2012)
Sydney (2012)


Flinders CMR (2011, 2013)

Maatsuyker Island (2015)

Legend
- coral
- kelp
- coral/kelp
- seagrass/algae
- sponge
- rocky reef
- canyon
- < 50000
- 50000 - 100000
- 100000 - 500000
- > 500000
Australia’s Network of Marine Protected Areas
Cyclone Ita path

Wind Speed, Air Pressure, Wind Direction at Lizard Island

Date (GMT+10:00)

Air Pressure Lizard Island Weather Station
Maximum Wind Speed 10 Minutes Lizard Island Weather Station
Wind Direction (Scalar Average 10 Minutes) Lizard Island Weather Station
Involute of a circle

\[ r = R \cdot \sqrt{1 + \alpha^2} \]

\[ \phi = \alpha - \arctan \alpha \]

\[ L = \frac{R}{2} \cdot \alpha^2 \]
Lizard Island post cyclone surveys
Path Length, area and spacing design curve
The shortest path (in links) to cameras within $2 \times \text{median(link size)}$ is illustrated in the diagram.
‘Reef Records’

• High overlap by design
• Robust to swell and current
• Easy line handling underwater
• Monitoring through revisiting sites
• Visible range, 6m radius
• ~110m² area

<table>
<thead>
<tr>
<th></th>
<th>Avg.</th>
<th>Std. Dev.</th>
<th>Max.</th>
<th>Min.</th>
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<tr>
<td>Duration</td>
<td>15:26</td>
<td>01:43</td>
<td>18:47</td>
<td>12:58</td>
</tr>
<tr>
<td>Stereo pairs</td>
<td>1853</td>
<td>205.3</td>
<td>2255</td>
<td>1557</td>
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<td>Image matches</td>
<td>19286.3</td>
<td>7098.1</td>
<td>33168</td>
<td>6194</td>
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</table>
Lizard Island – post cyclones ITA (and Nathan)

- APR 2014: 7 days, 23 sites
- OCT 2014: 7 days, 23 sites
- APR 2015: 5 days, 21+ sites
- NOV 2015, 21+ sites
- Data processed and delivered in field
- NOV 2016, 21+ sites

Map showing locations on Lizard Island.
Friedman et. al. 2013, Multi-scale measures of rugosity, slope and aspect from benthic stereo image reconstructions
Structural Complexity Measurement: Rugosity

Friedman et. al. 2013, Multi-scale measures of rugosity, slope and aspect from benthic stereo image reconstructions
Real Chain to Virtual chain

Figure 1: Mean, minimum and maximum rugosity for 98 different transects with varied bottom types. Also shown is the least-squares linear regression fit of the means for the real chain-tape rugosity vs virtual chain-tape rugosity for 98 different transects with varied bottom types. It shows a strong correlation and positioning of the chain and it is possible to acquire physical chain rugosity measurements for 98 different transects with varied bottom types. The area-based rugosity measurement takes more information into account, and it is strongly tethered to slope. The point of maximum N/E is at the point of maximum slope, where it is at the point of inflection between the peak and the valley of the terrain and drops off at the stationary points at the top of the size of the area-based calculations on a simulated terrain example.
Horseshoe reef record
Repeated
OCT 2014
x4 over one week
Horseshoe reef record repeats
Results: distribution of rugosity errors for each specific survey time

- For both single day and multiple day surveys, some sites exhibited significant per-survey biases (up to 7.5% of rugosity range)
- Highlights the importance in changes in survey conditions and survey trajectory parameters having a large influence on the actual measurements being made
SC measurement errors vs. mean rugosity

Rugosity Error vs. Rugosity (All quadrats) (N=191): Adj. $r^2 = 0.3088$, $p < 0.01$
SC measurement errors vs. mean rugosity and coral morphotype

massives (N=15): p < 0.01

plating (N=11): p < 0.01

coarse_branch (N=66): p < 0.01

fine_branch (N=52): p = 0.58
Western Australian 2011 marine heat-wave

Peak temperature 26.4°C

251 consecutive days

In-situ daily average

Long-term monthly average 1951 - 2005
Western Australian 2011 marine heat-wave

(a) Map of Western Australia showing the location of Carnarvon, Geraldton, and Perth. The Indian Ocean is also marked.

(b) Detailed map of the Geebank area with a scale of 10 km.

(c) Submerged structure map with a scale of 500 m, showing plots 1, 2, and 3.

Depth (m):
- 0
- 5
- 10
- 15
- 20
- 25
- 30
Western Australian 2011 marine heat-wave

April 2010

April 2011
Western Australian 2011 marine heat-wave

(a) April 2010

(b) April 2011

(c) April 2012

(d) April 2013
Changes in habitat structural complexity

![Imagery Mosaics](April 2010)

![Surface Topography](April 2010)

![Surface Rugosity](April 2010)

![Imagery Mosaics](April 2011)

![Surface Topography](April 2011)

![Surface Rugosity](April 2011)

![Imagery Mosaics](April 2013)

![Surface Topography](April 2013)

![Surface Rugosity](April 2013)

**Depth (m):** 18.4, 18.55, 18.7, 18.85, 19

**Rugosity:** 1.2, 1.4, 1.6, 1.8, >2
Changes in habitat structural complexity

- **Diagram a**: Box plot showing the change in surface rugosity (25 x 25 cm) for unbleached and bleached samples.

- **Diagram b**: Scatter plot showing the relationship between initial Acropora branching (m²) and change in surface rugosity. The plot includes data points for unbleached and bleached samples.
Changes in habitat structural complexity

- Bleaching event
- Recovery & growth
- Recovery
- Shift
- Shift
- Shift
- Shift
- Increase in surface rugosity
- Decrease in surface rugosity

Time:
- Days to weeks
- Months to one year
- One to five years

Seawater temperature
- 18
- 20
- 22
- 24
- 26
- 28
- 30
- 32

Surface rugosity
Acknowledgements

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