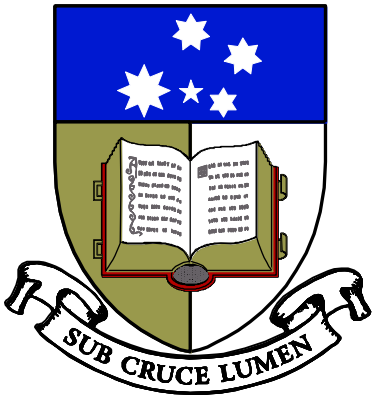

THE UNIVERSITY OF ADELAIDE

Remote sensing to monitor interactions between aquaculture and the environment of Spencer Gulf, South Australia

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Thesis submitted for the degree of

Doctor of Philosophy

Paul Erich Bierman
B.Sc. (Hons)

The University of Adelaide
School of Earth and Environmental Sciences

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Abstract

The southern bluefin tuna (SBT) aquaculture industry is based in the coastal waters of southwest Spencer Gulf, east of Port Lincoln, South Australia. It is known that open-intensive aquaculture operations can impact upon the surrounding marine environment through increases in water column nutrients, due to waste released from uneaten food and fish excretions, which under suitable conditions can lead to increased phytoplankton growth. Aquaculture operations are also susceptible to a changing environment and are at risk from the effects of harmful algal blooms and other processes that can potentially be damaging to the industry. As a result, it is necessary that the marine environment surrounding the aquaculture is understood and monitored. In response to concerns expressed by both the aquaculture industry and government regulators to increase the understanding of the marine environment, the Cooperative Research Centre for the Sustainable Aquaculture of Finfish (Aquafin CRC) established a research program titled "Risk and Response – Understanding the Tuna Farming Environment". This current project forms part of the Aquafin CRC"s Risk and Response project to increase the understanding of the SBT aquaculture environment through application of satellite-based remote sensing imagery.

Satellite-based imagery has the potential to measure concentrations of the photosynthetic pigment chlorophyll-*a*, which is commonly used as a proxy for phytoplankton abundance, and sea surface temperature (SST). The application of satellite imagery in coastal waters, however, is known to be limited by a number of factors that can reduce the accuracy, and thus applicability, of the imagery in such regions. Therefore, outputs from satellite-based remote sensing imagery were firstly compared to field-based measurements to determine whether the imagery is a suitable and reliable data source in South Australian coastal waters. Methods for examining spatial and temporal variability in SST and chlorophyll-*a* were reviewed, in order to identify useful techniques for analysing remote sensing imagery. The review recognised several techniques, including unsupervised classification and principal components analysis, which have the potential to investigate patterns in the imagery. Satellite imagery was then applied to observe the seasonal changes in chlorophyll-*a* and SST over the large area of Spencer Gulf, and then to investigate more detailed spatiotemporal variability over the SBT aquaculture region of southwest Spencer Gulf.

MODIS satellite-based imagery was selected over other forms of remote sensing imagery, based upon broad spatial coverage, high temporal frequency, good spectral and radiometric resolution, low cost, and ease of data access. It was found that MODIS chlorophyll-*a* imagery performed well against field-based data in the coastal waters of South Australia, although reduced accuracy was detected in very shallow waters where seafloor reflection contributed to increased chlorophyll-*a* estimations. Four different chlorophyll-*a* algorithms were examined and it was found that the standard OC3M empirical algorithm distributed by the NASA Goddard Space Flight Centre was most consistent in the study area. MODIS SST imagery showed very good agreement with SST from CTD measurements in the region. The night-time 4 μm SST method showed the smallest errors, but the day-time and night-time 11 μm SST methods also performed well.

MODIS monthly composite imagery was applied to study seasonal variability in chlorophyll-*a* and SST in and around Spencer Gulf over a 5-year period. It was shown that the region of the SBT aquaculture zone undergoes a seasonal chlorophyll-*a* cycle with a peak in chlorophyll-*a* between March and July each year consistent with other recent studies. The seasonal chlorophyll-*a* cycle in the region was seen to vary from other regions within Spencer Gulf and South Australia. Analysis of MODIS imagery showed apparent differences in seasonal chlorophyll-*a* characteristics between coastal and offshore regions. Sea surface temperature imagery showed a contrast between the waters of Spencer Gulf and adjacent waters of South Australia based on a greater annual range in SST within the gulf compared to outside.

Daily MODIS imagery over a 6-year period was then used to study the chlorophyll-*a* and SST of the tuna farming zone (TFZ) in more detail. The TFZ had greater variability in chlorophyll-*a* concentrations than previously believed. Both the day-to-day temporal variability, and the fine-scale spatial variability across the TFZ, followed seasonal trends, with greatest variability during periods of the year with highest average chlorophyll-*a* concentrations. Long-term mean chlorophyll-*a* averaged over the 6-year period showed a contrast between higher chlorophyll-*a* waters towards the coast and lower chlorophyll-*a* in the more exposed offshore waters, most likely related to the large-scale gulf-wide circulation. SST was much more uniform across the TFZ compared to chlorophyll-*a*, and daily deviations from the seasonal patterns were small.

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Declaration

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Paul Erich Bierman

Publications arising from thesis

Refereed Publications

Bierman, P. E., M. M. Lewis, J. E. Tanner and B. Ostendorf (In Press). „A review of methods for analysing spatial and temporal patterns in coastal water quality". *Ecological Indicators*

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Bierman, P. E., M. M. Lewis, J. E. Tanner and B. Ostendorf (2008). „Satellite derived phytoplankton variability in Spencer Gulf, South Australia". *14th Australasian Remote Sensing and Photogrammetry Conference*, Darwin, October 2008.

Reports

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Proportion of contribution by author

This section is a declaration of the extent of each author‟s contribution to the refereed paper arising from this thesis. The extent of each author‟s contribution is quantified for each of three categories: conceptualisation, realisation and documentation. Finally, each author gives permission for the paper containing their contribution to be included in this thesis.

Percent contribution and permission to include paper in thesis:

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	Conceptualisation	**Realisation**	**Documentation**	**Signature**
Bierman, P. E.	70 %	70 %	70 %	
Lewis, M. M.	10 %	10 %	10 %	
Tanner, J. E.	10 %	10 %	10 %	
Ostendorf, B.	10 %	10 %	10 %	

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