AN ASSESSMENT OF
EDDY CORRELATION TECHNIQUE
IN MARINE HABITATS

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CERTIFICATE OF AUTHORSHIP / ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Ponlachart Chotikarn

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ABSTRACT

Oxygen production and oxygen flux play an important role in marine habitats and ecosystems. The eddy correlation (EC) technique is a key aquatic flux measurement technique to measure and calculate vertical turbulent fluxes within aquatic boundary layers without disturbing environmental hydrodynamics. This method is based on the simultaneous measurement of two parameters at the same point; the turbulent velocity fluctuations and oxygen concentration. This thesis explores the reliability of the Eddy Correlation Microelectrode system (ECE) and Eddy Correlation Optode system (ECO) for O_2 flux measurement in seagrass meadows and benthic organisms in the laboratory and field. Although EC has been used in aquatic system for over a decade, this system is still under development to gain robust results. According to its complexity, the EC and software used to analyse and calculate flux have been significantly enhanced over past three years. The method development and preliminary investigations were provided in **Chapter 2**.

Generally, the oxygen concentration data from Eddy Correlation optode system (ECO) are converted from the raw oxygen signal based on the optode phase-shifted signal using Stern-Volmer-equation. **Chapter 2** also showed a new oxygen conversion method based on the raw O_2 intensity signal using Stern-Volmer-equation. Seagrass sediment O_2 uptake was investigated in a laboratory flume under controlled flow and temperature. The calculations of sediment O_2 uptake using two oxygen conversion methods were compared. The result showed that the new oxygen conversion method can be used for EC O_2 flux measurements. Although this method has lower fluctuation in O_2 concentration which leads to better flux calculation, it

needs to be considered whether the ECO is deployed under strong light or sunlight that may interfere with the O_2 intensity signal.

The reliability and limitations of Eddy Correlation Optode system (ECO) were investigated by measuring seagrass sediment O_2 uptake in a laboratory flume under controlled flow and temperature (**Chapter 3**). The seagrass sediment was treated with temperature varying from 18°C to 28°C and flow velocity from 17 cm s^{-1} to 51 cm s^{-1}. The EC data were validated by O_2 microprofiling technique, which can measure fluctuating O_2 concentrations at micro-scales. The results showed that O_2 microprofile and eddy correlation system provided the same range of O_2 flux where the O_2 consumption was observed due to microbial activities (respirations). It clearly showed that the eddy correlation systems using O_2 optode could be used for measuring O_2 flux in the marine system. Although the results of the ECO and O_2 microprofile were similar, the ECO results were not robust. This study provided verification for using eddy correlation system as a routine measurement for O_2 flux *in situ*.

Temperature and light are important controls of seagrass metabolism (photosynthesis, enzyme activity and maintenance of the carbon balance in seagrass) which in turn governs their growth, survival, reproduction and distribution. Optimal temperature and light requirements for photosynthesis and respiration in the temperate seagrass *Zostera muelleri* were examined using the non-invasive Eddy Correlation microelectrode system (ECE) and Chlorophyll *a* fluorescence using PAM under control-flow environment (**Chapter 3**). The results showed that the ECE has a potential to quantify O_2 flux and O_2 production in seagrass meadows at different light and temperature conditions within a control-flow environment. Temperature and light have an effect on production, photosynthetic efficiency, photoinhibition and capacity for photoprotection in *Z. muelleri*. Optimal temperature and light for photosynthesis for this temperate seagrass is 25°C and 150-250 μmol photons $m^{-2} s^{-1}$, respectively.

The Eddy Correlation microelectrode system (ECE), Eddy Correlation optode system (ECO) and MiniProfiler MP4 system, an *in situ* microprofiler using a microelectrode, were deployed in Tweed River (New South Wales), Moreton Bay (Queensland) and Heron Island (Queensland) to determine the O_2 flux of marine and estuarine benthic systems composed of seagrasses, benthic microalgae, and microbes (**Chapter 4**). There were some situations in which the EC was unable to measure O_2 flux correctly. However, the EC system can be used to measure O_2 flux in the non-complex environment (steady environmental condition, homogeneous habitat and flat terrain). After the deployments and a series of detailed investigation of ECE and ECO along with consulting with the manufacturer, the first generation of Eddy Correlation optode system (ECO1) was replaced with the second generation of Eddy Correlation optode system (ECO2) in order to improve the O_2 flux measurement.

Experimental results throughout the thesis provided a better understanding of the limitations and reliability of Eddy Correlation system for O_2 flux on seagrass meadows and benthic organisms in both laboratory flume and field. Although the EC has been developed with four major changes (from the first generation of the Eddy Correlation microelectrode system to the second generation of Eddy Correlation optode system), their stability and robustness still needs to be improved. Further investigation on the limitations and reliability of this new generation of the EC are needed.

ACRONYM

Term	Description
w'	Fluctuation of vertical velocity
ø	Phase angle
C'	Fluctuation of concentration
$\overline{w}$	Mean vertical velocity
τ	Luminescence decay time
ADV	Acoustic doppler velocimeter
AZAs	Auto-zero amplifiers
BMA	Benthic microalgae assemblage
C	Solute concentration
D_0	Molecular diffusivity of solute
DBL	Diffusive boundary layer
dC/dz	Linear slope of the O_2 concentration profile in the DBL
DIC	Dissolved inorganic carbon
DO	Dissolved oxygen
DPHI	Different phase angle (phase shift)
DWN	Dunwich, Queensland
EC	Eddy covariance or Eddy Correlation
ECE1	First generation of Eddy Correlation microelectrode system
ECE2	Second generation of Eddy Correlation microelectrode system
ECO1	First generation of Eddy Correlation optode system
ECO2	Second generation of Eddy Correlation optode system
F	Total flux

Term	Description
FFT	Fast fourier transform
F_V/F_M	Maximum quantum yield
GPP	Gross primary production
H	Water depth
h	Measurement height
H_2S	Hydrogen sulphide
h_{light}	Amount of light hours
h_{dark}	Amount of dark hours
I	Luminescence intensity
I_k	Minimum saturating irradiance
IT-LD	Intensity-Linear detrending
IT-RM	Intensity-Running mean
J	Flux
k	Decay rate
l	Footprint length
LAI	Leaf area index
MB	Moreton Bay
MP	Microprofiler
NEE	Net ecosystem exchange
NEM	Net ecosystem metabolism
NPP	Net primary production
OEM	Original equipment manufacturer
PAM	Pulse-Amplitude Modulated

Term	Description
PAR	Photosynthetically active radiation
PIER	Post-illumination enhanced respiration
POC	Particulate organic compound
PSII	Photosystem II
PS-LD	Phase-shifted-Linear detrending
PS-RM	Phase-shifted-Running mean
PWM	Pulse-width modulation
R	Respiration
RC	Reef crest
Re	Ecosystem respiration
rETR	Relative electron transport rate
$rETR_{max}$	Maximum relative electron transport rate
ROM	Read only memory
RS	Reef slope
SG	Seagrass beds
SSLCs	Steady state light curves
SWI	Sediment-water interface
TWD	Tweed River
VPM	Vegetation photosynthesis model
x_{max}	Upstream location of the strongest flux
Y(II)	Effective quantum yield
Y(NO)	Non-regulated
Y(NPQ)	Non-photochemical quenching yield

Term	Description
z_0	Sediment surface roughness
α	Light utilisation efficiency
$\Delta F/F_M'$	Effective quantum yield