Researcher Links UK-Russia Workshop Topic: Scientific and Technical Grounds of Future LowCarbon Propulsion

November 2018

Paolo pb346@cam.ac.uk
@ Department of Biochemistry (University of Cambridge, UK)

Name: Paolo

Research Interest(s):

- *Photosynthetic organisms*
- *Bioelectrochemistry*
- *Sustainable technologies*

Affiliation:
Department of Biochemistry
University of Cambridge
(pb346@cam.ac.uk)

Northumbria University NEWCASTLE

НАМИ

Newcastle University

University of Sunderland

BRITISH COUNCIL

Photosynthetic bio electrochemical systems (**photosynthetic-BES**):

possible areas of application

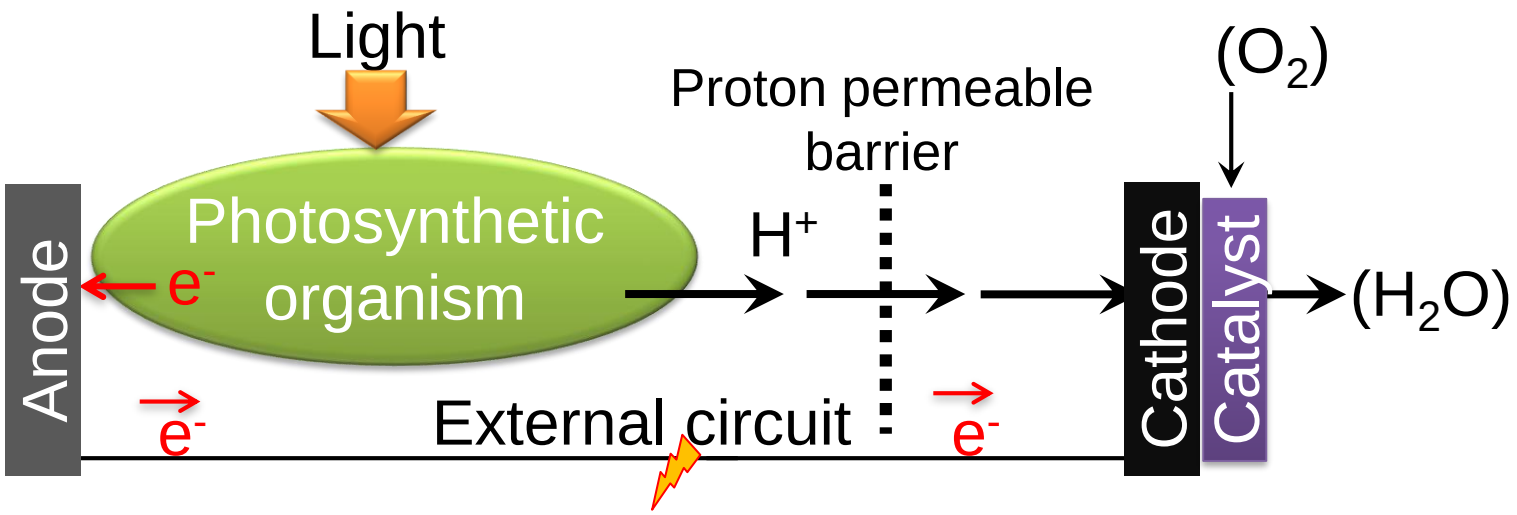
November 2018

Photosynthetic **BESs**

Photosynthetic-**BES**s are electrochemical apparatus powered by light and operated with photosynthetic organisms (cyanobacteria, μ-algae, vascular/not-vascular plants)

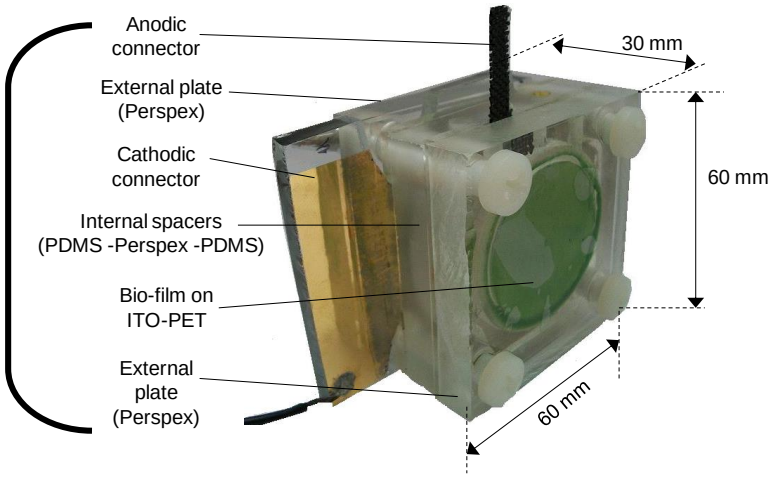
BESs could be used to generate electricity and biomass/food, enable processing of wastewater treatment and, if adequately arranged, to be used as biosensor as well as tool of educations

All **BES**s include few key elements



Photosynthetic **BESs**

Cyanobacteria & µ-algae



Bio Photo Voltaic (BPV)

Plants & Mosses

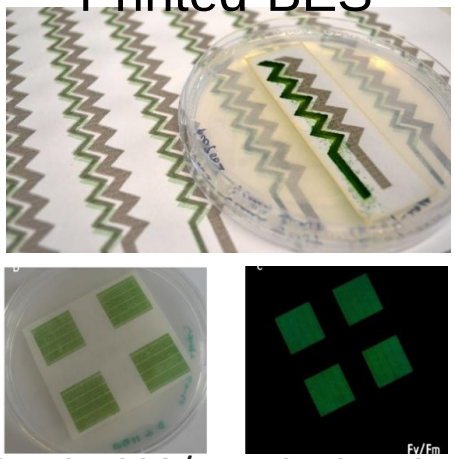
Plant Microbial fuel cell (pMFC)

Recently published photosynthetic-BES

Cyanobacteria/algae

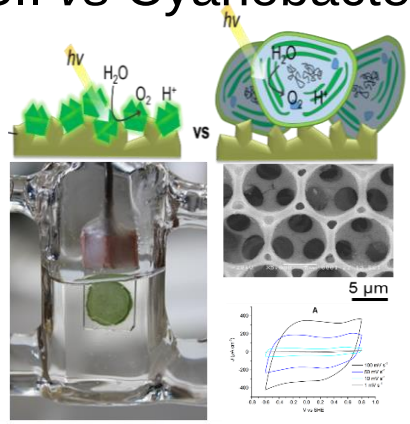
plants

Printed-BES



DOI:10.1038/s41467-017-01084-4
Nature Communications, 2017

PSII *vs* Cyanobacteria

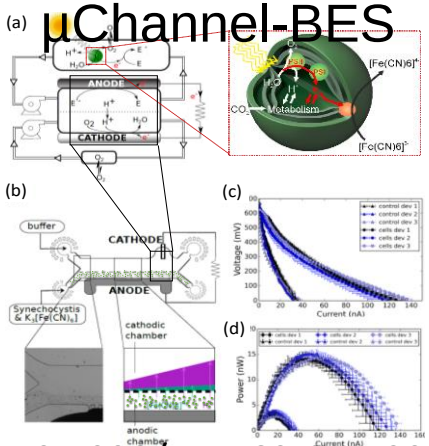


DOI: 10.1021/jacs.7b08563
J. Am. Chem. Soc., 2017

Electricity from rice

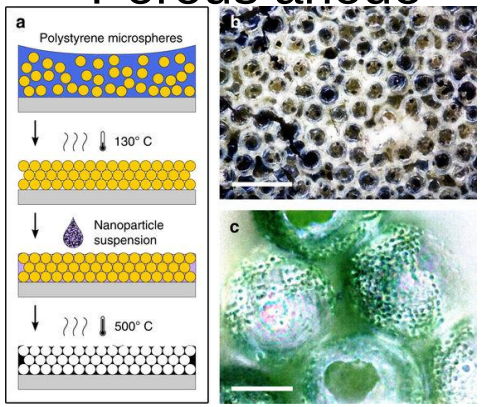
DOI: 10.1007/s00253-012-4473-6
Ap. Microb. and Biotech., 2013

µChannel-BES



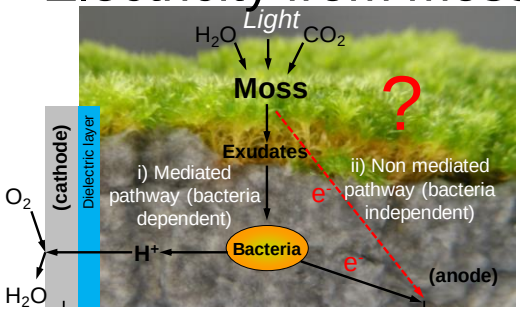
DOI:10.1038/s41560-017-0073
Nature Energy, 2018

Porous anode



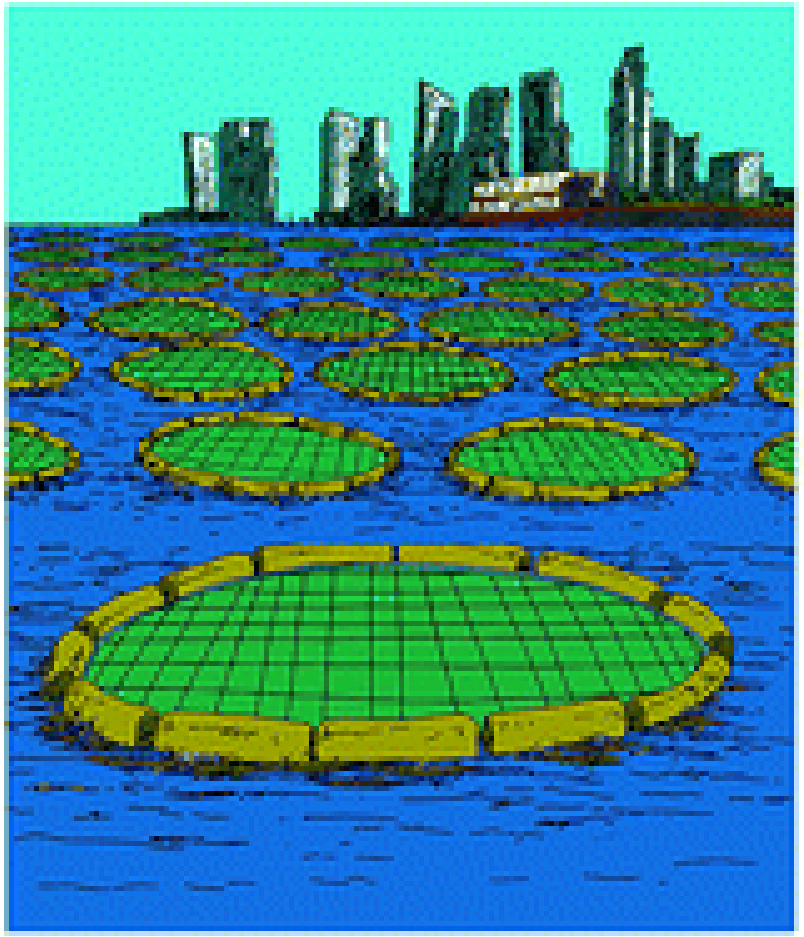
DOI: 10.1038/s41467-018-03320-x
Nature Communications, 2018

Electricity from moss

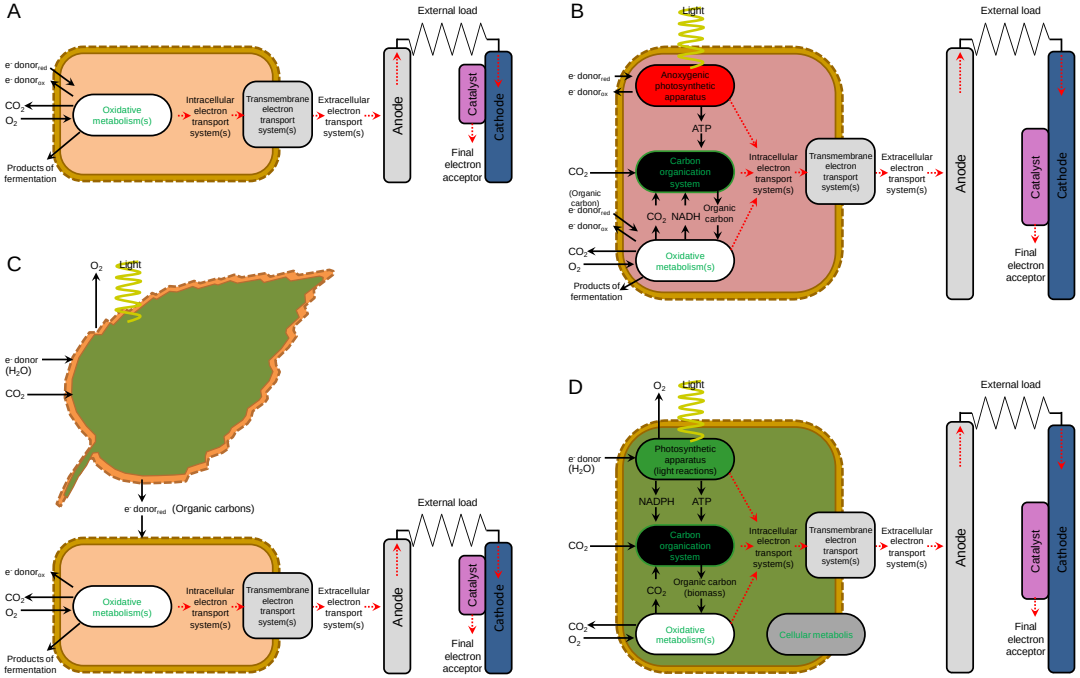


DOI: 10.1098/rsos.160249
Royal Society j. *Open Science*, 2016

Recently published photosynthetic-BES



Review



McCormick *at al*. 2015 ***Energy Environ. Sci.***, 2015,**8**, 1092-1109

I will focus my talk on what the photosynthetic-BESs can be used for

Photosynthetic-BESs generate electricity

< £0.01 m^{-2} day^{-1}

Cyanobacteria & µ-algae

Best published: 0.5W m^{-2}
(*Synechocystis* PCC 6803)
Nature Energy, 2018, 3: 75–81

0.012 kWh m^{-2} day^{-1}
£ 0.1-0.2 kWh^{-1}
£0.0012 -.0.0024 m^{-2} day^{-1}

Plants & Mosses

Best published: 0.44W m^{-2}
(*S. anglica*)
Biotechnology for Biofuels, 2012, **5**:70

0.011 kWh m^{-2} day^{-1}
£ 0.1-0.2 kWh^{-1}
£0.0011 -.0.0022 m^{-2} day^{-1}

Are photosynthetic-BESs
feasible for actual applications?

It depends from the
given conditions…

Palermo (Sicily)
Summer

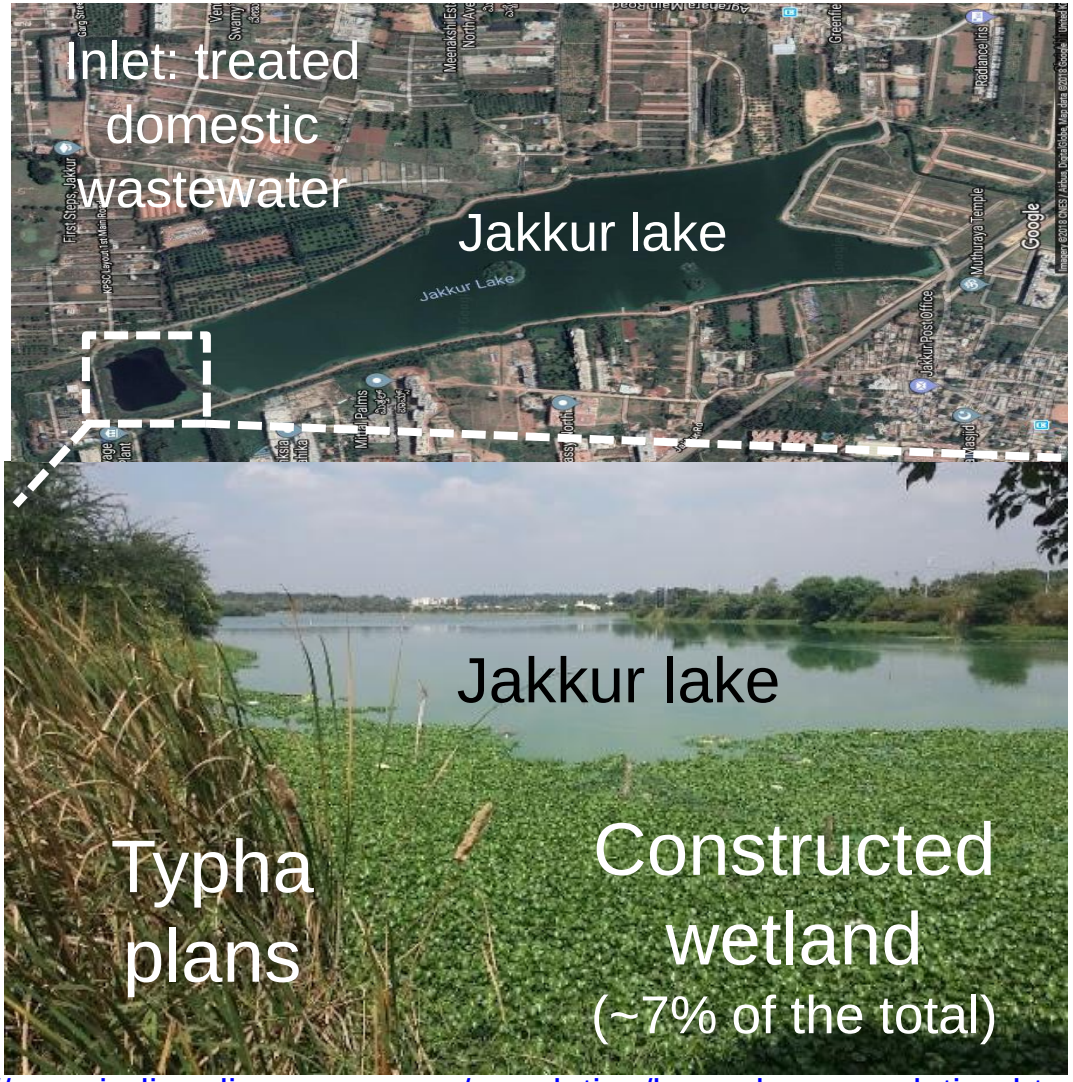
Newcastle / Moscow
Winter

~€ 0.1 kg^{-1} !!!

>£ 5 kg^{-1} / ₽?? kg^{-1}

Photosynthetic-BES combined with wastewater treatment

Jakkur lake ~160-acre (~647,000 m2)

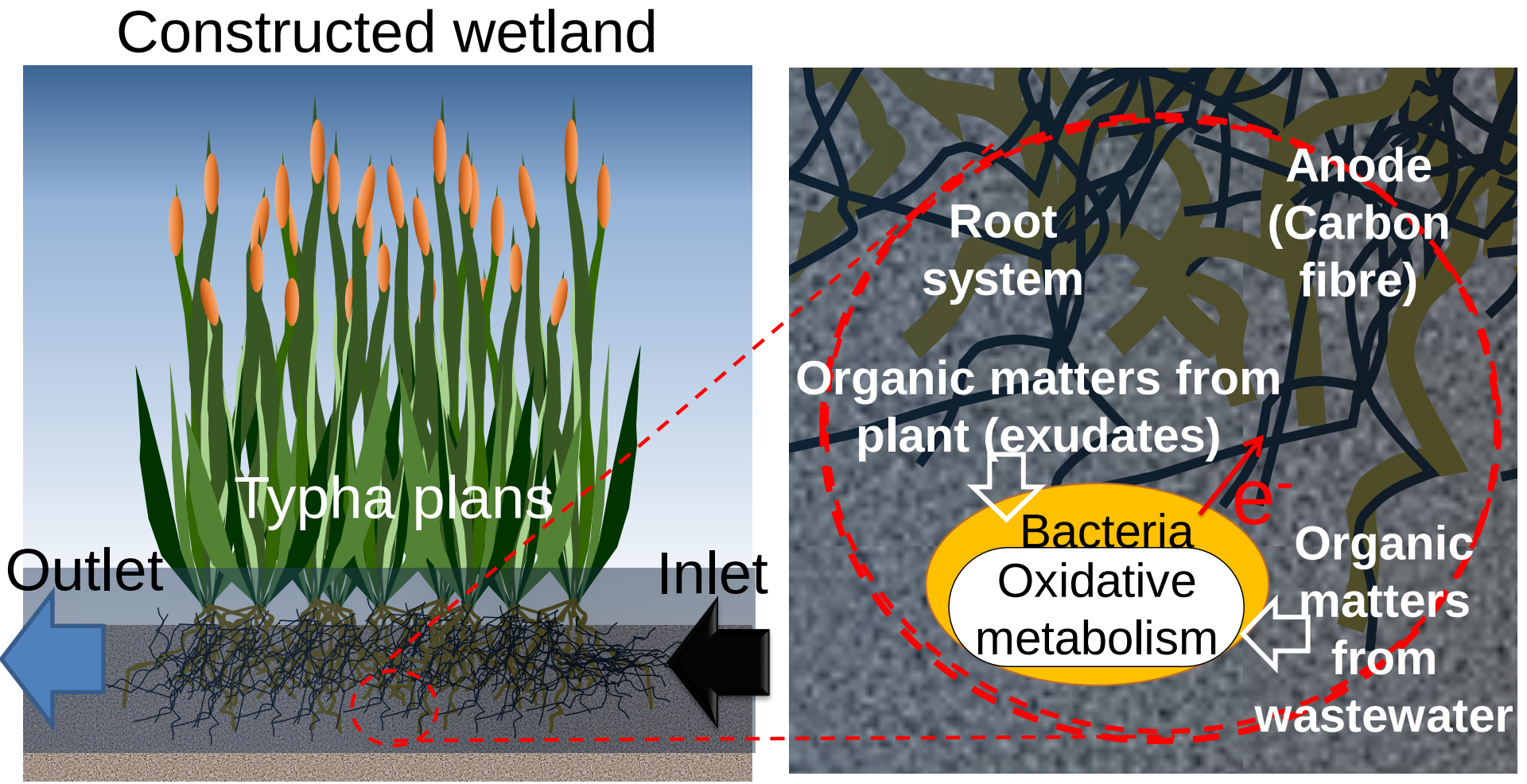


Priyanka Jamwal

Sue Harrison

* http://www.indiaonlinepages.com/population/bangalore-population.html

Photosynthetic-BES combined with wastewater treatment



Photosynthetic-BES combined with wastewater treatment

April 2018

Photosynthetic-BES combined with wastewater treatment

April 2018

Photosynthetic-BES combined with wastewater treatment

April 2018

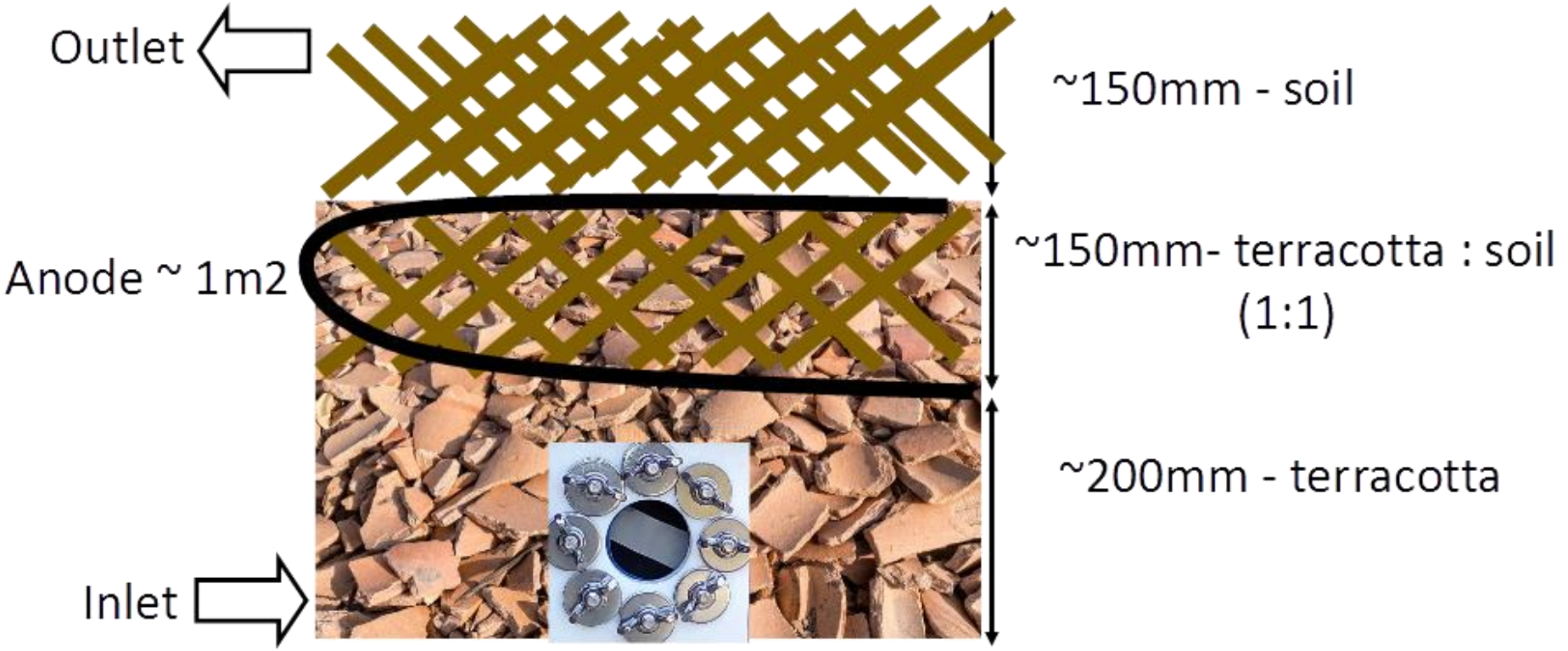
Photosynthetic-BES combined with wastewater treatment

April 2018

Photosynthetic-BES combined with wastewater treatment

April 2018

Photosynthetic-BES combined with wastewater treatment



plant-BES – frontal cross section (tot mass ~ 0.5 tonne)

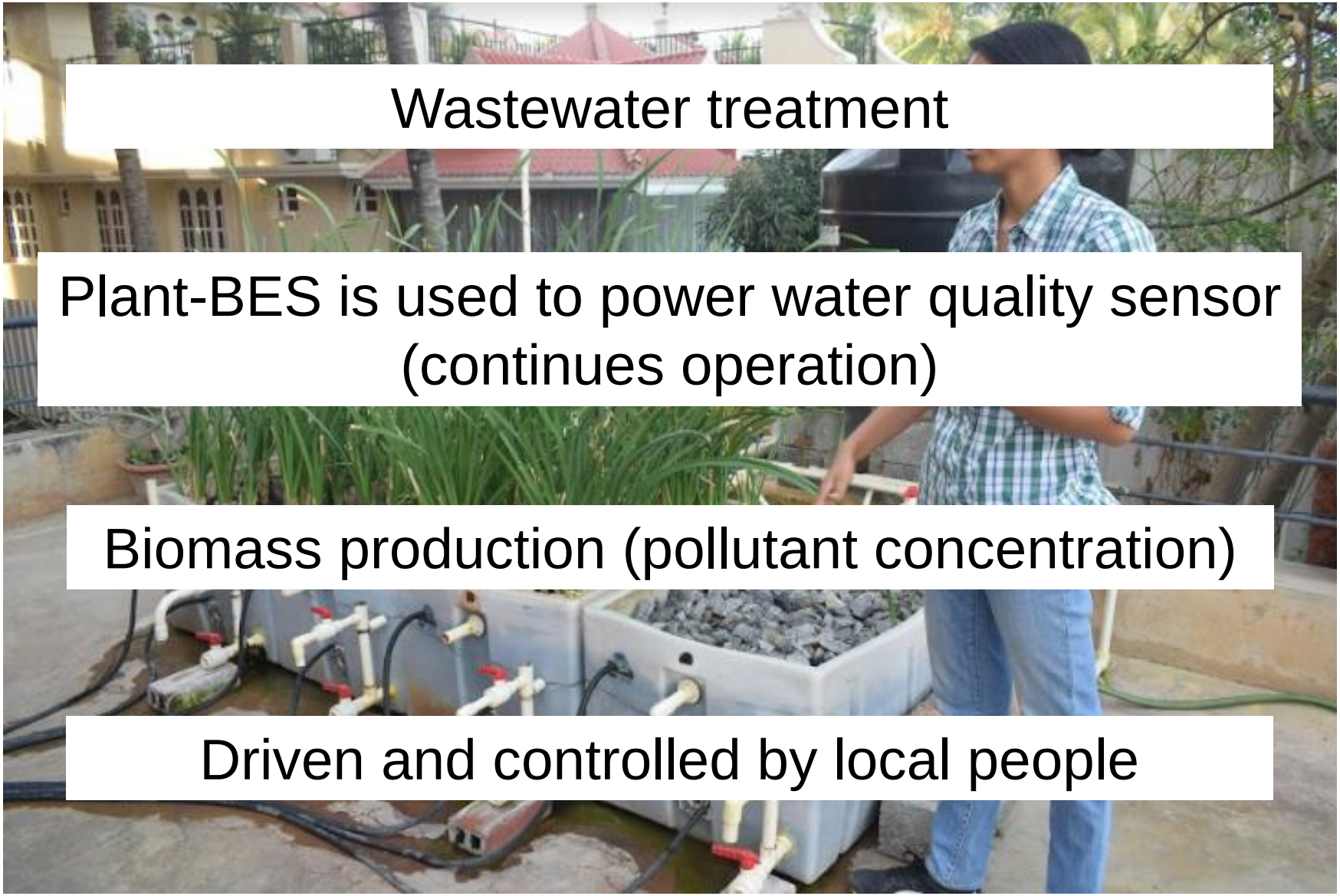
Photosynthetic-BES combined with wastewater treatment

April 2018

Photosynthetic-BES combined with wastewater treatment

November 2018

Photosynthetic-BES combined with wastewater treatment



Wastewater treatment

Plant-BES is used to power water quality sensor (continues operation)

Biomass production (pollutant concentration)

Driven and controlled by local people

November 2018

Photosynthetic-BES used to run environmental sensor in remote locations (e.g., tropical forest)

ZSL
LIVING CONSERVATION

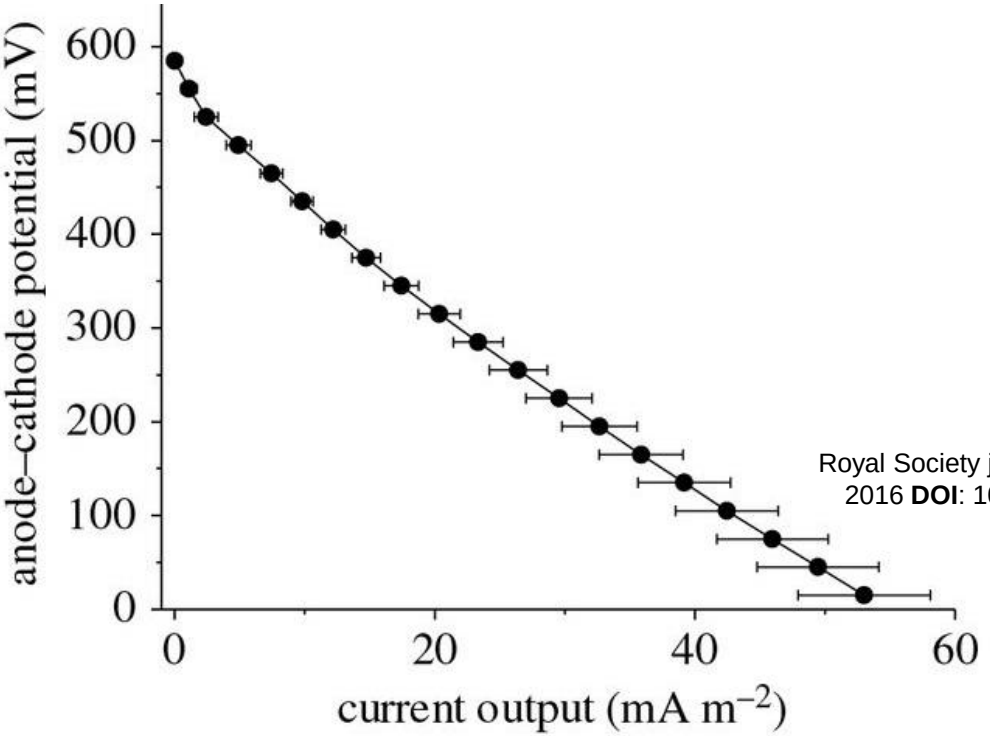
Alasdair Davies Rachael Kemp

Photosynthetic-BES used to run environmental sensor in remote locations (e.g., tropical forest)

The environmental sensor requires:
5000 mC (@ 5V) per day

Photosynthetic-BES used to run environmental sensor in remote locations (e.g., tropical forest)

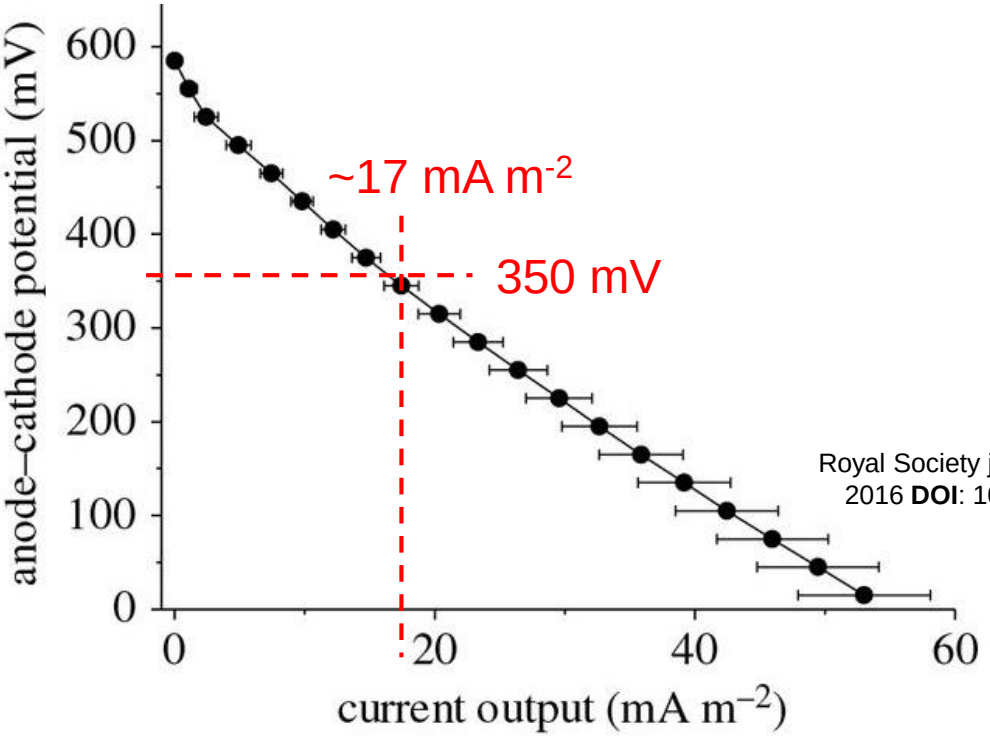
The environmental sensor requires:
5000 mC (@ 5V) per day



Royal Society journal *Open Science*, 2016 **DOI**: 10.1098/rsos.160249

Photosynthetic-BES used to run environmental sensor in remote locations (e.g., tropical forest)

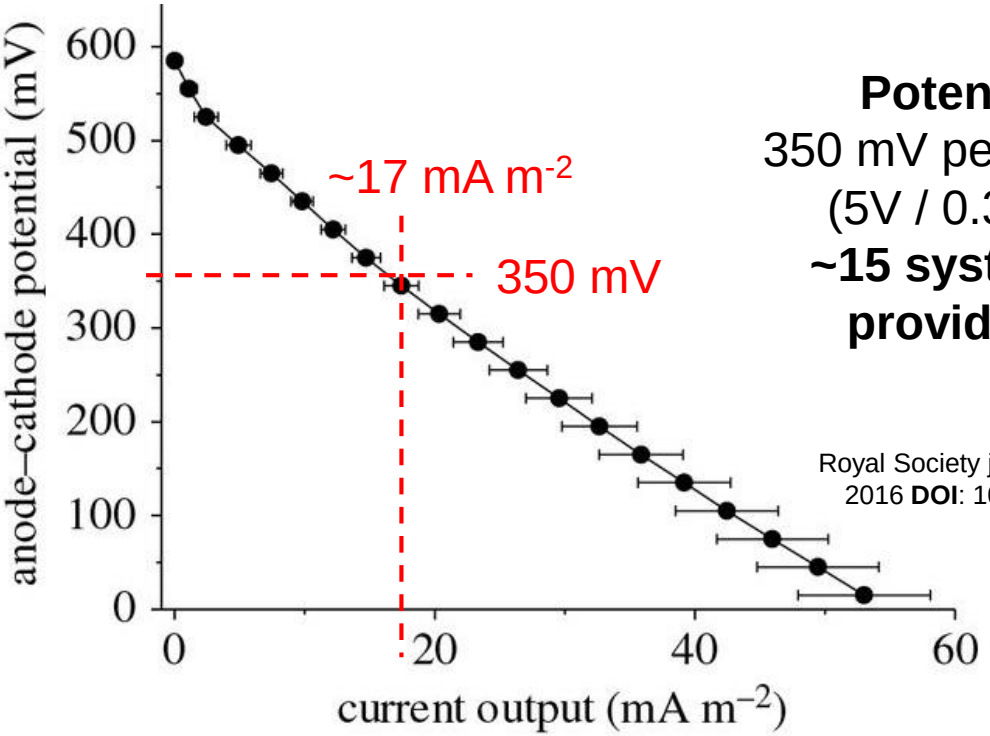
The environmental sensor requires:
5000 mC (@ 5V) per day



Royal Society journal *Open Science*, 2016 **DOI**: 10.1098/rsos.160249

Photosynthetic-BES used to run environmental sensor in remote locations (e.g., tropical forest)

The environmental sensor requires:
5000 mC (@ 5V) per day

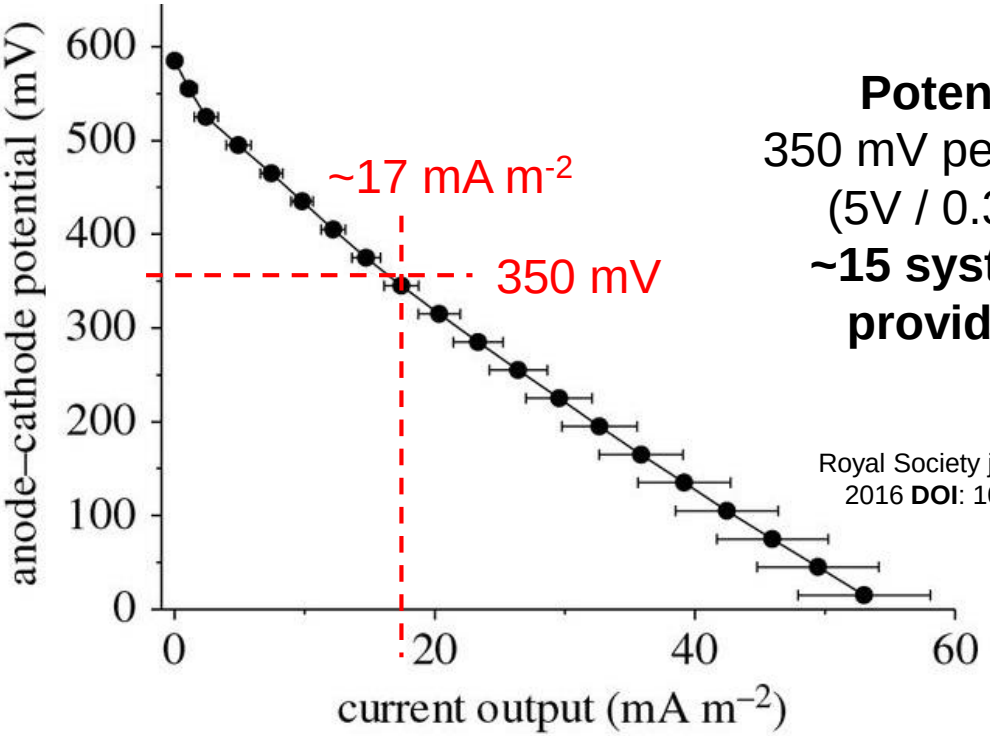


Potential:
350 mV per system
(5V / 0.35V)=
~15 system to provide 5V

Royal Society journal *Open Science*, 2016 **DOI**: 10.1098/rsos.160249

Photosynthetic-BES used to run environmental sensor in remote locations (e.g., tropical forest)

The environmental sensor requires:
5000 mC (@ 5V) per day

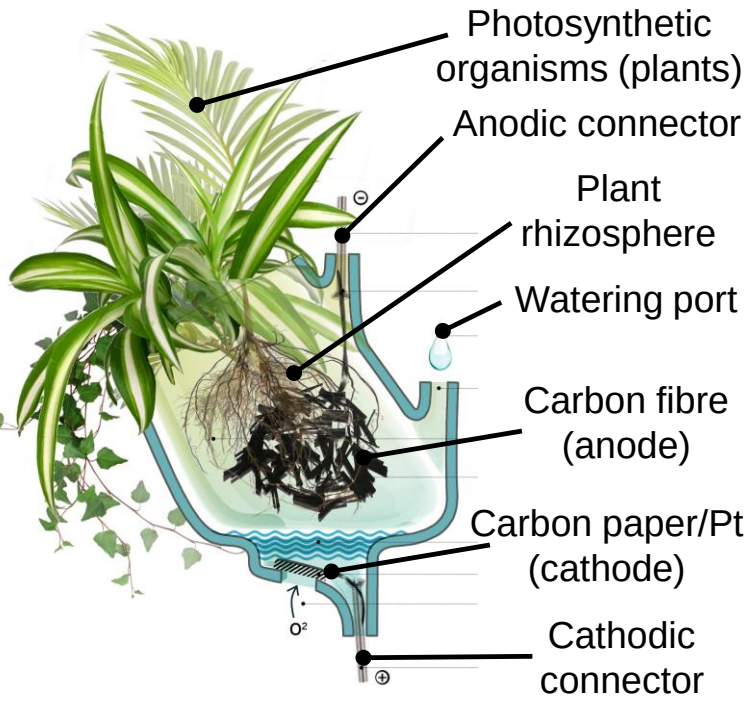


Potential:
350 mV per system
(5V / 0.35V)=
~15 system to provide 5V

Royal Society journal *Open Science*, 2016 **DOI**: 10.1098/rsos.160249

Current: 17 mA m^{-2} = 1.7 µC s^{-1} cm^{-2}
1.7 µC s^{-1} cm^{-2} = 146.9 mC cm^{-2} per day
5000/146 = ~ **34 cm^{-2}**

… and, photosynthetic-BES for art exhibition



Gorky Park (Moscow, May 2018)

ELENA MITRO

http://elenamitro.com/

Elena Mitrofanova

Maria Kuptsova

Acknowledgments

Howe's lab

- **<u>Chris Howe (Group Leader)</u>**
- Jack Hervey (Graduate Student)
- Isabel Nimmo (Postdoctoral Researcher)
- Ellen Nisbet (Senior Research Associate)
- Elfadil Osman (Graduate Student)
- Stephen Rowden (Graduate Student)
- Barnaby Slater (Graduate Student)
- Laura Wey (Graduate Student)
- Wendy Gibson (Lab Manager)

UNIVERSITY OF CAMBRIDGE

Acknowledgments

UNIVERSITY OF CAMBRIDGE

Chris Howe

Jenny Zhang

Alison Smith

Erwin Reisner

Tuomas Knowles

Silvia Vignolini

Lara Allen

Centre for Global Equality

Imperial College London

Andrea Fantuzzi

Peter Nixon

Marin Sawa

ZSL LIVING CONSERVATION

Alasdair Davies

Rachael Kemp

a/ree

Priyanka Jamwal

Sumita Bhattacharyya

Pavan Muttepawar

CCBER

Sue Harrison

Jessica Feel

Kevin Winter

Iaac

Chiara Farinea

ELENA MITRO

Elena Mitrofanova

Maria Kuptsova

arm

Emre Ozer

Anand Savanth

UNIVERSITAS STUDIORUM MEDIOLANENSIS

Andrea Schievano

Matteo Tucci

Acknowledgments

Acknowledgments

Thank you for your attention