课程大纲
COURSE SYLLABUS

1.	**课程代码/名称** **Course Code/Title**	水生微生物培养实验高级讲习班 A Masterclass in Aquatic Microbial Incubation Experiments
2.	**课程性质** **Compulsory/Elective**	专业选修课 Elective
3.	**课程学分/学时** **Course Credit/Hours**	3 学分、64 学时 3 Credits, 64 Hours
4.	**授课语言** **Teaching Language**	英语 English
5.	**授课教师** **Instructor(s)**	郝马克 （助理教授） Mark James Hopwood （Assistant Professor）
6.	**是否面向本科生开放** **Open to undergraduates or not**	不开放 No
7.	**先修要求** **Pre-requisites**	

8. 教学目标
Course Objectives

学会如何提高单个实验与复数实验整体的可重复性；提升实验室技能和样品处理技术；从理论和实操两方面学会实验设计技能；提高对水生环境初级生产动态导因的理解。

To learn how to improve reproducibility within and between experiments. To improve laboratory and sample handling techniques. To gain practical and theoretical skills in experiment design. To improve knowledge of drivers of primary production dynamics in aquatic environments.

9. 教学方法
Teaching Methods

课堂教学、实践练习（校内与实验室）、研讨学习、少量文献综述讨论（课堂讨论）。

Practical exercises (on campus/in laboratory), workshops, lectures, a small amount of literature review (key papers discussed in class)

10. 教学内容
Course Contents

Section 1

1. Introduction to Bioassay Experiments (16 hours)
生物测定实验简介 （16 课时）

1.1 **An introduction to drivers, multi-drivers and biogeochemical experimental approaches** （2 hours Lecture）
简介生物地球化学实验方法以及相关的主导因素和多因素共同作用。（2 课时理论学习）

- What are multi-drivers? How do changes in the environment affect primary production and spatial/temporal patterns of productivity in marine environments.
- 什么是多主导因素？环境变化如何影响海洋环境中的初级生产和生产力的时空间模式。

1.2 **Sampling aquatic environments, how to minimize errors and reproducibly subsample** （2 hours Lecture, 4 hours Demonstration）
水相环境采样，如何将实验误差最小化以及提高二次采样的可重复性。(2 课时理论学习，4 课时示范性实验学习)

- Biological incubations are always subject to poor reproducibility compared to sterile conditions, but reproducibility can be markedly increased through good quality experimental plans and best practice.
- 与无菌条件相比，生物培养的可重复性往往较弱，但通过高质量的实验计划和实操

	工作可以明显提高可重复性。 1.3 **Nutrient dynamics in aquatic systems and their bottom-up effects on marine primary production** （2 hours Lecture） 水生生态系统中的营养素动态机制及其对海洋初级生产“自下而上”的影响。（2 课时理论学习） ● How do macronutrients and micronutrients act to control patterns of primary production in aquatic environments? What general patterns are evident in the nutrients limiting primary production worldwide? ● 常量营养素和微量营养素如何调控水生环境中初级生产的模式？全球范围营养限制初级生产的常见模式有哪些? 1.4 **Results and interpretation of a bioassay experiment** （2 hours Lecture, 4 hours Demonstration） 生物测定实验的实验结果和分析。(2 课时理论学习，4 课时示范性实验学习) ● Use of bioassays to assess the ‘limiting’ nutrient in aquatic environments. Critiquing the strengths and weaknesses of this approach. ● 使用生物测定来评估水生环境中“限制性”营养素。评判这种方法的优缺点。
Section 2	**2. Multi-drivers and multiple effects, how do we optimize our experiments to solve multiple problems? (16 hours)** **多主导因素与多效应，如何通过优化实验解决复数问题？(16 课时)** 2.1 **Multi-drivers and interactive effects** （2 hours Lecture） 多主导因素及其相互作用。（2 课时理论学习） ● Multiple drivers of productivity often change concurrently in the natural environment e.g. ocean deoxygenation reflects a loss of O_2, but also generally a decline in pH and increase in temperature. How do such changes acting together affect primary producers? ● 在自然环境中，影响生产力的多种主导因素常常同时发生改变，例如海洋脱氧反映了溶解氧的降低，但通常也伴随着 pH 的降低和温度的升高。这些变化是如何共同作用并影响初级生产的? 2.2 **Bioassay experiment** （2 hours Lecture, 4 hours Demonstration） 生物测定实验。(2 课时理论学习，4 课时示范性实验学习) ● Bioassays can be conducted in a wide range of environments to assess spatial and temporal shifts in the resources constraining primary production. We will test the resources limiting primary production in a variety of micro-environments around Shenzhen. ● 生物测定可以应用在很多环境中，以评估限制初级生产的资源的空间和时间变化。我们将在深圳周边的各种微环境中测试限制初级生产的资源。 2.3 **Weaknesses of experimental approaches, what do we and don’t we know?** （2 hours Lecture） 实验方法中的缺点：我们知道什么？不知道什么？（2 课时理论学习） ● Whilst powerful tools for assessing nutrient limitation of primary production, there are limits to any experimental approaches. In small experiments we refer to these as ‘bottle effects’. What are these undesired effects and how do we account for them? ● 实验方法虽然是评估初级生产营养限制性的有力工具，但任何实验都有其局限性。在小型实验中，我们将之称为“瓶子效应”。这些不良效应是什么？我们该如何解释他们? 2.4 **Multi-driver experiment construction** （2 hours Lecture, 4 hours Demonstration） 多主导因素实验的构建 (2 课时理论学习，4 课时示范性实验学习) ● Multi-drivers are notoriously challenging to investigate because of the huge experiment sizes involved e.g. whilst the effect of temperature on plankton could be tested with a 4 unit experiment, an experiment with temperature and pH would require a grid of 4×4 units, and an experiment with pH, temperature and oxygen would require a grid of 4×4×4 units.

	● 由于涉及的实验规模巨大，多主导因素的实验对于研究极具挑战性。例如，虽然单一变量温度对于浮游生物的影响仅需 4 个实验即可实现科学研究；若将之扩展到温度与 pH 主导的双重自变量，则需要 4*4 个实验单元的实验设计；再进一步研究温度、pH 和溶解氧的三重自变量则需要 4*4*4 个实验单元。
Section 3	**3. Improving experiment design, balancing logistics and scientific concerns, and improving reproducibility （24 hours）** **改进实验设计，平衡后勤和科学问题，提高实验可重复性 (24 课时)** 3.1 **Mesocosms, are larger experiments better?** （2 hours Lecture） 中宇宙实验装置：实验规模是否越大越好？（2 课时理论学习） ● Size is always desirable in experiment units e.g. moving from a 1 L to 1000 L scale, there is much more volume to subsample and the volume, surface area ratio of our incubations is increased. But larger experiments require more expensive logistics. How do we find a good compromise in these considerations? ● 一般来说，实验单元的规模越大，对实验来说都有好处，例如将容积从 1 升放大到 1000 升，可采样的体积自然也越大，培养的比表面积也会提高。然而，更大的实验规模也要求更昂贵的后勤支持。如何在这些因素中找到一个更好的折衷方案? 3.2 **Multi-driver experiment results and interpretation** （2 hours Lecture, 4 hours Demonstration） 多主导因素共同作用的实验结果和分析。(2 课时理论学习，4 课时示范性实验学习) ● We will use bioassays to test the response to plankton to multiple drivers in micro-environments around Shenzhen, interpreting the results in terms of the stress induced by individual and multiple stressors. ● 我们将通过生物测定实验来测试深圳周边微环境中浮游生物对多主导因素的反应，从单一到复数压力源引起的压力方面解释实验结果。 3.3 **Writing assignment. Guidelines on writing a good scientific report.** （2 hours Lecture） 写作任务。撰写优秀科学报告的指引。（2 课时理论学习） ● Well annotated and detailed notes are key to writing up and reproducing any experiment. We will briefly discuss different approaches to note taking and prepare for the course assignment which will be a report on our practical activities and results. ● 详尽且带有注释的笔记是记录和重复实验的关键。我们将简要讨论不同的记录方法，并为课程任务做准备，并最终用于撰写实践活动的报告。 3.4 **Bioassay experiment, assessing reproducibility.** （6 hours Demonstration） 生物测定实验，评估其可重复性。(6 课时示范性实验学习) ● We will test our own reproducibility, splitting into groups and aiming to perform the same experiments independently to assess how good our practical skills are, and how reproducible our methods are in practice. ● 我们将测试所设计实验的可重复性，分组并独立完成相同的实验，以评估实践能力的强弱与实验方法在实操中的可重复性。 3.5 **Mind-mapping bottom-up and top-down control of ecosystem dynamics. What factors are most important in our incubation experiments?** （2 hours Lecture） 自下而上和自上而下两种群落控制理论的思维导图。在培养实验中，哪些因素最重要?（2 课时理论学习） ● Many environmental factors affect primary production, in designing experiments we must focus on the most important, but also note the potential limitations of this. ● 很多环境因素会影响初级生产，在设计实验时必须关注最重要的影响因素，但也要注意其潜在的局限性。 3.6 **Bioassay experiment, assessing reproducibility.** （6 hours Demonstration） 生物测定实验，评估其可重复性。(6 课时示范性实验学习) ● We will test our own reproducibility, splitting into groups and aiming to perform the same

	experiments independently to assess how good our practical skills are, and how reproducible our methods are in practice. ● 我们将测试所设计实验的可重复性，分组并独立完成相同的实验，以评估实践能力的强弱与实验方法在实操中的可重复性。
Section 4	**4. Frameworks for understanding experimentally derived relationships between nutrients and primary production （8 hours）** **助理解实验推导的营养素与初级生产间关系的框架 （8 课时）** 4.1 **SCOR working group on improving experiment reproducibility & workshop on class results** （4 hours Lecture） 海洋研究科学委员会（SCOR）工作组关于提高实验可重复性的说明。课堂实验结果研讨。（4 课时理论学习） ● Many international organizations have published guides and suggested approaches to improving experimental reproducibility, we will discuss these guidelines and the practicalities of following them. ● 很多国际性组织已经发布了旨在提高实验可重复性的指南与建议方法，我们将讨论上述指南及遵循它们的实际意义。 4.2 **Case study: an experimental approach to N/P dynamics in aquatic environments.** （2 hours Lecture） 案例分析：水生环境中氮磷动态实验方法。（2 课时理论学习） ● We will review our experimental results considering classic arguments concerning the control of primary production in aquatic environments by N and P. ● 结合氮磷控制水生环境中初级生产的经典论点，回顾实验结果。 4.3 **Case study: an experimental approach to trace element (micronutrient) dynamics in aquatic environments.** （2 hours Lecture） 案例分析：水生环境中痕量元素（微量营养素）动态实验方法。（2 课时理论学习） ● We will review our experimental results considering new arguments that some trace elements (e.g. cobalt) may also be important in determining primary production in aquatic environments. ● 结合部分微量元素（如钴）可能也是水生环境中初级生产的重要决定因素的论点，回顾实验结果。

11. 课程考核 Course Assessment

①考核形式 Form of examination:

实验报告撰写：课堂提供所需文字材料，实验结果从实验课获取

Written report (material provided during class time, open book).

②分数构成 grading policy:

出勤率与课堂参与度 25%、文献综述（解读与讨论）15%、实验报告（课堂提供所需材料、开卷）60%。

Attendance and participation (25%), literature review (discussion of a research paper 15%), written report (material provided during class time, open book) 60%.

12. 教材及其它参考资料 Textbook and Supplementary Readings

主要参考教材：

（必读）海洋研究科学委员会工作组 149：Best Practice Guide for Multiple Drivers Marine Research。

(Mandatory) Scientific Committee on Oceanic Research Working Group 149, Best Practice Guide for Multiple Drivers Marine

Research. https://meddle-scor149.org/wp-content/uploads/2019/12/MEDDLE-Handbook.pdf