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福建台湾海峡海洋生态系统国家野外科学观测研究站

2023年度报告

T-SMART

福建台湾海峡海洋生态系统
国家野外科学观测研究站
National Observation and Research Station
for the Taiwan Strait Marine Ecosystem

厦門大學

2023 年度报告
Annual Report

T-SMART INTRODUCTION

福建台湾海峡海洋生态系统国家野外科学观测研究站（以下简称“台海站”，英文缩写T-SMART）依托厦门大学，于2021年10月获科技部批准建设。台海站由“东山太古海洋观测与实验站”（简称“东山实验场”）和“漳江口红树林湿地生态站”（简称“漳江口实验场”）两个分站组成，涵盖台湾海峡上升流、东山湾、漳江口三个观测区，致力于台湾海峡海洋生态系统结构与功能的长期观测和实验生态研究，为保障海洋生态环境健康和促进经济可持续发展提供科技支撑。

National Observation and Research Station for the Taiwan Strait Marine Ecosystem (T-SMART) was approved by the Ministry of Science and Technology of China in October 2021. T-SMART consists of two substations, "Dongshan Swire Marine Station (D-SMART)" and "Zhangjiang Estuary Mangrove Wetland Ecosystem Station (M-ECORS)", which covers three observation areas including Zhangjiang Estuary, Dongshan Bay, and Taiwan Strait Upwelling. It is mainly committed to the long-term monitoring and experimental research on marine ecosystem structure and function, which provides science and technology support for the marine health and the sustainable economic development.

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序言

征程万里风正劲，重任千钧再奋蹄。回首2023年，厦门大学福建台湾海峡海洋生态系统国家野外科学观测研究站（以下简称台海站）在机遇与挑战中不断成长，围绕“观测、研究、示范、服务”蓬勃发展。

科学观测筑基石

台海站围绕“观测、研究、示范、服务”的国家野外站的总体定位，组织开展台湾海峡上升流、东山湾、漳江口三个观测区冬、春、夏、秋季度航次以及东山湾上升流航次观测，同时完成漳江口红树林和盐沼样方观测各1次，滨海湿地鸟类、鱼类和底栖动物观测各2次，结合红树林湿地涡度通量、滨海湿地地表高程、东山湾水文浮标、东山珊瑚在线观测、渔排基水生态在线观测等14套自动观测系统长期连续观测，获取观测数据总量约33 GB。珊瑚监测视频超过2500小时。新建1套阳光紫外辐射自动观测装置。

科学研究促创新

台海站新获批纵向科研项目23个，合同经费共4599万元，包括国家重点研发计划项目2项、国家重点研发计划青年科学家项目1项、基金委重大项目1项、基金委联合基金重点项目2项；授权发明专利3件。62名固定人员中，焦念志获自然资源部2022年度“海洋人物”荣誉称号；焦念志、张瑶团队参与合作的科研成果“海洋人工上升流技术及应用”获浙江省技术发明奖一等奖；江毓武参与合作的研究成果“潮间带贝类地理分布格局及适应机制研究”获2022年海洋科学技术奖一等奖；游伟伟获第一届中国科技青年论坛最佳策论奖。

科学示范助发展

台海站开发红树林、滨海盐沼等滨海蓝碳计量方法学，为蓝碳生态产品价值实现和蓝碳交易提供技术依据；日本囊对虾“闽海2号”耐高温性状选育取得重要进展；依托罗源红树林生态修复及社区发展项目探索“红树林+”的生态经济发展新模式；科技赋能保护东山海域珊瑚群落生态系统。台海站数据中心进一步完善建设覆盖台湾海峡-海湾-河口-湿地-流域的生态环境数据库，开发了“海岸带遥感数据库系统”和“生态环境数据共享服务平台”。

人才汇聚孕未来

台海站新增新增固定人员8人，包括2名教授，2名副教授，1名助理教授，1名工程师，2名助理工程师。培养博士后1名，博士研究生10名，硕士研究生43名。在东山实验场和漳江口实验场开展珊瑚保育与河口红树林湿地相关研究达3254人天。来自厦门大学海洋与地球学院、环境与生态学院，以及生命科学学院的本科生在站内开展生产实习活动达517人天。设立海洋开放日活动，与70.8海洋媒体实验室、东海卫士等平台联合举办科普活动10场，到站访问达1800人次。

一路走来，台海站取得的成绩离不开社会各界的关心和厚爱！在此，谨向长期以来关心、支持和帮助台海站建设发展的国家相关部委、地方政府、社会各界人士和国际同仁表示衷心感谢！向太古集团慈善信托基金、厦门大学及其相关职能部门表示诚挚感谢！未来，全体台海站人将继续聚焦野外观测、科学研究、示范服务，积极开拓创新，谱写台海站发展新篇章。

站长：黄邦钦

于2024年3月

Message from Director

Looking back on 2023, the national observation and research station for the Taiwan Strait Marine Ecosystem (T-SMAR) has achived a siginificant progress in observation, research, demonstration and social services facing chances and challenges.

Long-term observation

In 2023, quarterly cruises were completed in three observation areas, including the upwelling area in the Taiwan Strait, Dongshan Bay, and Zhangjiang Estuary, with a special upwelling cruise in Dongshan Bay; Flora and fuana surveys in Zhangjiang Estuary were conducted in time; Over 33 GB of data and 2500 hours of coral vedio were collected. We constructed a new solar ultraviolet radiation observation system in D-SMART further improved our observation capability. T-SMART Data Cneter developed and launched the Marine Monitoring and Information Service Cloud System (Marine Cloud), also the portal website for Data Center of T-SMART.

Scientific research

A total of 42 research projects were approved, including two National Key Research and Development Programs, one Yong Scientists Project of National Key Research and Development Programs, one Major Project funded by the National Natural Science Fund of China (NSFC), and two joint projects funded by the NSFC; In addition, 71 research articles were published. Among 62 regular researchers, Nianzhi Jiao was elected an “Ocean Figure 2023” by the Ministry of Natural Resources of China; Co-research on the “Application of Marine artificial upwelling technology” joined by team of Nianzhi Jiao and Zhang Yao won the Zhejiang Province 1st Class of Science and Technology Progress Award; Co-research on the “Geographical Distribution Pattern and Adaptation Mechanism of Shellfish in the Intertidal Zone” joined by Yuwu Jiang won the 1st Class of Marine Science and Technology Award, 2022 by the Chinese Society for Oceanography. Weiwei You won the Best Theroy Award in the First China Science and Technology Youth Forum.

Knowledge transfer

Luzhen Chen’s team at T-SMART has developed a comprehensive coastal blue carbon methodology focusing on mangroves and coastal salt marshes to leverage the value of blue carbon; Yong Mao’s team continuously developed the precise and intelligent phenotypic evaluation technologies for shrimp and applied to the selective breeding of the new variety *M. japonicus* “Minhai No. 2”. Addtionally, we continuously focused on mangroves and coral ecosystem conservation. Our Data Center further developed the ecological environment database covering the Taiwan Strait, the “Ecological Environment Data Query, Display, and Sharing Service System” and “Coastal Remote Sensing Database”.

Talent cultivation

There are 8 scientists and technical personnel joined our team, including 2 associate professors, 1 assistant professor, 1 engineer, and 2 assistant engineer. We also provided platforms and resources that help one post-doctoral student, 10 doctoral students and 43 master's students conducted their research. The research on coral conservation and estuarine mangrove wetlands conducted at the D-SMART and M-ECORS amounted to a total of 3,254 person-days. Additionally, undergraduates from the College of Ocean and Earth, the College of Environment and Ecology, and the College of Life Sciences at Xiamen University engaged in production practice activities at the station for a total of 517 days. At the same time, T-SMART has made many outreach efforts. 10 events for talent training and popularization of science were carried out in 2023; more than 1,800 participants took part in these activities.

Thanks to strong partners including Swire Trust, Xiamen University and etc., the achievements of the past year are only the beginning. Fueled by enthusiasm and determination, the leadership and staff of T-SMART will remain dedicated to prioritizing field observation, scientific research, knowledge transfer, and social services to promote marine conservation.

Director: Bangqin Huang

March, 2023

数字台站 2023

DATA

33 GB
DATA PRODUCED

2500 HOURS
CORAL VIDEO STORAGE

12 RESEARCH CRUISES

71 RESEARCH PAPERS

54 STUDENTS AT THE STATION

10 OUTREACH EVENTS

45 INSTITUTIONS AND UNIVERSITIES REPRESENTED

1800+ VISITORS

42 项

新增项目

Newly Funded Projects

2 项

国家重点研发计划

National Key Research and Development Programs

1 项

国家重点研发计划青年科学家项目

Yong Scientists Projects of National Key Research and Development Programs

1 项

国家自然科学基金重大项目

NSFC Major Projects

2 项

国家自然科学基金联合基金项目

NSFC Joint Fund Projects

3 项

国家自然科学基金面上项目

NSFC General Programs

9

省部级项目

Provincial and Ministerial level Projects

2023 Headlines

5月/May

台海站漳江口实验场参与央视漳江口红树林生物多样性大型现场直播

T-SMART participated in the large-scale live broadcast of mangrove biodiversity in Zhangjiangkou National Nature Reserce by CCTV

6月/June

台海站东山实验场实验场参与央视新闻录制

T-SMART participated in news recordings on CCTV

11月/November

台海站主办第十届“两岸海洋环境监测及预报技术研讨会”

T-SMART hosted the 10th “Symposium on Marine Environment Monitoring and Forecasting Technologies”

12月/December

◉ “台海站第一届学术委员会第二次会议”顺利召开

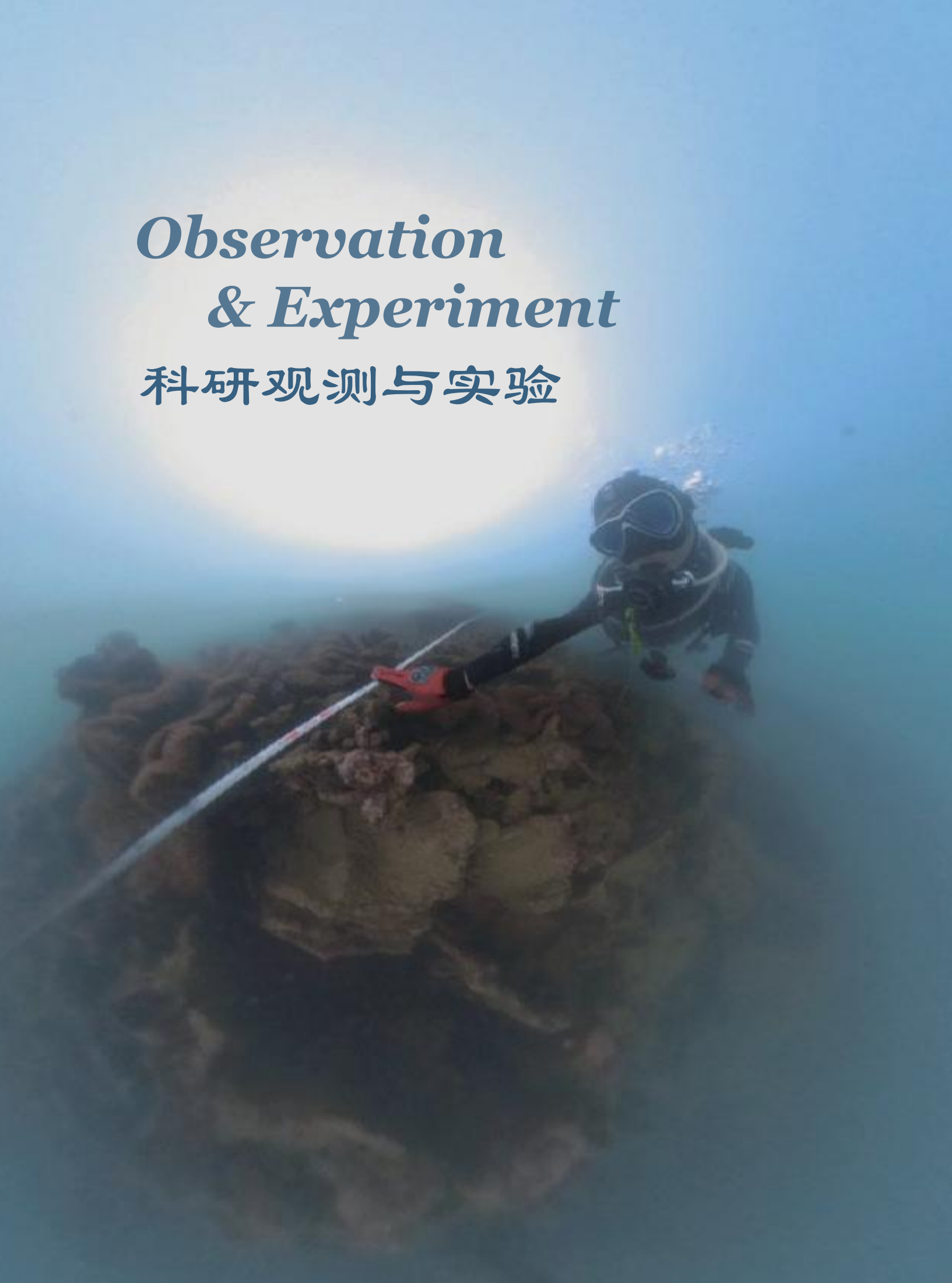
The second meeting of the first Academic Committee Conference of T-SMART was held in Yunxiao county

◉ 台海站漳江口实验场承办“2023年全国红树林保护与修复研讨会”

M-ECORS hold the “2023 Mangroves Conservation and Restoration Conference”

Observation & Experiment

科研观测与实验



台湾海峡上升流观测区航次

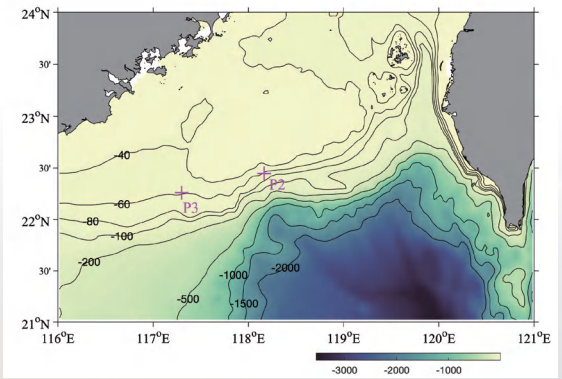
Cruises of the T-SMART in the Taiwan Strait upwelling observation area

台海站台湾海峡上升流观测区位于台湾海峡南部海域，在东山外海至南澳岛以东海域设置3条断面，进行长期观测研究，获取上升流区域海水物理、化学、生物参数，以探究台湾海峡上升流区生态系统特征、动态变化及其驱动机制。

2023年，台海站完成台湾海峡上升流观测区春季（5月）、夏季（7-8月）、秋季（11月）3次大面站航次调查。此外，在夏季8月份还进行台湾海峡上升流定点专项观测，在上升流区域设置2个时间序列站进行定点连续观测，获取高频的物理、化学、生物参数。

The Taiwan Strait upwelling observation area of T-SMART is located in the southern area of the Taiwan Strait. Three sections were set up in the observation area, which spanning from the offshore area of Dongshan Island to the eastern sea area of Nan'ao Island. Its primary objective is to conduct extensive and enduring observations and research, aimed at acquiring comprehensive physical, chemical, and biological data regarding the seawater parameters within the upwelling zone. Such endeavors are pivotal in elucidating the upwelling ecosystem's inherent characteristics, dynamic changes, and their underlying mechanisms within the Taiwan Strait.

During 2023, T-SMART successfully executed three cruises within the Taiwan Strait upwelling observation area in spring (May), summer (July-August), and autumn (November). Notably, a dedicated set of observation focusing on upwelling system was conducted in August during summer cruise, wherein two time series stations were set for continuous observation at fixed point, which aimed to obtain high-frequency marine physical, chemical and biological parameters..



夏季定点站位图

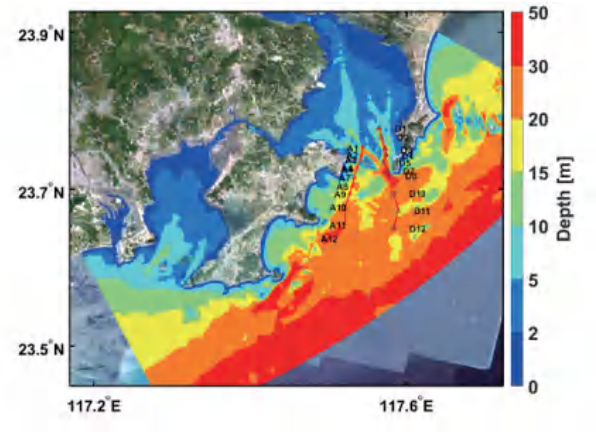
Fixed point of summer cruise

东山湾上升流高频观测航次

Cruises of the T-SMART in the Dongshan Bay upwelling area

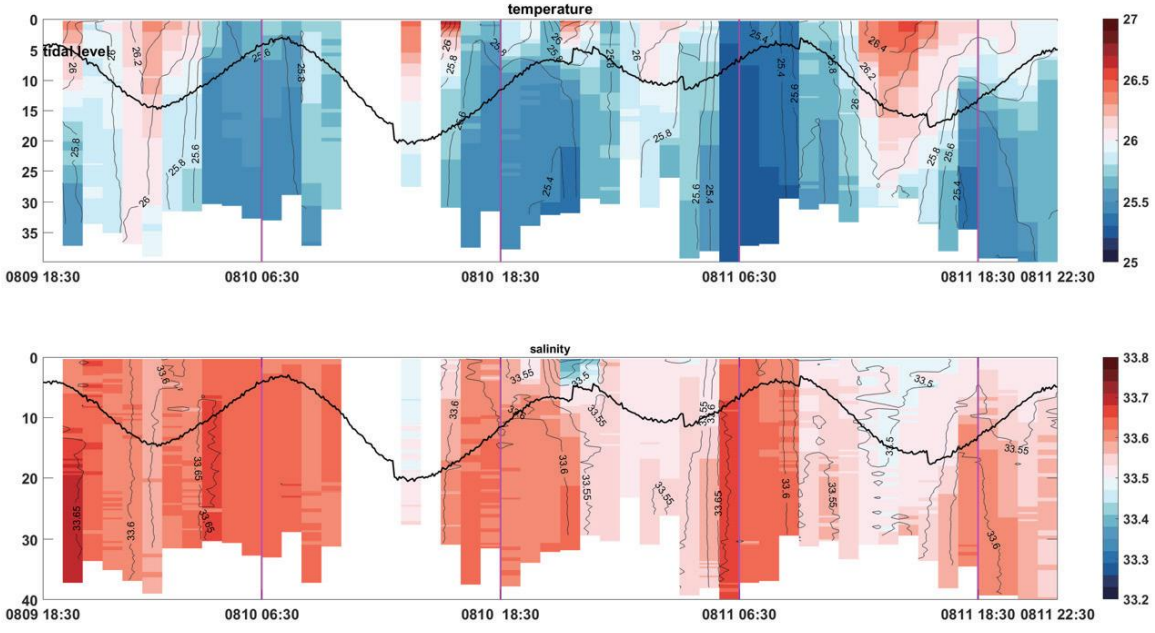
上升流是对海洋生态系统有重要作用的海洋动力过程，其广泛分布于全球海洋生产力较高的海岸区。东山实验场地处南海和东海交界的关键区，该海域附近的沿岸上升流及外海浅滩上升流构成了我国最大的上升流系统之一，动力过程复杂而多样。为进一步加强对东山海域上升流产生机制及全球气候变化背景下海洋生态系统对上升流的响应研究，台海站在2023年8月针对东山海域上升流过程开展高频观测，完成大面观测站位24个，在东山湾口门深槽位置完成52小时时间序列定点站位连续观测。

Upwelling is an ocean dynamic process that plays an important role in Marine ecosystems and is widely distributed in coastal areas with high Marine productivity in the world. D-SMART is located in a key area at the junction of the South China Sea and the East China Sea. Coastal upwelling and offshore shoal upwelling near this area constitute one of the largest upwelling systems in China, and the dynamic processes are complex and diverse. In order to further strengthen the research on the mechanism of upwelling in Dongshan Sea area and the response of Marine ecosystems to upwelling in the context of global climate change, the Taiwan Strait Station carried out high-frequency observation on the upwelling process in Dongshan Sea area in August 2023, completed 24 large-area observation stations, and completed 52-hour continuous observation at the deep-trough of Dongshan Bay estuary.



东山湾上升流高频观测航次：大面观测（A、D断面）
Observation sections A and D of the cruise

东山湾上升流高频观测航次照片
Group photo of the cruise



东山湾上升流高频观测航次：定点观测（A5）温盐时序
Time-series temperature and salinity data of fixed point observation (A5)

东山珊瑚省级自然保护区赤屿-头屿片区珊瑚资源潜水调查

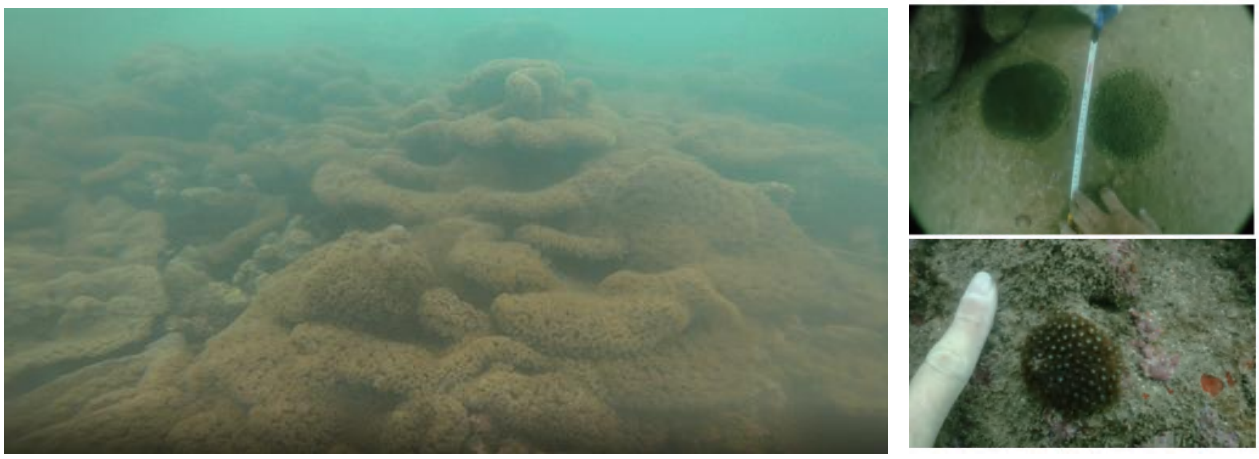
Diving survey of coral resources in the Dongshan Bay

2023年8月，东山实验场技术团队在东山珊瑚省级自然保护区赤屿-头屿片区开展珊瑚资源潜水调查，9月，团队按计划完成了福建东山珊瑚省级自然保护区范围内20个站位的珊瑚生态调查工作的野外作业部分，海水营养盐和水下测线视频数据正在有序分析中。根据调查获取的影像资料，经过初步分析，该区域的造礁珊瑚整体趋势与历史数据吻合，头屿片区石珊瑚覆盖度高，二屿堤坝外部发现大片造礁珊瑚分布且长势良好，鸡心屿和澳角片区覆盖度较低。本次调查的站位设置在参考历史工作的同时也根据近年来在东山海域开展的各类航次和潜水调查进行了优化，因此在历史数据记录以外的站位也发现了较好的珊瑚覆盖率，表明东山的珊瑚群落生物量可能超出预期。东山水域常见的几种造礁石珊瑚的小型个体都有在这次调查中记录到，表明本底种群有得到补充，但是补充机制仍需深入研究。另外，我们发现可能有一到两个石珊瑚种类是历史数据中没有记录的，但仍需进行采样利用形态学和分子生物学手段进一步确认。

In August 2023, the D-SMART technical team conducted a diving survey of coral resources in the Chiyu-Touyu area within the Dongshan Coral Nature Reserve. Subsequently, in September, our team successfully completed the field operations for the coral ecological survey at 20 designated stations within the Fujian Dongshan Coral Provincial Nature Reserve, in line with our planned objectives. Currently, the analysis of video data capturing seawater nutrients and underwater landscapes is underway in an organized manner.

Preliminary findings from the survey's video data suggest that the overall trend of reef-building corals in the area aligns with historical data. High coverage of stony corals was observed in the Touyu area, with significant expansion of healthy reef-building corals detected beyond the Eryu dyke. Conversely, lower coral coverage was noted in the Jixinyu and Aojiao areas. By optimizing the survey site selection based on recent voyages, diving expeditions in Dongshan waters, and historical references, enhanced coral coverage was observed at stations not previously documented, hinting a potentially greater biomass of coral communities in Dongshan.

Furthermore, the survey documented several young individuals of common reef-building corals in Dongshan waters, indicating a replenished background population. However, the mechanism behind this replenishment warrants further investigation. Additionally, the survey uncovered potential existence of one or two stony coral species not previously recorded in historical data, necessitating sampling for conclusive identification through morphological and molecular biological analyses.



赤屿-头屿片区常见造礁石珊瑚小型个体
（右上：标准蜂巢珊瑚；右下：锯齿刺星珊瑚）
Small reef-forming corals are common in Chiyu- Touyu area
(Right-top: Standard Honeycomb coral; Right-bottom: Acanthastra serrata)

地下河口观测

Subterranean estuary monitoring

地下河口观测系统配备了锚定自动升降系统，多参数温盐深仪、微型井潜水采样泵和多通道远程数据传输系统，以实现地下水中温度、盐度、地下水位及理化参数的长期观测。2023年W4观测井水深、温度、电导率的波动如图A所示。总的来说，水深（m）随时间出现下降，其变化范围为18.26-19.67，平均值为18.94± 0.27。温度（℃）不存在单调下降的趋势，而是呈现明显的季节特征，高值见于5月与8月之间，应是夏季较强的太阳辐射导致。温度（℃）变化范围为23.68-23.77，平均值为23.74±0.03。电导率（μs/cm）的变化趋势较复杂，其变化范围为516.1-524.2，平均值为522.1±1.7。在3月份和7月份之间，电导率明显低于其他月份的平均值。

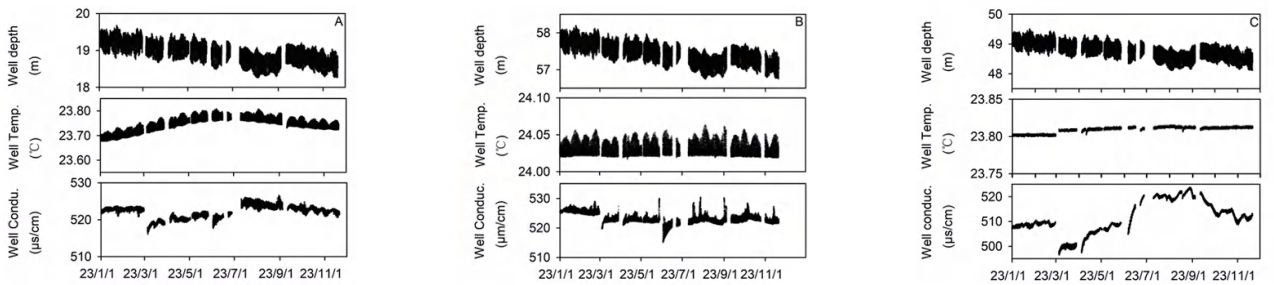
W3观测井水深、温度、电导率的波动如图B所示。与W4相同，W3的水深（m）也随时间出现下降的趋势，其变化范围为56.75-58.19，平均值为57.45±0.28。温度（℃）则不存在明显的变化趋势，其变化范围为24.02-24.06，平均值为24.03±0.01。电导率（μs/cm）与水深相同，有随时间下降的趋势，其变化范围为515.1-530.3，平均值为523.1±1.8。与水深不同的是，6月初，电导率出现最低值。

W1观测井水深、温度、电导率的波动如上图C所示。与W4和W3相同，W1的水深（m）也随时间出现下降的趋势，其变化范围为48.11-48.80，平均值为48.78±0.27。温度（℃）与W4相同，呈现夏季较高的季节特征，其变化范围为23.80-23.81，平均值为23.81±0.01。电导率（μs/cm）也与W4相同，在3月到7月之间，其均值低于1月-2月。与W4不同的是，W1的电导率在7月到九月之间还呈现出峰值信号。总的来说，电导的变化范围为496.5-512.4，平均值为511.5 ± 6.5。

The variations in depth, temperature, and conductivity of DSMART well 4 in 2023 are illustrated in the left figure. The depth generally exhibited a decreasing trend over time, ranging from 18.26 m to 19.67 m, with an average of 18.94 ± 0.27 m. In contrast to a monotonous downward trend, temperature displayed a noticeable seasonal change influenced by strong solar radiation in summer, peaking between May and August. Specifically, the temperature varied from 23.68 to 23.77 ˚C, with a mean value of 23.74 ± 0.03˚C . The variation in conductivity was more intricate, ranging from 516.1 μs/cm to 524.2 μs/cm, with an average of 522.1 ± 1.7 μs/cm. A decline in conductivity was observed between March and July compared to the average for other months.

The fluctuations in depth, temperature, and conductivity of DSMART well 3 are presented in the middle figure. Similar to W4, the depth of W3 also demonstrated a decreasing trend over time, ranging from 56.75 m to 58.19 m, with an average value of 57.45 ± 0.28 m. Temperature exhibited very subtle changes, ranging from 24.02˚C to 24.06˚C , with a mean value of 24.03 ± 0.01˚C. The conductivity exhibited a similar pattern to the depth, decreasing over time. Unlike water depth, the conductivity reached a transient lowest value in early June. Overall, the conductivity varied from 515.1 to 530.3 μs/cm, with a mean value of 523.1 ± 1.8 μs/cm.

Finally, DSMART well 1 also experienced variation in depth, temperature, and conductivity, as depicted in the right figure above. The variation in depth of W1 resembled that of W4 and W3, decreasing from 48.11 m to 48.80 m, with an average value of 48.78 ± 0.27 m. The temperature exhibited a pattern similar to that of W4, showing higher values in summer. Specifically, the temperature ranged from 23.80˚C to 23.81˚C, with an average of 23.81 ± 0.01˚C. The variation in conductivity was also similar to W4, with a lower average between March and July. However, unlike W4, the conductivity of W1 also showed a peak value between July and September. In general, the conductivity varied from 496.5 μs/cm to 512.4 μs/cm, with an average of 511.5 ± 6.5 μs/cm.



2023年观测井水深、温度、电导率的波动。A：W4观测井；B：W3观测井；C：W1观测井

Variations in depth, temperature, and conductivity in three monitoring wells in 2023. A: DSMART well 4; B: DSMART well 3; DSMART well 1

陆-海、海-气界面气象观测

Land-ocean and ocean-atmosphere interface meteorological observation

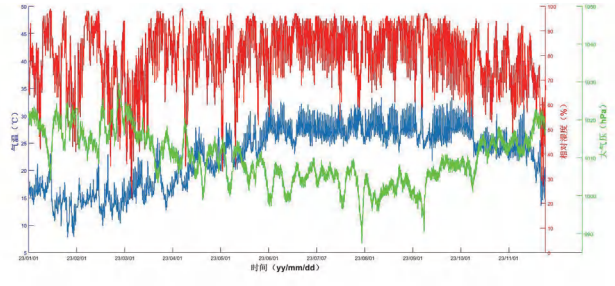
东山实验场目前使用的自动气象站为DZZ4型区域自动气象站，是完全满足中国气象局《新型自动气象（气候）站功能规格书（业务试用版）》的新一代自动气象站，其技术指标完全满足或优于业务化部门的要求，并获得气象专用技术装备使用许可证和国家高新技术产品认证。该气象站采用当今成熟的、稳定的、先进的电子测量、数据传输和控制系统技术，能满足现有气象观测站的气候观测、天气观测和区域观测业务的需要，具有高可靠性、高准确性、易维护等特点。

2023年1月1日零时起，截止至2023年11月20日，数据接收率在97%以上，系统运行情况稳定。系统观测参数包含：风速、风向、温度、相对湿度、大气压强及雨量。

The D-SMART currently utilizes the DZZ4 regional automatic weather station, a cutting-edge system that conforms to the “Function Specification of New Automatic Weather (Climate) Station (Business Trial Version)” set by the China Meteorological Administration. This next-generation weather station surpasses operational requirements, holding licenses for special meteorological technical equipment and national high-tech product certification. Equipped with state-of-the-art electronic measurement, data transmission, and control system technologies, the weather station ensures precision and reliability in climate observation, weather monitoring, and regional data collection at meteorological stations. Notable features include high reliability, accuracy, and ease of maintenance.

Operating from January 1 to November 20, 2023, the system boasted a data receiving rate exceeding 97% with stable performance. Observation parameters encompass wind speed, wind direction, temperature, relative humidity, atmospheric pressure, and rainfall, contributing to comprehensive weather monitoring capabilities.

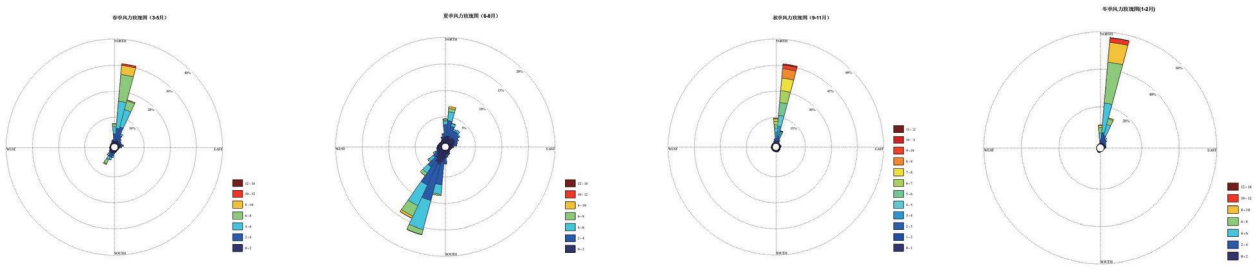
根据观测，东山实验场在春、秋、冬季受东北风影响为主，在夏季则是以西南风为主。其中春季主要风力为5级及以下，夏季以2~4级风为主，秋季天气多变，5级及以下各等级风力出现频率相近，出现6级以上强风天气增多；在冬季以四级以上风力居多。



气象观测数据

Data collected by the atmosphere observation system

Based on observations, D-SMART experiences predominant northeast winds during spring, autumn, and winter, while southwest winds prevail in the summer. In spring, predominant winds generally range up to level five, while in summer, they typically fluctuate between level two and four. Autumn weather is characterized by variability, with frequencies of winds at level five and below being comparable and an upsurge in strong winds exceeding level six. Winter sees winds frequently exceeding force four.



东山季节风力玫瑰图

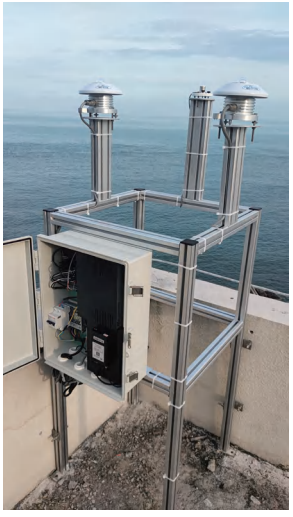
Seasonal wind rose diagrams in Dongshan

东山阳光紫外辐射观测

Solar ultraviolet radiation observation system

2023年，台海站固定研究人员高坤山教授及其团队在东山实验场新布设一套阳光紫外辐射观测系统，该系统主要由一套EKO紫外辐射检测仪MS-212A/W以及光合有效辐射传感器（ML-020P）组成，用于配合东山近海浮游植物群落固碳与环境变化关系研究。通过数据采集模块（CR300）及通信模块，可实时将数据上传至云平台，并可视化。后期还将搭载两台SR05总辐射表用于测量净辐射，进一步加强光照辐射观测能力。

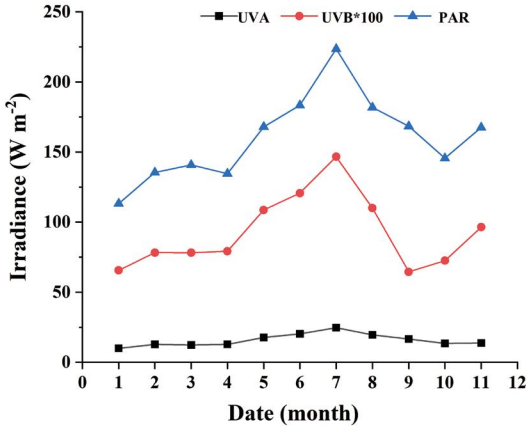
In 2023, Kunshan Gao and his team set up a new solar ultraviolet radiation observation system in D-SMART, which mainly consists of a set of EKO ultraviolet radiation detector MS-212A/W and photosynthetically active radiation sensor (ML-020P). It is used to study the relationship between carbon sequestration and environmental change of phytoplankton community in Dongshan coastal area. Through the data acquisition module (CR300) and the communication module, the data can be uploaded to the cloud platform in real time and visualized. At a later stage, two SR05 total radiometers will be installed to measure net radiation, further enhancing the ability to observe light radiation.



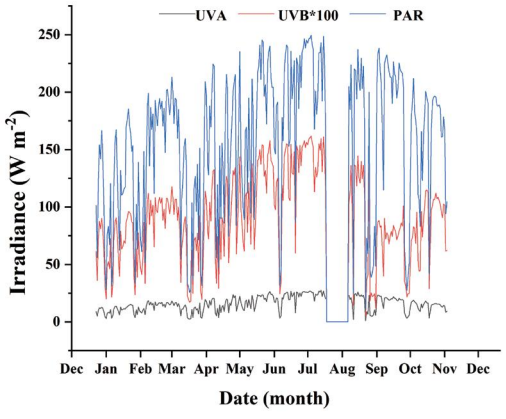
阳光紫外辐射观测系统
Solar ultraviolet radiation observation system

根据日平均与月平均阳光紫外线辐射强度观测，从1月到7月PAR、UVA和UVB总体呈增加趋势，且在7月份达到最大值，从7月份到12月份呈现先降低后升高的趋势。PAR、UVA和UVB的最大日均辐射强度分别为249.63 W m^{-2}（7月13日）、27.44 W m^{-2}（7月22日）和1.62 W m^{-2}（7月13日）；最小日平均辐射强度分别为11.09 W m^{-2}（8月31日）、1.18 W m^{-2}（8月31日）和 0.05 W m^{-2}（8月31日）。

By mapping the daily average solar UV radiation intensity, the results show that PAR, UVA, and UVB generally increase from January to July, and reach the maximum value in July, and then decrease from July to December. The maximum average daily radiation intensity of PAR, UVA, and UVB was 249.63 W m^{-2} (July 13), 27.44 W m^{-2} (July 22), and 1.62 W m^{-2} (July 13), respectively. The minimum average daily radiation intensity was 11.09 W m^{-2} (August 31) 1.18 W m^{-2} (August 31) 0.05 W m^{-2} (August 31).



2023年阳光PAR、UVA和UVB辐射的日平均变化
Average daily changes in solar PAR, UVA, and UVB radiation in 2023



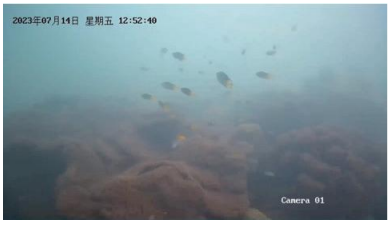
2023年阳光PAR、UVA和UVB辐射的月平均变化
Average monthly changes in solar PAR, UVA, and UVB radiation in 2023

海底有缆珊瑚生态在线观测

Coral ecosystem cabled observatory (CECO)

2023年，虽然经历人为破坏和台风影响，但第二代海底有缆珊瑚生态在线观测系统数据产出天数仍超过120天，经过7次维护，累计获取高清录像时长2500小时。台海站团队与中国科学院沈阳自动化研究所团队展开合作，利用人工智能实现水下视频的自动目标识别。

台海站团队针对系统暴露的问题进行迭代升级，并自主研发小型光电接驳仓和科学仪器接口模块（SIIM），可实现2km内的电力传输和高带宽通讯。解决了轻量化海底观测网组网问题，提升了观测能力，为开展造礁珊瑚生态实验、保育及救护工作提供技术支撑。



东山珊瑚群落水下观测视频截图
Dongshan coral community underwater observation video screenshot

In 2023, despite the impact of man-made destruction and typhoons, the data output days of the second-generation submarine cable coral ecological online observation system are still more than 120 days, and after 7 maintenance, a total of 2500 hours of high-definition video is obtained. T-SMART team collaborated with the Shenyang Institute of Automation of the Chinese Academy of Sciences to achieve automatic target recognition in underwater video using artificial intelligence.

The T-SMART team has iteratively upgraded the exposed problems of the system, and independently developed a small photoelectric connection bin and scientific instrument interface module (SIIM), which can achieve power transmission and high-bandwidth communication within 2 km. It solves the networking problem of the lightweight submarine observation network, improves the observation capacity, and provides technical support for ecological experiments, conservation and rescue work of reef-building corals.

水动力浮标观测

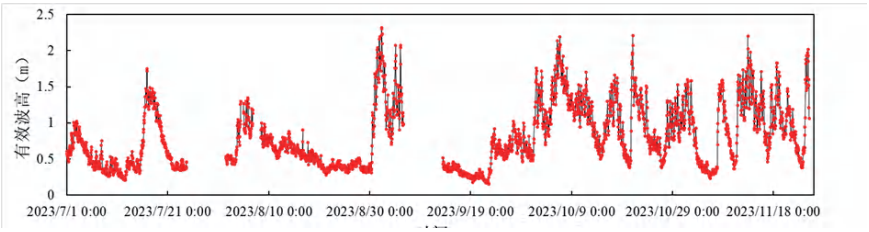
Hydrological observation system

2023年6月，台海站在东山湾上升流海域投放水动力浮标观测系统，收集气象、水文及水质等参数。7月1日开始计算数据产出，目前浮标仍处于运行状态。

根据实测的波浪数据表明：7月至11月期间，该海域有效波高平均值为0.79m，平均周期为5.67s，8月份出现全年最大波高极值3.35m。有效波高小于0.5m的波浪频率为 31%，小于1.25m的波浪频率为82%。

In June 2023, T-SMART introduced a hydrodynamic buoy observation system within the upwelling area of Dongshan Bay to gather meteorological, hydrological, and water quality data. Data calculations commenced on July 1, and the buoy remains operational.

Based on the recorded wave data from July to November, the average effective wave height in the sea area is 0.79m, with an average period of 5.67s. Notably, the maximum annual wave height of 3.35m occurred in August. Furthermore, waves with an effective wave height below 0.5m accounted for 31% of the observations, while those below 1.25m constituted 82% of the total observations.



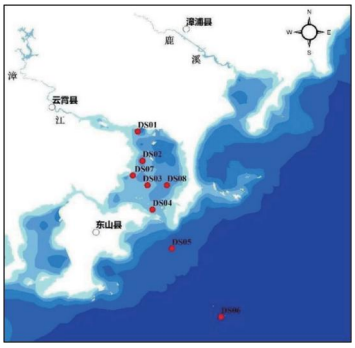
有效波高时序图
Time series of effective wave height

东山湾观测区季节航次调查

The quarterly cruise in the Dongshan Bay observation area

东山湾观测区位于福建省漳州市东山湾及邻近海域，以上升流、珊瑚保护区、水产养殖密集区、核电站及石化基地附近海域为重点观测区域，观测项目包括物理要素、化学要素、底质生化要素、生物要素等内容。2023年，台海站东山实验场继续开展季度航次调查，累计完成冬季（2月）、春季（5月）、夏季（8月）、秋季（11月）4个季度的航次调查。

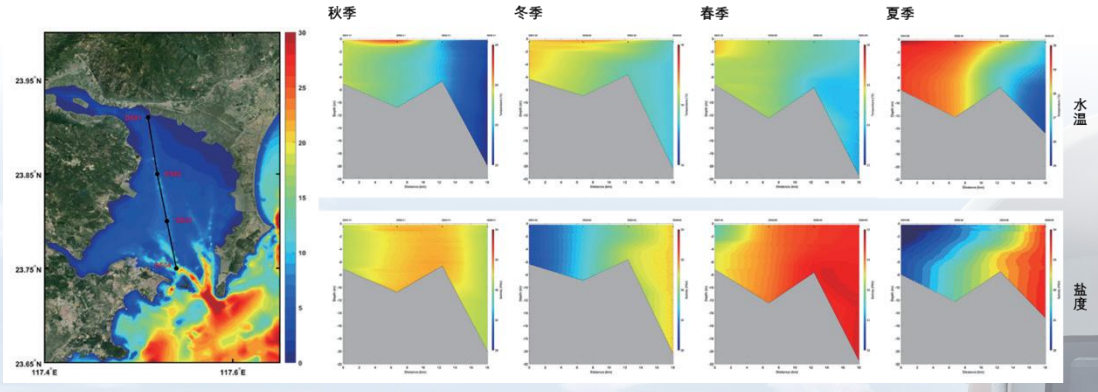
东山湾海域温度分布由湾顶向湾外呈现“内高外低”的态势，盐度分布由湾内向湾外呈现“内低外高”的态势。DS02与DS03附近海域的水体由于上下两种性质不同水体的影响，会存在比较明显的温度和盐度跃层。



东山湾季度航次站点图

Cruise sites of Dongshan Bay cruise

The Dongshan Bay Observation Area is located in Dongshan Bay, Zhangzhou City, Fujian Province, and the adjacent sea areas, focusing on upwelling, coral protection areas, aquaculture intensive areas, and the waters near nuclear power plants and petrochemical bases. The observation items include physical elements, chemical elements, biochemical elements of the bottom material, and biological elements. In 2023, the D-SMART will continue to carry out quarterly voyage surveys, and a total of four quarterly voyage surveys will be completed in winter (February), spring (May), summer (August) and autumn (November). The temperature distribution in Dongshan Bay is "high inside and low outside" from the bay top to the bay, and the salinity distribution is "low inside and high outside" from the bay top to the bay. Due to the influence of the upper and lower water bodies of different nature, the water body near DS02 and DS03 will have obvious temperature and salinity jump layer.



东山湾DS01至DS04断面温度、盐度分布

Distribution of temperature and salinity in DS01 to DS04 section of Dongshan Bay

东山湾养殖区水环境参数实时观测

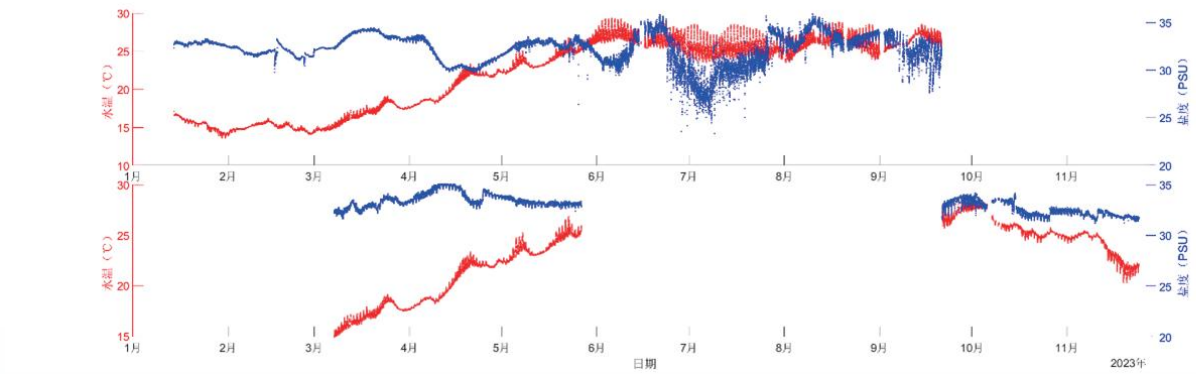
Real-time observation of water environment parameters in Dongshan Bay culture area

东山实验场依托渔排基海洋观测平台，利用物联网技术，在东山湾养殖密集区布放温盐链，实现温度、盐度、电导率等参数的实时观测。2023年度渔排基养殖水体观测系统，收集数据10MB。期间共计运行维护7次；主要进行传感器清洁校准维护，传输系统维护。

据统计，在平均水深5.23米处的温盐深仪测量得平均水温为21.84±4.76℃，平均盐度为32.15±1.57；在平均水深12.07米处的温盐深仪平均水温为22.44±3.44℃，平均盐度为33.05±0.86。

D-SMART relies on the Marine observation platform based on fishing row and uses the Internet of Things technology to distribute temperature and salt chain in the intensive area of Dongshan Bay culture to achieve real-time observation of temperature, salinity, conductivity and other parameters. In 2023, fishery row-based aquaculture water body observation system collected data up to10MB.. During the period of operation and maintenance 7 times; Mainly for sensor cleaning and calibration maintenance, transmission system maintenance.

According to statistics, the average water temperature and salinity measured by the thermosalinity meter at the average depth of 5.23 meters are 21.84±4.76℃ and 32.15±1.57. At an average depth of 12.07 meters, the average water temperature of the thermohaline bathymeter is 22.44±3.44℃ and the average salinity is 33.05±0.86.



渔排基养殖水体观测系统表底层温盐数据

Temperature and salinity data of bottom layer of fishery and aquaculture water observation system

漳江口观测区季度调查航次

The quarterly cruise in the Zhangjiang Estuary observation area

漳江口滨海湿地的长期定点观测是台海站的主要任务之一，也是揭示人类活动和全球变化对滨海湿地生态系统长期影响的研究基础。漳江口观测区位于福建省漳州市云霄县漳江口，包含红树林潮沟、漳江下游至入海口水域，结合潮汐周期人工取样，2023年台海站漳江口场完成冬季（2月）、春季（5月）、夏季（8月）、秋季（11月）的航次调查，获得水体理化参数、浮游生物、底栖生物等方面的监测数据，以监测漳江口生态系统长期变化，以及量化地表水-地下水垂向交换水量和物质通量、红树林/互花米草-河口系统横向物质交换通量等。

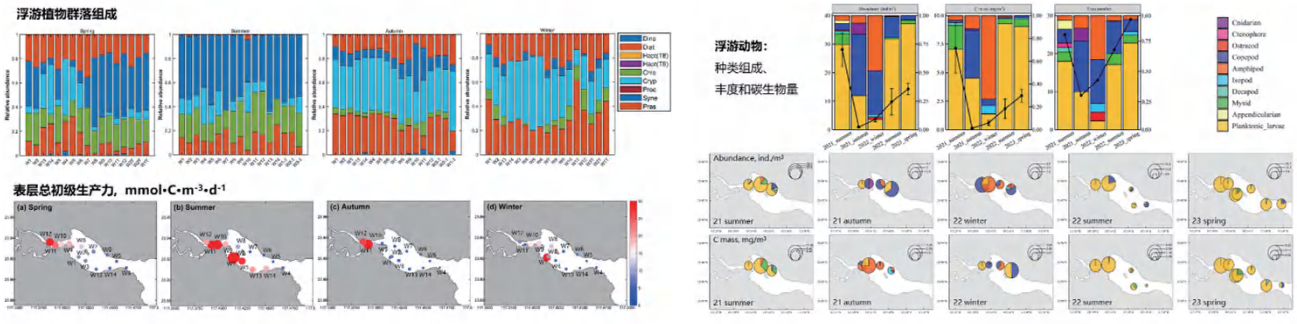
现有监测数据表明，浮游植物与浮游动物群落存在显著季节性波动和空间变化。浮游植物在河口不同区域群落组成相差较大。浮游动物群落呈现春、夏季多样性、丰度和生物量较高，秋、冬季较低的变化。在总初级生产力方面，上游方向的站位初级生产力较高，而靠近口门处的初级生产力较低，且夏季是初级生产力最高的季节。

漳江口观测站位
Observation sites in the Zhangjiang Estuary

漳江口站航次监测合照
Photos of Zhangjiang Estuary cruises

Long-term field fixed-point observations are one of the main tasks of T-SMART. It also serves as a base to reveal the long-term impact of human activities and global change on coastal wetland ecosystems. The quarterly cruise was officially launched in Zhangjiang Estuary in Feburary, May, August, and November 2023. Samplings have been set during a tidal cycle from Zhangjiang estuarine waters to mangrove tidal creeks, to quantify surface water-groundwater vertical exchanges of water and material flux, and mangroves/Spartina alterniflora-estuary system horizontal material exchange flux. M-ECORS provides technical and logistical support for the cruise.

The available monitoring data indicate notable seasonal variations and spatial dynamics in both phytoplankton and zooplankton communities. Phytoplankton community composition displays significant diversity across various estuarine regions. Meanwhile, zooplankton community exhibits higher diversity, abundance, and biomass during spring and summer, contrasting with lower levels during autumn and winter. Regarding total primary productivity, upstream areas exhibit higher levels compared to locations near the estuarine mouth, with summer emerging as the peak season for primary productivity. These findings underscore the dynamic nature of phytoplankton and zooplankton communities, reflecting seasonal patterns and spatial disparities in marine ecosystems.



漳江口初级生产力及浮游植物、浮游动物群落结构
Primary productivity and community structure of phytoplankton and zooplankton in Zhangjiang Estuary

滨海湿地植物样方监测

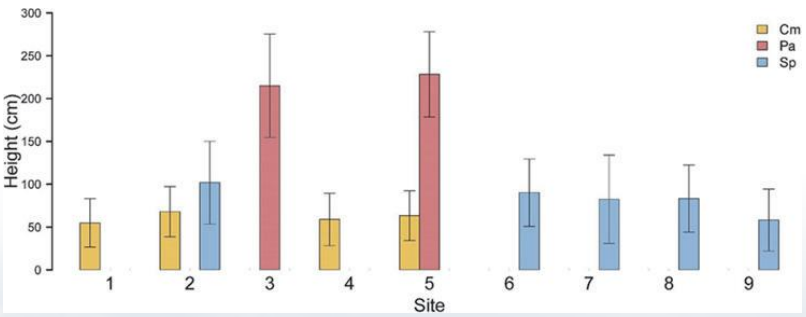
Flora biodiversity surveys for coastal wetlands

为长期跟踪监测红树林及盐沼湿地植被生长情况、湿地面积变化、外来物种入侵情况，及其对全球气候变化和人类活动的响应等，漳江口实验场设置了6个红树林永久样地，观测频率为每年1次，观测指标包括红树植物群落种类、高度、密度、胸径以及红树植物凋落物的类别、质量等，同时设置了10个盐沼植物样地。2023年漳江口实验场完成红树林和盐沼固定样方监测各1次，观测指标包括盐沼植物群落种类、高度、密度、基径等。以上观测为红树林生态系统研究、红树林湿地蓝碳以及互花米草入侵红树林的格局、过程和机制研究提供重要支撑。

To ensure the continuous tracking and monitoring of vegetation growth in mangroves and salt marsh wetland, wetland area variation, alien species invasions, and responses to global climate change and human activities, six permanent mangrove plots have been set in the M-ECORS, with observations conducted annually. These plots monitor various parameters such as species composition, height, density, and diameter at breast height (DBH) of the mangrove plant community, as well as the type and quality of mangrove plant litter. In addition, ten salt marsh plant samples are included in the observation protocols.

In 2023, M-ECORS completed monitoring of the fixed mangrove and salt marsh samples, incorporating observations on species composition, height, density, and base diameter of salt marsh plant communities. These comprehensive observations offer crucial support for studying the mangrove ecosystem, coastal wetland blue carbon, and patterns, processes, and mechanisms related to the invasion of mangrove *Spartina alterniflora*.

盐沼监测照片
Salt marsh observation in Zhangjiang Estuary



不同盐沼植物的生长状况（Cm茳芏，PA芦苇，SA互花米草）
Growth status of different salt marsh plants (Cm茳芏, PA reed, SA *Spartina alterniflora)*

滨海湿地动物样方监测

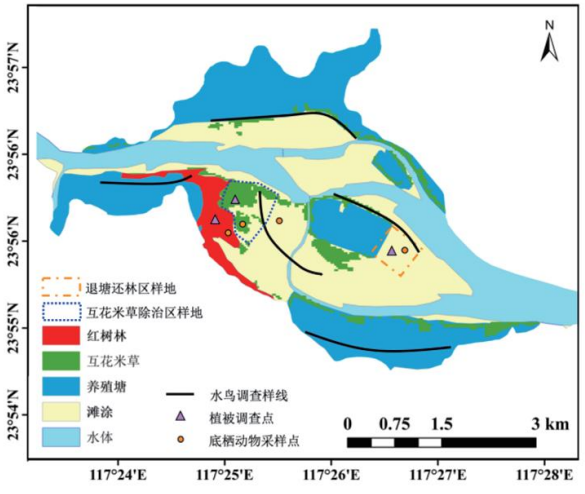
Faunal biodiversity surveys for coastal wetlands

为长期跟踪监测漳江口红树林湿地的动物多样性，漳江口实验场为鸟类、鱼类和潮间带底栖动物等动物的多样性观测设置了监测样线、样点和样方，监测指标包括动物的种类、数量、生物量和分布等。2023年，漳江口实验场完成动物多样性监测2次。在漳江口红树林国家级自然保护区的支持下，漳江口实验场开展了多年的鸟类、鱼类、底栖动物等调查，掌握了动物类群长期的种群动态和分布，为生物多样性保护提供了重要的基础数据支撑。

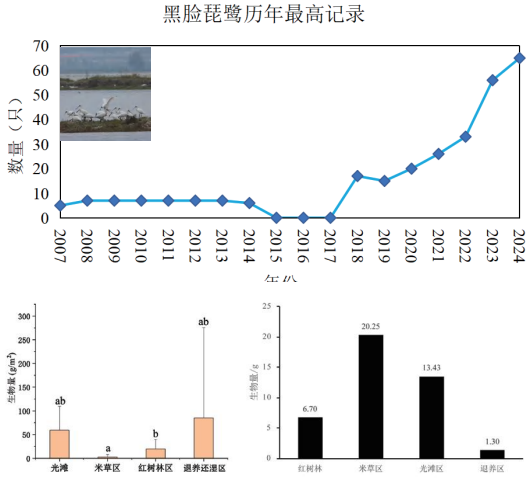
现有观测研究结果表明：漳江口保护区退养还湿成效明显，鸟类种群数量稳步上升，其中珍稀濒危物种黑脸琵鹭（*Platalea minor*）数量逐年增加；退养还湿区和退养区分别在低潮和涨潮时为鸟类提供了重要的栖息地。另外，退养还湿区内的底栖动物逐步恢复，不同生境中的底栖动物多样性存在显著差异。基于此研究，建议对漳江口保护区范围内退养还湿区和退养区开展连续的生物多样性监测，并及时控制互花米草（*Spartina alterniflora*）和无瓣海桑（*Sonneratia apetala*）的入侵和扩散，在对退养的养殖塘进行管理和修复的过程中，不仅需要考虑红树植物的恢复以及红树林面积的增加，同时需要考虑生物多样性的保护以及生态系统的完整性。

To carry out long-term surveys of the faunal biodiversity, line transects and quadrats have been set in Zhangjiang Estuary to conduct bird, fish, and benthic fauna surveys. M-ECORS, with supports from Zhangjiang Estuary Mangrove Nature Reserve, The survey are conducted twice in 2023 to record species and their quantity as well as distribution, which provides basic evidence for biodiversity conservation in this estuary.

The current observational findings highlight significant achievements in humidity restoration within the Zhangjiang Estuary, leading to a steady increase in the bird population. Particularly noteworthy is the year-on-year growth of the rare and endangered species *Platalea minor*. Both roosts and retreats play crucial roles in providing vital habitats for birds during low and high tides respectively. Moreover, the recovery of benthic fauna in the area has been observed, with notable variations in benthic fauna diversity across different habitats. These findings suggest the importance of ongoing biodiversity monitoring in degraded areas of the Zhangjiangkou Nature Reserve. Effective control measures are recommended to manage the invasion and spread of *Spartina alterniflora* and *Sonneratia apetala*. Furthermore, the management and restoration of retired aquaculture ponds should prioritize not only the rehabilitation and expansion of mangrove vegetation but also the conservation of biodiversity and ecosystem integrity. Such integrated approaches are essential for achieving sustainable ecosystem management in the reserve.



漳江口样线样点图
Zhangjiang Estuary transect point map



鸟类监测结果历年变化
Continous variation ourcome from bird survey

水位梯度控制实验

Water level gradient control experiment

实验系统位于云霄漳江的河口地区，利用沿流域水位梯度控制平台实现自然水—盐控制梯度，研究海平面上升背景下淹水时长和海水盐度协同变化对红树植物幼苗更新和生长的驱动机制，现已完成2023年持续监测。

The experimental system is located in the Zhangjiang Estuary, and uses the water level gradient control platform along the basin to achieve natural water-salt control gradient. It studies the driving mechanism of the synergistic change of flooding duration and seawater salinity on the regeneration and growth of mangrove seedlings under the background of sea level rise. The continuous monitoring has been completed in 2023.

水位梯度控制实验系统
Water level gradient control experimental system

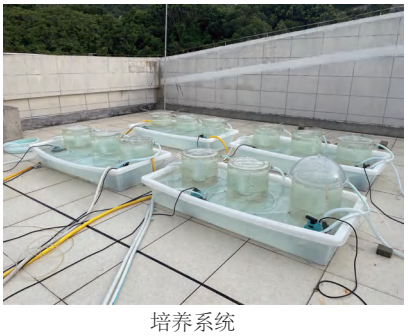
实验现场照片
Photo of experiment

海洋酸化和暖化微尺度控制实验

Microscale control experiment of ocean acidification and warming

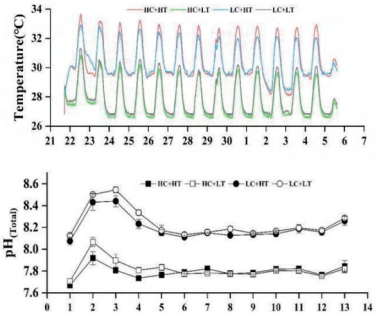
利用东山实验场培养系统和控温系统，通过模拟海洋酸化和暖化，设置仅酸化组、仅暖化组、酸化暖化组3个实验组和1个对照组，研究海洋酸化和暖化会对近海浮游生物的生长和分布以及群落组成产生影响。

The study aimed to investigate the impacts of ocean acidification and warming on the growth, distribution, and community composition of offshore plankton. D-SMART established a culture system and a temperature control system, which could simulate ocean acidification and warming. The system included three experimental groups: an acidification-only group, a warming-only group, an acidification and warming group, and a control group.



培养系统
Culture system

控温设备
Temperature control equipment



培养系统温度控制（上）和酸度控制（下）实验结果
Temperature control (top) and pH control (bottom) outcomes of the culture system

海洋生物声学与仿生实验

Acoustic and biomimetic experiments of marine organisms

该研究结合室内声学实验系统、野外声学实验系统、听觉诱发电位实验系统、珊瑚礁野外监测系统，研究生物发声特性与声感知特性、海洋生态环境变化如何影响生物发声与感知、生物智慧如何启发发展仿生技术。研究发现：大黄鱼发声能量主要集中在 1 kHz以内，且其发声后向能量较强。鼓虾声信号是典型的宽带脉冲信号；鼓虾、大黄鱼，在 80-2000 Hz均具有声感知，鼓虾对 200-600 Hz声刺激最敏感；大黄鱼等石首鱼对 300 Hz声刺激最敏感。

This study integrates an indoor acoustic experiment system, field acoustic experiment system, auditory evoked potential experiment system, and coral reef field monitoring system to investigate the characteristics of biological vocalization and sound perception. It examines how changes in the marine ecological environment impact biological vocalization and perception, and explores how biological intelligence can inspire the development of bionic technology.

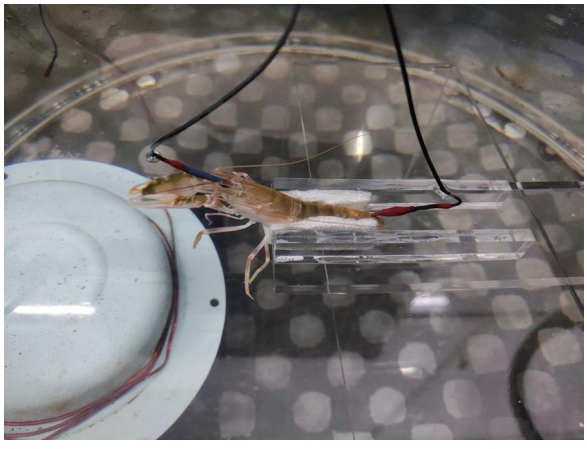
The study reveals that the sound energy emitted by the large yellow croaker is primarily concentrated within the 1 kHz range, with a strong presence of backward sound energy. The detected sound signal exhibits typical broadband pulse characteristics. Both drum shrimp and large yellow croaker demonstrate acoustic sensitivity within the 80-2000 Hz frequency range, with drum shrimp being most responsive to acoustic stimulation in the 200-600 Hz range. Additionally, large yellow croaker and other totoaba species exhibit heightened sensitivity to 300 Hz acoustic stimulation.

室内声学实验系统

Laboratory acoustics experiment system

野外声学实验系统

Field acoustics experiment system



听觉诱发电位实验系统

Auditory evoked potential test system

珊瑚礁野外监测系统

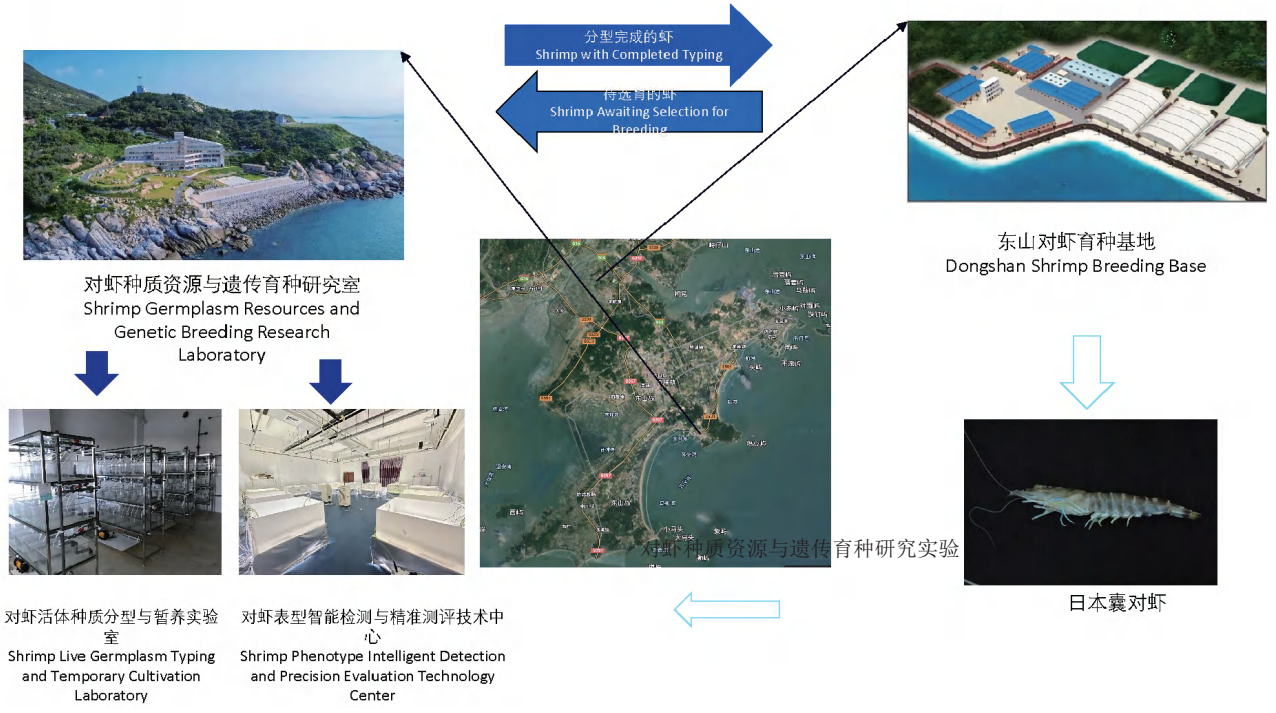
Coral reef field monitoring system

对虾种质资源与遗传育种研究实验

Research on germplasm resources and genetic breeding of shrimp

该研究设有对虾活体种质分型与暂养实验室和对虾表型智能检测与精准测评中心，以日本囊对虾为研究对象，通过多维高通量表型智能测评，对虾依据目标性状进行分型。分型完成后的对虾，送至育种基地培育成下一代亲虾，进而实现该技术在对虾育种中的应用。目前该系统已全面应用于日本囊对虾“闽海2号”耐高温品种选育过程中。

D-SMART established a laboratory dedicated to live germplasm typing and temporary breeding of prawns, along with a center for intelligent detection and precise evaluation of prawn phenotypes. Using multi-dimensional and high-throughput intelligent phenotype evaluation, shrimp *M. Japonica* were classified based on specific traits. Following the typing process, the shrimp were transferred to the breeding base to facilitate the breeding of the next generation of parent shrimp, thus effectively applying this technology in shrimp breeding practices. Currently, the system has been successfully implemented in the breeding program for the high temperature-tolerant variety “Minhai No. 2”.



Research Projects

科研课题

生态敏感地区的可持续发展及其调控机制

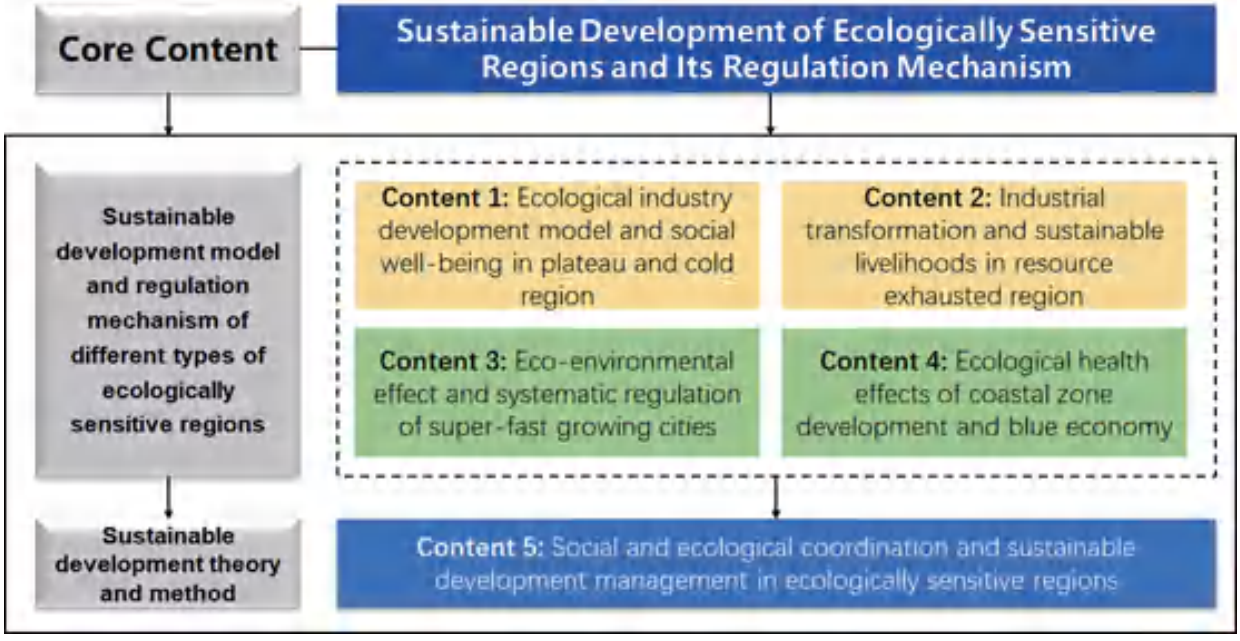
Sustainable Development of Ecologically Sensitive Regions and Its Regulation Mechanism

国家自然科学基金重大项目 2024-2028 | 吕永龙

NSFC Major Project 2024-2028 | Yonglong Lu

项目针对生态敏感地区社会经济发展与自然环境承载能力之间的突出矛盾，面向国家生态文明建设的重大需求和可持续性科学的国际前沿，将围绕“生态敏感地区的可持续发展与调控机制”这一核心主题，聚焦生态敏感地区社会经济与环境耦合关系的演变规律及驱动机制、不同类型开发活动对区域的生态环境影响及其相互作用关系、区域生态对经济社会持续发展的支撑效应及其一体化管理模式三大关键科学问题。通过管理科学、生态学、地理科学、环境经济学等学科的交叉融合，创新社会-经济-自然耦合的区域可持续发展理论体系和定性定量研究方法，探索生态敏感地区人与自然相互作用的科学规律，揭示人类开发活动与区域生态的耦合机制为国家可持续发展议程创新示范区的建设提供重要科技支撑，为全球生态敏感地区的可持续发展模式提供崭新的中国范本。

This project is aiming at solving the pressing contradiction between the socio-economic development and environmental carrying capacity in ecologically sensitive regions, and meeting the major needs of national ecological civilization and the international frontier of sustainability science. It is intended to focus on the theme of “Sustainable Development of Ecologically Sensitive Regions and Its Regulation Mechanism”, with the purpose of tackling three key scientific questions, including the evolution and driving mechanism of the coupling relationship between socio-economy and environment in ecologically sensitive regions, the impacts of different types of human activities on regional ecology and their interaction, and the supporting function of regional ecology in sustainable economic and social development and the integrated management model. To give full play to the advantages of the interdisciplinary interactions of management science, ecology, geography, and environmental economics, it is aimed to innovate the theoretical system and qualitative and quantitative research methods for sustainable development of regional social-economic-natural complex ecosystem. It is also designed to explore the scientific law of human-nature relations in ecologically sensitive regions, reveal the coupling mechanism between human activities and regional ecology, provide important scientific and technological support for the construction of innovation driven demonstration areas for the delivery of sustainable development goals, and provide a new Chinese model for sustainable development of ecologically sensitive regions in the world.



微生物共存网络与主要生态模块

The Structural equation model (SEM)

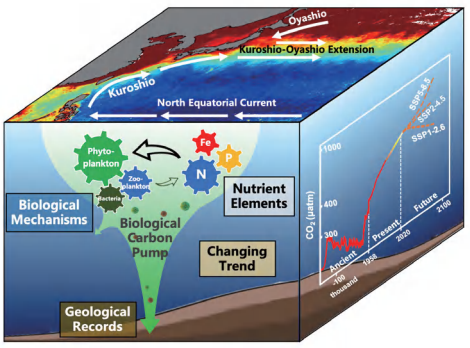
西北太平洋生物碳泵的氮磷铁调控及演变趋势

Nutrient Regulation and Evolution of the Biological Pump in the Western North Pacific

国家重点研发计划 2023-2028 | 史大林

National Key Research and Development Program 2023-2028 | Dalin Shi

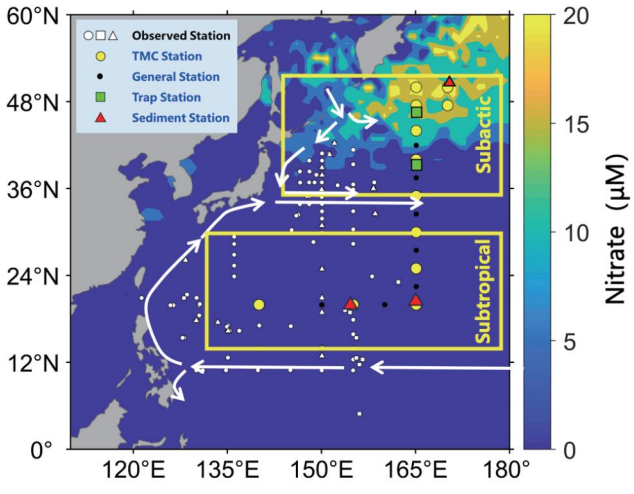
项目针对西北太平洋生物泵固碳和储碳的氮、磷、铁调控及碳汇演变趋势这一重大科学问题，围绕生物碳泵的“物质基础 - 生物机制 - 地质记录 - 演变趋势”的核心主线，以西北太平洋中低纬寡营养盐和中高纬高营养盐海区为研　究区域，从现代过程入手，结合地质记录和未来预测，开展全球变化背景下氮、磷、铁等营养元素对生物泵固碳和储　碳关键过程的调控及其机制和气候效应研究。通过不同时空尺度的比较研究，揭示氮、磷、铁等元素循环的特征，阐　明其对生物泵固碳、储碳关键过程的调控机理；重建古生物泵演变历史，诠释气候变化对其影响，最终评估不同气候　场景下西北太平洋碳汇的演变趋势。



项目框架图

Overview of the Project

This project focuses on the key issue of how essential nutrients such as nitrogen, phosphorus, and iron control the biological carbon pump in the Northwest Pacific, as well as how carbon sinks change under global environmental shifts. Accordingly, a framework of “nutrient elements–biological mechanisms-geological records–changing trend" for the biological carbon pump has been established. Two typical regions (low-latitude oligotrophic and high-latitude eutrophic) in the Northwest Pacific, exhibiting distinct nutrient and ecosystem structures, are chosen as the primary study sites. The project will focus on the modern biogeochemical process, combined with geological records and predictive modeling, to explore the critical processes and mechanisms of the biological pump under global change circumstance. The project aims to reveal the biogeochemical cycle of nitrogen, phosphorus, and iron, their effects on carbon fixation and storage. Additionally, reconstruction of the historical evolution of the paleo-biological pump offers insights into the influence of climate change on the evolution trend of biological carbon pump. Combining the studies of modern and paleo biological pump, carbon sinks in the Northwest Paicific will be assessed by biogeochemical modeling under distinct climatic scenarios.



项目主要研究区域

Selected sites in Northwest Pacific

基于环境基因组的近海生物多样性解析

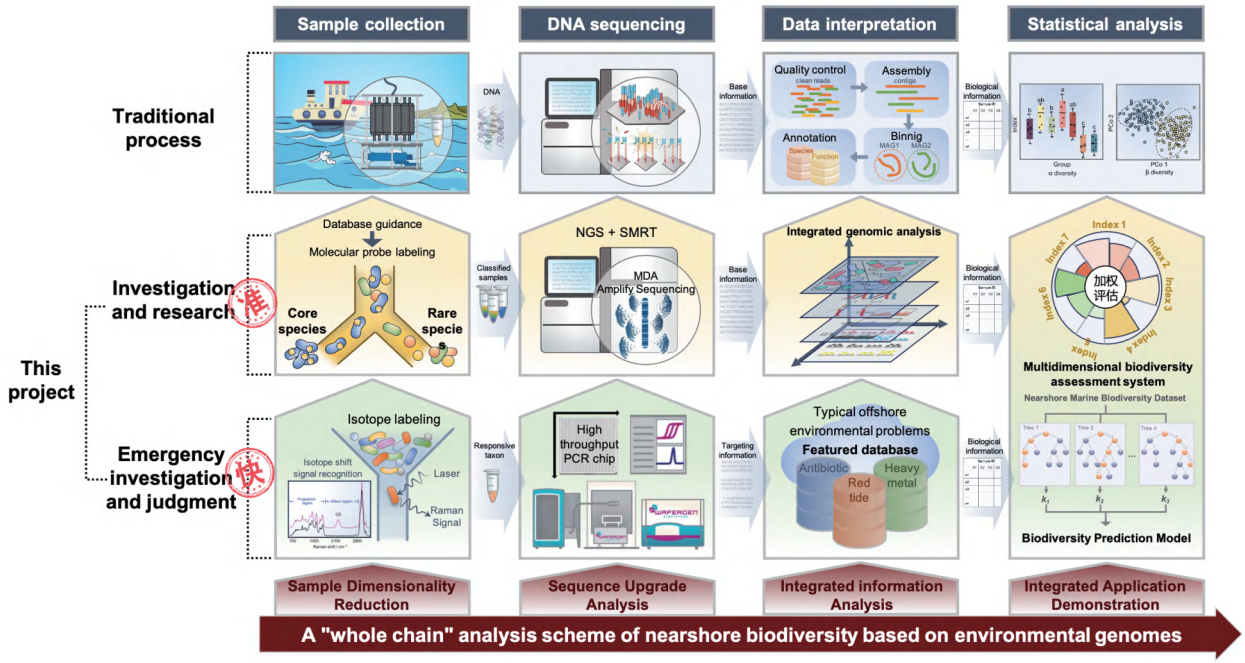
Precision and Rapid Analysis of Nearshore Biodiversity Based on Environmental Genomics

国家重点研发计划青年科学家项目 2023-2026 | 郑越

Young Scientist Project of National Key Research and Development Program 2023-2026 | Yue Zheng

项目针对我国近海生物多样性“精准” 和“快速”解析的两大需求，以近海多重环 境胁迫为研究背景，以环境胁迫下显著响应 的微型生物为研究对象，以生物多样性解析 技术创新为突破口，围绕解析“测序前、中、后”的三大环节，通过样品降维处理、序列升级分析、信息整合解析，研发更准和更快的生物多样性解析技术，发展生物多样性评估新指标和构架预判新模型，最终形成“多场景、全链条、一键式”的近海生物多样性解析方案， 服务于海洋生态环境保障体系的构建和推广 应用，为近海生态环境可持续发展提供技术 支撑。

This project aims to meet the demands for both "precision" and "speed" in analyzing biodiversity in China nearshore. Under the background of multiple environmental stressors in the nearshore, the project focuses on microorganisms with remarkable response to environmental stress and employs innovative biodiversity analysis techniques as a breakthrough. By targeting the three key stages of analysis, namely "pre-sequencing, sequencing, and post-sequencing," the project employs sample dimension reduction, sequence upgrading analysis, and integrated information interpretation. The aim is to develop more accurate and faster biodiversity analysis techniques, create new indicators for biodiversity assessment, construct predictive models, and ultimately establish a "multi-scenario, full-chain, one-click" solution for nearshore biodiversity analysis. This comprehensive approach aims to contribute to the construction and widespread application of marine ecological environmental protection systems, providing technical support for the sustainable development of nearshore ecological environments.



项目的主要研究内容

The main research content of the project

海洋荒漠生物泵固碳机理及增汇潜力

Carbon Fixation and Export in oligotrophic ocean

国家自然科学基金重大项目 2019-2023 | 戴民汉

NSFC Major Project 2019-2023 | Minhan Dai

全球表层海洋面积约30%为低生物量的寡营养海域，通常称为“海洋荒漠”。尽管单位面积的生产力很低，但“海洋荒漠”面积巨大，故而对全球海洋碳汇具有潜在的重要贡献，具有很大的增汇潜力，是全球海洋碳循环的重要环节，但却也是研究最为匮乏的海域，缺乏理论框架。项目聚焦北太平洋副热带流涡区（NPSG），围绕真光层双层结构下海洋荒漠生物泵的物质基础、结构、时空格局、效率及其固碳和增汇潜力，构架寡营养海域生物泵新理论框架，并为海洋荒漠的增汇途径及其有效性提供科学论证。

This project aims to meet the demands for both "precision" and "speed" in analyzing biodiversity in China nearshore. Under the background of multiple environmental stressors in the nearshore, the project focuses on microorganisms with remarkable response to environmental stress and employs innovative biodiversity analysis techniques as a breakthrough. By targeting the three key stages of analysis, namely "pre-sequencing, sequencing, and post-sequencing," the project employs sample dimension reduction, sequence upgrading analysis, and integrated information interpretation. The aim is to develop more accurate and faster biodiversity analysis techniques, create new indicators for biodiversity assessment, construct predictive models, and ultimately establish a "multi-scenario, full-chain, one-click" solution for nearshore biodiversity analysis. This comprehensive approach aims to contribute to the construction and widespread application of marine ecological environmental protection systems, providing technical support for the sustainable development of nearshore ecological environments.

项目实施以来，通过现场观测、遥感反演和数值模　拟等综合手段，在技术方法、数据产品和科学认识等方面取得了一系列进展和突破。本年度的主要发现和成果 如下：

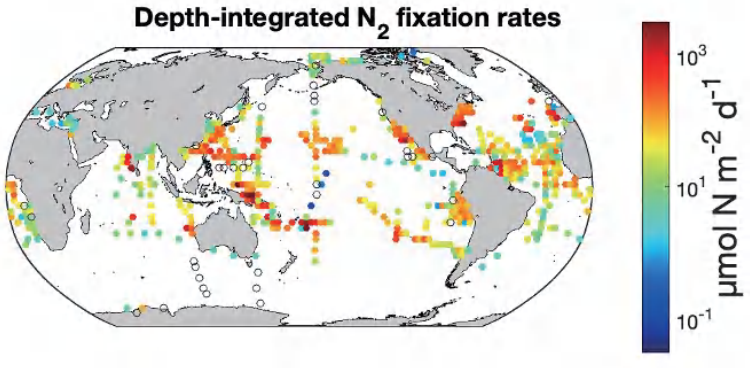
（1）大气沉降是西北太平洋副热带流涡区西南部上 层水体中溶解态铁的最重要输入途径，其输入通量比菲律宾岛屿沉积物贡献高近一个数量级，且比从营养盐充 足层向匮乏层垂向输运的铁通量高约 50 倍；

（2）集成观测数据、全球历史资料及模型预测结果，系统揭示了西北太平洋副热带流涡区生物固氮的时空格局（图 A），首次发现 UCYN-B 是该区域高固氮速率站位的主导固氮生物类群，并阐明其在全球海洋固氮中的重 要性；

（3）结合高分辨率现场观测与遥感数值模型，揭示了西太平洋低纬海域不同流系、特征迥异的物理 - 生物地球化学背景下中尺度涡旋对浮游植物群落空间分布的 调控机制及其主要影响因素（图 B）；

（4）基于 10 台 BGC-Argo 浮标的长期观测数据，提出了光驱动和营养盐驱动的双种群竞争模型，为海洋荒漠寡营养水体中次表层叶绿素极大值深度变化的驱动机 制提供了更合理的解释。

利用放射性 234Th 示踪剂，揭示了西北太平洋副热带 流涡区输出生产力的时空格局，该流涡区的输出生产力存在高度的空间变异性：流涡中心输出通量较低，而在受北赤道流影响的边缘区域则输出较高。



图A. 新版海洋固氮速率（3度空间分辨率）(Shao et al., Earth System Science Data, 2023)

Fig. A N_2 fixation rates in version 2 of the database (3° latitude × 3° longitude bins) (Shao et al., Earth System Science Data, 2023)

By integrating in-situ and remote sensing observations, and numerical simulations, Carbon-FE has been carrying out innovative researches since the launch of the project. The project has achieved a series of breakthroughs in optimization and innovation of methods and techniques, generations of data products, and scientific understanding. We highlight some of the major achievements over the past year as follows:

(1) Atmospheric deposition has been identified as the predominant source of dissolved iron in the upper waters of the southwestern North Pacific Subtropical Gyres (NPSG), with its input fluxes approximately one order of magnitude higher than those from sediment contributions of the Philippine Islands and about 50 times higher than the vertical transport of iron from the nutrient-replete layer to the nutrient-depleted layer.

(2) The spatiotemporal patterns of biological nitrogen fixation in the NPSG has been revealed by integrating observation data, global historical data, and model predictions (Fig. A). For the first time, it was found that UCYN-B dominated the diazotroph community in the high nitrogen-fixing rate stations in this region, highlighting its significance in global marine nitrogen fixation.

(3) The integration of high-resolution field observations and remote sensing numerical models has revealed the mechanisms and main influencing factors of mesoscale eddies on the spatial distribution of phytoplankton communities in the western equatorial Pacific Ocean, within distinct physical-biogeochemical backgrounds of different current systems (Fig. B).

(4) A two-group competition conceptual framework driven by light and nutrients (Fig. 3), built upon long-term observation data from 10 BGC-Argo floats, has been proposed. This provides a more rational explanation for the variations of the depth of sub-surface chlorophyll maximum in oligotrophic waters.

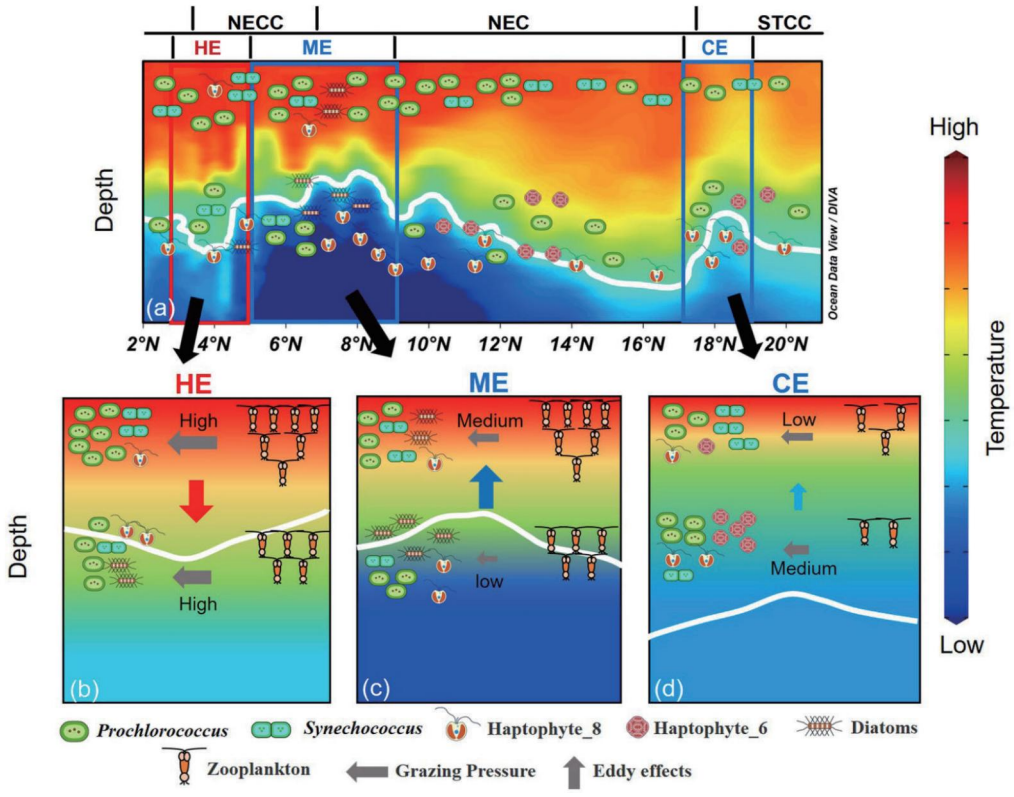


图 B. 130°E剖面(a)和三个中尺度涡旋(b-d)的生物地球化学响应示意图(An et al., Deep Sea Research I, 2023)。
白线表示22°C等温线。灰色、蓝色和红色箭头分别代表微型浮游动物摄食压力、气旋涡旋和反气旋涡旋的影响作用。
Fig. B Schematic diagram of biogeochemical effects in 130°E section (a) and from three mesoscale eddies (b–d)
(An et al., Deep Sea Research Part I: Oceanographic Research Papers, 2023).
White lines represent 22°C isotherm. Gray, blue, and red arrows represent the pressure of microzooplankton grazing, the cyclonic eddies effect and anticyclonic eddy effect respectively.

台湾海峡冬季及初春离岸藻华的锋面不稳定机制研究

Frontal instability induced offshore phytoplankton bloom in winter and early spring Taiwan Strait

国家自然科学基金联合基金重点支持项目 2023-2026 | 江毓武

Key Supported Project of Joint Fund 2023-2026 | Yuwu Jiang

台湾海峡冬季及初春，大陆离岸藻华经常发生，并与沿海峡锋面联系紧密。作为物理海洋学的前沿与热点，锋面 亚中尺度不稳定具有与浮游植物生长一致的时间尺度，同时强化垂向物质输运及水体层化，从而显著调控藻华的发生。

基于此，本项目采用台湾海峡立体监测长时间序列资料、多年现场航次及遥感数据，结合双船同步走航与漂流浮子阵 列实验，通过高分辨率物理生态模型实验、不稳定理论分析等手段，对离岸藻华时空规律和锋面不稳定动力特征及其 藻华调控机制进行深入研究。项目成果将为台湾海峡浮游植物生长繁殖提供新的物理动力学依据，并拓展亚中尺度物 理生态耦合研究前沿，对海洋渔业发展与有害赤潮的预警有重要意义。

项目开展一年来，已取得若干成果：

1）三种类型的漂流浮子海上实验轨迹具有理想的效果；

2）多年现场航次及遥感数据统计分析表明，离岸藻华发生于东北季风松弛期的锋面区域；

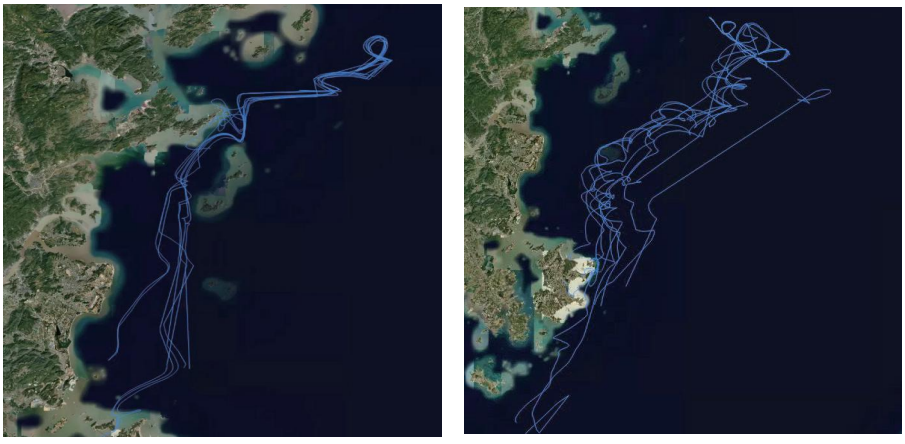
3）台湾海峡高分辨率实际模型诊断结果表明亚中尺度不稳定的再层化作用是促进离岸藻华发生的主因；

4）使用台湾海峡理想模型敏感性实验揭示对称不稳定、中尺度和亚中尺度斜压不稳定对藻华发展的不同贡献；

5）使用理想模型揭示亚中尺度过程对海表高度的影响及其偏度特征。

Off-coast blooms frequently occur in the winter and early spring Taiwan Strait, closed associated with the alongshore front. As a frontier and hotspot in physical oceanography, frontal submesoscale instabilities significantly modulate the occurrence of the blooms due to their consistent timescale as well as the enhancement of vertical transport and stratification of the water column. Based on long-term monitoring data, cruise and satellite data analyses, two-ship synchronous cruises and drifting buoy array experiments, high-resolution physical-biological model experiments, and the instability theory analyses, this project aims at revealing the spatiotemporal characteristics of the blooms, as well as the dynamics of the frontal instabilities and their modulations on the blooms. The study will provide new dynamical explanations of the phytoplankton growth and reproduction in the Taiwan Strait, with expectations of expanding the frontier of submesoscale physical-biological coupling research, and promoting the development of marine fisheries and the warning of harmful algal blooms.

Over the past year, the project has achieved the following progresses: 1) Robust results of the trajectories of three types of drift buoys were obtained from the in situ experiment; 2) Statistical analysis of multi-year cruise and satellite data indicated the blooms occur in the frontal region during the northeasterly monsoon relaxation period; 3) Diagnostics of the high-resolution realistic model suggested the restratification effect of submesoscale baroclinic instability mainly triggers the off-coast blooms; 4) Sensitivity experiments of the idealized model revealed the different contributions of symmetric, mesoscale and submesoscale baroclinic instabilities on the blooms; 5) Idealized model analysis showed the influence of submesoscale process on sea-surface height.



台湾海峡漂流浮标阵列实验初步结果
Preliminary results of the drifting buoy array experiments in the Taiwan Strait

我国近海典型海域浮游生态系统演变、临界点与重构

Tipping points, resilience and reconstructure of plankton ecosystem in typical marine areas of China

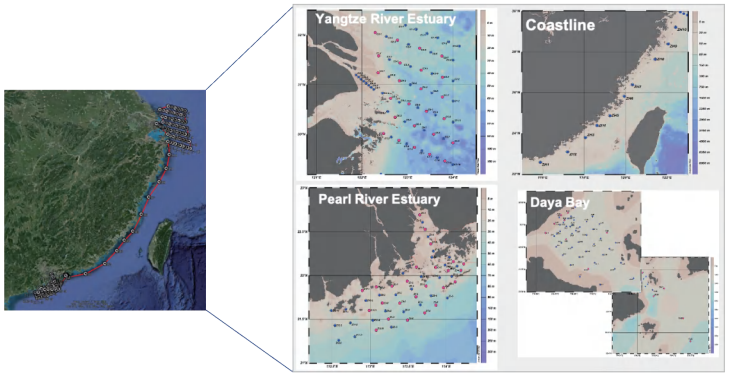
国家重点研发计划 | 2022-2025 王大志

National Key Research and Development Program 2022-2025 | Dazhi Wang

项目执行以来取得了显著进展：1）完成我国近海典型海域浮游生态系统春夏季现场调查；2）收集整理了长江口、珠江口及邻近海域浮游微生物、动植物等近50年的历史数据；3）重建过去百年浮游植物的组成和结构，反演了初级生产力变化特征；4）揭示大亚湾核电温排水海域浮游植物和浮游细菌群落结构变化的温度临界点；5）构建了长江口和珠江口邻近海域的物理-生态系统耦合模式；6）完成长江口和珠江口及邻近海域人为源碳氮磷排放清单编制。

Targeting the core scientific question of "Tipping points, resilience and reconstructure of plankton ecosystem in typical marine areas under co-stresses of human activities and global changes", this project selected the plankton ecosystems in the Yangtze River Estuary, the Pearl River Estuary and adjacent waters that are significantly stressed by human activities and global changes, as the research objects. We will integrate the existing pattern, historical data, sediment records of plankton diversity, and the ecosystem's steady-state transformation in different stressed environments and extreme events, establish the theory and method of characterizing and quantifying the ecosystem's tipping points, evaluate the resilience and restoring ability under multiple environmental stresses, built the theory and method of ecosystem reconstruction, develop the prediction model of ecosystem evolution trend and achieve the application demonstration of intelligent and situational prediction, and put forward management strategies suitable for the coordinated development of China's offshore economy, human health and ecological environment, strengthen the scientific understanding of the tipping points, resilience and restoring ability of plankton ecosystem, and clarify the evolution history, current situation and driving mechanism of planktonic ecosystem under co-stressors of global change and human activities. This project will provide theoretical and methodological supports for formulating biodiversity conservation and climate change strategies, and implementing national strategies such as land and sea integration and carbon neutrality.

Since the implementation of the project one year ago, significant progress was made: 1) conducting on-site investigation of the planktonic ecosystem in typical coastal areas of China during spring and summer; 2) collecting and analyzing the historical data of plankton in the Yangtze River Estuary and Pearl River Estuary over the past 50 years; 3) reconstructing the composition and structure of phytoplankton over the past century, and inverting the characteristics of primary productivity changes; 4) revealing the tipping point of temperature changes in the community structure of phytoplankton and planktonic bacteria in the Daya Bay; 5) constructing the physics-ecosystem coupling model of the Yangtze River Estuary and Pearl River Estuary; 6) completing the preparation of carbon, nitrogen and phosphorus emission inventory of anthropogenic sources in the Yangtze River Estuary and Pearl River Estuary.



Main samples of spring and summer cruises

Samples	Spring	Summer
DO	698	1110
DIC/TA	349	555
DIC-^{13}C	156	360
Inorganic nutrients, urea	670	852
Particulate matter	378	470
Ammonia/nitrate/urea absorption rate and Michaelis parameters	282	282
Fractionated Chlorophyll a	1452	929
Net-phytoplankton	174	362
Water-phytoplankton	367	88
Diversity	1334	1200
Bacterial productivity and respiration	1128	1210
Meta-Omics	136	152

2023年春夏季航次调查海域及采样统计

The investigation areas and sampling statistics in spring and summer 2023

Research Highlights

成果亮点

浮游植物群落对羽流-上升流耦合系统响应研究新进展

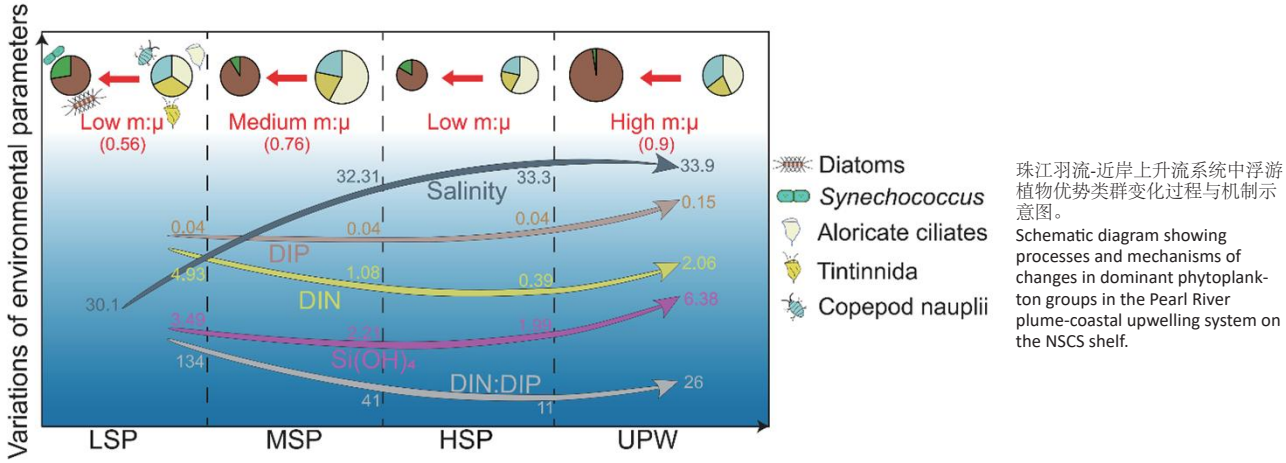
Responses of Phytoplankton Communities to the Effect of Both River Plume and Coastal Upwelling

河流羽流是河流通过河口向外海排放的羽毛状淡水盖，其中富含大量陆源营养盐和颗粒物，为浮游植物提供了光照充足且富含营养的理想生长环境。上升流将营养物质丰富的深层水输送到真光层，从而刺激浮游植物繁殖。早期研究多集中在浮游植物对羽流和上升流响应的独立研究上。近年来的研究表明羽流离岸扩散时会与上升流相遇并产生相互作用，这两种水团的混合在不同程度上促进浮游植物的生长，上升流显著缓解了羽流中的磷限制，增加了羽流中的浮游植物生物量。然而，对于浮游植物生物量和群落组成在羽流-上升流耦合系统中响应过程和机制的研究仍然相当有限。因此，阐明这些过程和机制对于理解浮游植物群落在海洋生态系统结构和功能方面发挥的关键作用是非常必要的。

研究团队在夏季南海北部珠江羽流和近岸上升流影响区域开展观测，采集了浮游植物群落组成、小型浮游动物群落组成和小型浮游动物摄食数据。结果表明，羽流中的浮游植物生物量低于上升流中的浮游植物生物量。硅藻是上升流中唯一的优势类群，而硅藻和聚球藻在羽流中共为优势类群，且二者相对丰度呈负相关，说明他们占据不同的生态位。羽流扩散过程中发生了由磷限制向氮限制的转化，营养限制导致了浮游植物生物量减少。这种上行控制主要作用于硅藻，聚球藻主要受小型浮游动物摄食的下行控制，这种差异导致了羽流-上升流系统中浮游植物优势类群的生态位分化。

本研究证实并扩展了先前关于羽流中营养限制转化导致浮游植物总生物量降低的研究结果，阐明了羽流-上升流系统中浮游植物群落组成的动态变化及其驱动因素。这项研究有助于提升对中尺度物理过程在生物地球化学循环中的重要性的理解。

River plumes and coastal upwelling systems are both nutrient-abundant habitats compared to the open ocean, and the mechanisms that structure the phytoplankton community when these occur together are unclear. In this study we investigated the dynamics and drivers of phytoplankton biomass and community composition in the Pearl River plume-coastal upwelling system on the northern South China Sea shelf during summer. We found that phytoplankton biomass was lower in the plume than in upwelled water. Diatoms were the only dominant group in the upwelled water. In contrast, diatoms and Synechococcus were co-dominant in the plume, and the negative correlation between the proportions of these two groups indicated that they occupied distinct niches. The lower phytoplankton biomass in plume waters was due to nutrient limitation, and there was a transition from limitation by phosphorus to limitation by nitrogen in the plume along its path. This bottom-up control limited only diatoms, whereas Synechococcus was limited mainly by top-down control via microzooplankton grazing. This difference led to niche differentiation of the dominant phytoplankton groups in the plume-upwelling system. This discovery of niche differentiation enhances understanding of food web structure and will facilitate modeling of marine biogeochemical cycles.



珠江羽流-近岸上升流系统中浮游植物优势类群变化过程与机制示意图。

Schematic diagram showing processes and mechanisms of changes in dominant phytoplankton groups in the Pearl River plume-coastal upwelling system on the NSCS shelf.

以上工作于2023年10月发表于*JOURNAL OF GEOPHYSICAL RESEARCH: BIOGEOSCIENCES*期刊，博士生佟竺殷为第一作者，肖武鹏副教授和王磊研究员为共同通讯作者。

Reference： Tong Z., Ma L., Cai S.,Wang L., Xiao W., Huang B., Laws E. Responses of phytoplankton communities to the effect of both river plume and coastal upwelling. *JOURNAL OF GEOPHYSICAL RESEARCH: BIOGEOSCIENCES*. 2023. 128. e2023JG007486.

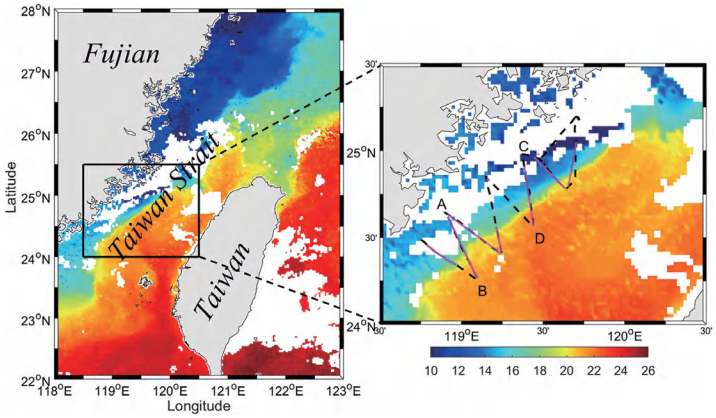
台湾海峡锋面区温盐补偿的尺度依赖性

Scale-dependent temperature-salinity compensation in frontal regions of the Taiwan Strait

某一深度的海水密度大小是由该深度的海水温度和盐度大小共同决定的。当海水温度和盐度各自的变化对密度变化的贡献相互抵消时，该现象称为温盐补偿。冬春季节，台湾海峡盛行东北季风，大陆沿岸存在向西南方向流动的浙闽沿岸流，其水体呈冷而淡的特征；海峡中部存在一支向东北方向流动、携带暖而咸海水的海流。这两支海流相遇，在台湾海峡形成了显著的温盐锋面。显然，锋面两侧水体均存在温盐相互补偿的特征。研究团队于2019年春季在台湾海峡开展了高分辨率的跨锋面拖曳现场观测，旨在厘清台湾海峡锋面区的温盐补偿特征及其尺度依赖性。

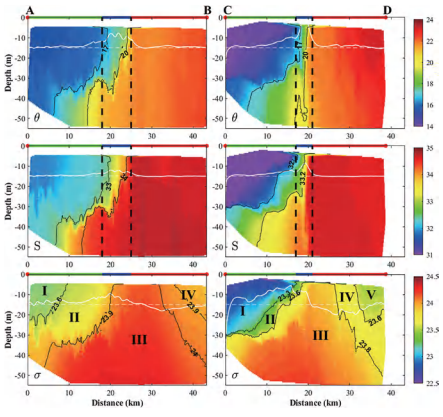
拖曳观测结果清晰揭示了台湾海峡存在的温度锋面及盐度锋面，二者位置也几乎重叠。与单一温度或盐度锋面不同的是，交汇区存在两个垂向倾斜的密度锋面，使得跨锋面断面的等密线呈锥形分布。分析表明，西侧密度锋面水体为盐度主控型，而东侧密度锋面水体为温度主控型，而交汇区水体的温度和盐度则接近完全补偿。进一步的尺度依赖性分析表明，从O（10km）到O（1km）温盐补偿程度在盐度主控型锋面区提高，而在温度主控型锋面区则降低。具体来说，由亚中尺度不稳定诱导的次级翻转环流将混合层内较陡的等密面放平，使得观测断面两端的混合层均变浅。在相同的海表冷却条件下，更浅的混合层会经历更大的降温，而这将使原本处于盐度主控型水体的温盐补偿性在亚中尺度不稳定发生的尺度上提高，但使原本就属于温度主控型水体的温盐补偿性进一步降低。

Based on high-resolution, cross-frontal towed measurements, this study investigates temperature-salinity (T-S) compensation and its scale dependence in the Taiwan Strait. In winter and spring when the northeasterly monsoon is prevailing, colder and fresher waters flow southward along the coast of the Chinese mainland, which encounter the northward-flowing, warmer and saltier waters in the Taiwan Strait. Two slanted density fronts are generated across the interfacing zone forming a cone-shaped isopycnal distribution in the cross-frontal direction. Analyses based on the density ratio and Turner angle suggest the expected S-dominated and T-dominated types of density variations at the western and eastern density fronts, respectively. Exact T-S compensation is observed within the interfacing zone. Analysis of the scale dependence indicates that temperature and salinity get more (less) compensated from O(10 km) to O(1 km) scale in the S-dominated (T-dominated) frontal zone. Although contrasting density compensating features are observed on the two flanks of the transition zone, they can both be interpreted by the restratification-cooling mechanism. Specifically, the overturning cells due to submesoscale instabilities in the upper mixed layer slump isopycnals in the frontal zone, inducing shoaling of the mixed layer at both ends of the sampled sections. Surface cooling results in larger temperature drops in the shallower mixed layers, and thus increases (decreases) the degree of T-S compensation in the S-dominated (T-dominated) frontal zone at the scale for submesoscale instabilities to develop.



2019年3月10-11日台湾海峡海表温度图与叠加现场观测船行轨迹（黑色虚线）及拖曳观测位置（玫红线）。

(Left) Map of the Himawari 8-based sea surface temperature (SST) (in °C) on 10–11 March 2019 in the vicinity of Taiwan Strait. (Right) Zoom-in version of SST in the Taiwan Strait superimposed with the ship trajectories (black dashed lines) and locations where towed measurements were conducted (magenta lines).



基于拖曳观测得到的断面AB（左）和CD（右）的位温（上）、盐度（中）及位密（下）断面分布图

Sectional distribution of the (top) potential temperature (middle) salinity (S) and (bottom) potential density across sections (left) AB and CD.

以上工作于2023年发表于*JOURNAL OF GEOPHYSICAL RESEARCH: OCEANS*期刊，林宏阳副教授为第一作者，刘志宇教授为通讯作者。

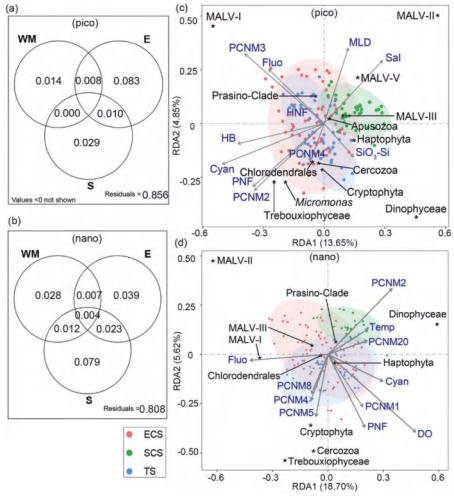
Reference：Lin H., Xu S., Liu Z.*, Hu J.*, Zhang F., and Cao Z. Scale-dependent temperature-salinity compensation in frontal regions of the Taiwan Strait. *JOURNAL OF GEOPHYSICAL RESEARCH: OCEANS*. 2023. 128(2):e2022JC019134.

水团驱动下多重生态效应决定了中国近海亚热带-热带海区微型鞭毛虫群落的生物多样性和生物地理分布格局

Water mass-driven multiple ecological effects determine the biodiversity and community assembly of microbial flagellates in subtropic-tropic marginal seas in China

海洋微型鞭毛虫是海洋微食物环的重要组成部分，在维持生态系统结构和功能方面起着重要作用。在地理范围的尺度上（~2000km）开展微生物群落的生物地理研究至关重要，这是由于具有空间异质性和水文条件差异的不同水团会在该尺度上发生混合，从而塑造了微生物群落的生物多样性和时空分布格局。然而，以往研究大多局限于某一局域范围的海域，对地理尺度上形成海洋微型鞭毛虫群落的生物地理过程和生态效应仍不清楚，尤其缺乏由水团带来的环境梯度和空间效应对微型鞭毛虫群落构建影响的探讨。

研究团队在中国3个亚热带-热带边缘海域采集了nano（2-20 μm）和pico（0.8-2 μm）两个粒级的微型鞭毛虫群落样本，对其18S rRNA基因V4区进行高通量测序。结果表明，微型鞭毛虫群落的多样性大致呈现随离岸距离的增加而增大的趋势（图1）。研究区域微型鞭毛虫的生物地理分布是非随机的，受到环境选择、扩散限制、中性过程和群落内生物相互作用等多种生态过程的共同影响。这些生态过程由地理尺度上形成的复杂水团所驱动，不同过程对群落构建的相对重要性也随着空间尺度、细胞粒级大小和采样季节的不同而发生变化。例如，环境异质性是影响3个局域海区微型鞭毛虫群落构建的主要因素，而空间因子的重要性随着空间尺度的增加而增大。这种效应在nano粒级微型鞭毛虫群落中更为明显（图2），这可能是由于其细胞粒级较大而受到较强的扩散限制作用。此外，群落内部生物相互关系在地理尺度上的作用也明显弱于局域尺度。在季节上，由于水团的复杂性和多向性增强了环境异质性，群落生物共现网络在春季比在夏秋季更加紧密。



水团（WM）、环境因子（E）和空间因子（S）在地理尺度上微微型（a）和微型（b）鞭毛虫群落构建过程中的相对贡献以及影响几种优势类群生物地理分布的重要因子（相对丰度在全部样本中大于0.5%的为优势类群）（Mg DW ha^{-1} y^{-1}）
Variation partitioning analyses (VPA) show the contributions of water masses (WM), environmental variables (E), and geographic distance (S) on the community structure of pico-sized (a) and nano-sized (b) microbial flagellate in the geographical scale; Redundancy analyses (RDA) show the compositions of pico-sized (c) and nano-sized (d) microbial flagellate communities in relation to significant ($p < 0.01$) environmental and spatial (PCNM) variables.

Marine microbial flagellates form an important part of marine ecosystems, and play an essential role in maintaining ecosystem functions. However, the underlying biogeographic processes and ecological effects that shape marine microbial flagellate communities (MFCs) on the geographical scale (~ 2,000 km) remain unclear, especially how their composition is related to movements of water masses. In this study, high-throughput sequencing of 18S rRNA genes was conducted to survey two size-fractioned groups (0.8–2.0 μm for pico-sized and 2.0–20 μm for nano-sized groups) of MFCs in three subtropic-tropic marginal seas of China. In addition, the impacts of environmental factors, spatial factors, and water masses on MFCs were explored and compared across different spatiotemporal conditions. The results demonstrate non-random biogeographic distributions of MFCs in the studied area. These distributions were affected by several ecological processes, such as environmental selection, dispersal limitation, neutral process, and interactions within communities. These processes were driven by complex water masses that formed on a geographical scale. Notably, environmental heterogeneity was identified as the principal determinant of MFCs in each sea area. However, the importance of spatial factors increased with the spatial scale, which weakened biotic interactions within the community on a geographical scale. This effect was more apparent in nano-sized MFCs, indicating stronger dispersal limitation because of their larger cells and weaker dispersal ability. In summary, this study expands the available knowledge on the dynamic biogeographic patterns of MFCs associated with water masses on a geographical scale where strong spatial and environmental gradients exist.

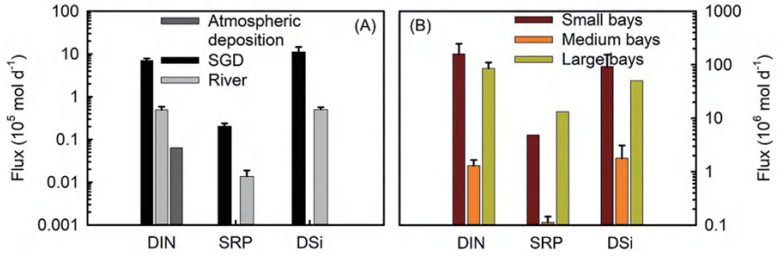
以上工作于2023年11月发表于*ESTUARINE, COASTAL AND SHELFSCIENCE*期刊，博士后郭馨为第一作者，黄凌风教授为通讯作者。

Reference：Guo X., Liu Q., Lin X., Zheng X., Huang C., Pang M., Huang L. Water mass-driven multiple ecological effects determine the biodiversity and community assembly of microbial flagellates in subtropic-tropic marginal seas of China. *ESTUARINE. COASTAL AND SHELFSCIENCE*. 2023. 280: 108166.

海底地下水排放主控东山湾春季营养盐的输入和分布以及小型海湾的研究意义

Submarine groundwater discharge in Dongshan Bay, China: a master regulator of nutrients in spring and potential national significance of small bays

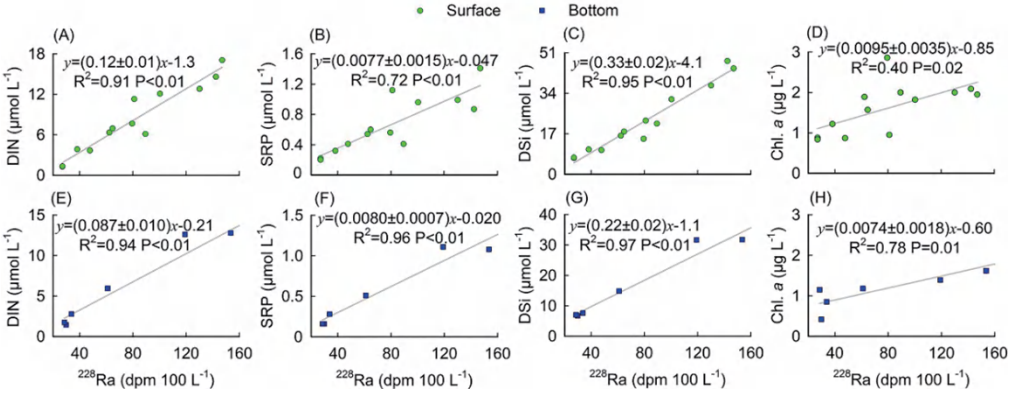
海底地下水排放（submarine groundwater discharge，SGD）是造成近岸海域富营养化的重要推手之一。尽管中国沿岸90%的海湾面积不足500km²，SGD对这些小型海湾的营养盐含量、分布以及生物地球化学循环的影响尚未明确。研究团队以长半衰期镭同位素（^{226}Ra和^{228}Ra）作为示踪剂，基于大面观测和定点连续观测数据建立质量平衡模型，估算出2020年5月SGD向东山湾输入的溶解无机氮（DIN）、磷（SRP）、硅（DSi）净通量比漳江输入和大气沉降分别高出一至两个数量级，是东山湾最主要的营养盐来源。同时，东山湾内^{228}Ra活度和营养盐浓度以及叶绿素（Chl.a）浓度之间存在显著的正相关关系（P<0.05）。推测SGD可通过控制营养盐的输入和分布调节东山湾浮游植物的生物量。在定点站位，^{228}Ra活度的最高值和Chl. a浓度的最高值协同出现，再次确证SGD对湾内浮游植物生物量的调控作用。最后，对中国沿岸海湾进行k-means聚类分析。结合文献，估算得到小型海湾对整个中国沿岸SGD营养盐通量的贡献超过50%，加强小型海湾的调查对于提高大空间尺度SGD营养盐通量估计的准确性至关重要。



（A）SGD、河水以及大气沉降向东山湾输入的营养盐通量；（B）中国沿岸大型、中型以及小型海湾的SGD输入的营养盐通量汇总

(A) The nutrient fluxes carried by SGD, the Zhangjiang River, and atmospheric deposition in Dongshan Bay; (B) The SGD-associated nutrient fluxes in small bays, medium bays, and large bays along the entire Chinese coast

Despite over 90% of China's coastal bays have an area less than 500 km², the geochemical effects of SGD on those ecosystems are ambiguous. Based on mapping and time-series observations of Ra isotopes and nutrients, a case study of small bays (<500 km²), we revealed that submarine groundwater discharge (SGD) predominately regulated the distribution of nutrients and fueled algal growth in Dongshan Bay, China. On the bay-wide scale, the SGD rate was estimated to be 0.048 ± 0.022 m day^{-1} and contributed over 95% of the nutrients. At the time-series site where the bay-wide highest Ra activities in the bottom water marked an SGD hotspot with an average rate an order of magnitude greater, the maximum chlorophyll concentration co-occurred, suggesting that SGD may support the algal bloom. The ever-most significant positive correlations between ^{228}Ra and nutrients throughout the water column (P< 0.01, R^2 > 0.90 except for soluble reactive phosphorus in the surface) suggested the predominance of SGD in controlling nutrient distribution in the bay. Extrapolated to a national scale, the SGD-carried dissolved inorganic nitrogen flux in small bays was twice as much as those in large bays (>2,000 km²). Thus, the SGD-carried nutrients in small bays merit immediate attention in environmental monitoring and management.



东山湾内^{228}Ra和DIN、SRP、DSi以及Chl.a之间的关系。（A-D）表层水；（E-H）底层水

Relationships between Ra and DIN, SRP, DSi and Chl. a in Dongshan Bay. (A-D) Surface water; (E-H) bottom water

以上工作于2023年3月发表于*FRONTIERS IN MARINE SCIENCE*期刊，硕士生孙亚飞为第一作者，王桂芝教授为通讯作者。

Reference：Sun, Y., Wang G., Weng Y., Li, Q., Zhang F., Jiang W., Dai G., Lin W., Sun S., Jiang Y., Zhang Y. Submarine groundwater discharge in Dongshan Bay, China: a master regulator of nutrients in spring and potential national significance of small bays. *FRONTIERS IN MARINE SCIENCE*. 2023. 10:1164589

基于智能手机的便携式pH分析——手机上的海洋酸化观测系统

Toward Citizen Science-Based Ocean Acidification Observations Using Smartphone Devices

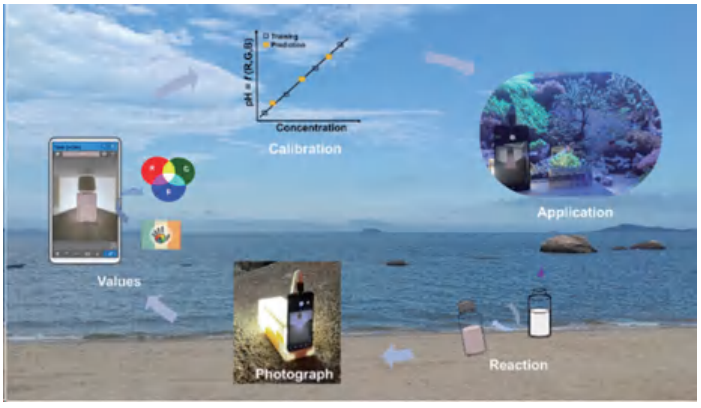
海洋pH值是影响海水碳酸盐体系的重要变量。近期，海洋pH值被世界气象组织宣布为气候指标，并被联合国大会确定为可持续发展目标指标。

全球海洋酸化的研究和全球观测网的精确测量要求，不仅是对海水pH测量技术的考验，更是对传统分析方法的挑战。尤其是对pH值变化较大的沿海水域，既要求满足全球海洋酸化观测网“天气”目标的精度（pH不确定度小于0.02），还需实现现场快速测量。传统的台式分光光度法因仪器体积较大，不便用于现场测定，而便携的电极法仪器又精度不足。因此，开发简单便携的pH测量技术，发挥公民科学在环境监测和研究中的作用，将有助于实现对沿海地区的广泛动态监测。

公民科学项目的成功将依赖于轻巧、便携和低成本的技术，以及对科学、有效、准确的实测数据的收集能力。随着智能手机质量和性能的不断提高，其所展现出的先进成像和处理技术能够满足上述要求，为开发可靠、可广泛获取和低成本的分析工具提供了新的机会。目前，许多研究通过建立图像颜色信息与分析物之间的关系，直接基于智能手机获取的图像分析测量分析物浓度，简化设备的分析要求，使智能手机成为分析测定的主要工具。该领域取得了较大进展，但基于智能手机的高精度pH测量仍然存在挑战。

在前期工作中，研究团队开发了一种基于智能手机的多功能环境分析仪（vSEA），并成功用于营养盐的现场测定。本研究在此基础上进一步拓展，将vSEA系统推广至海水pH的快速测量，建了一种基于智能手机的便携式海水pH现场快速检测装置vSEA-pH，具有成本低、简单、精度高的优点，适用于公民科学和教育应用。易于操作的vSEA系统为非专业人员参与科学研究提供了机会，促进了公民科学的实施，为全球海洋酸化的监测和研究提供技术支撑。

pH is a key parameter in many chemical, biological, and biogeochemical processes, making it a fundamental aspect of environmental monitoring. Rapid and accurate seawater pH measurements are essential for effective ocean observation and acidification investigations, resulting in the need for novel solutions that allow robust, precise, and affordable pH monitoring. In this study, a versatile smartphone-based environmental analyzer (vSEA) was used for the rapid measurement of seawater pH in a field study. The feasibility of the use of the vSEA algorithm for pH quantification was explored and verified. When used in conjunction with a three-dimensional (3D)-printed light-proof shell, the quality of captured images is guaranteed. The quantitative accuracy of vSEA pH measurements reached 0.018 units with an uncertainty of <0.01, meeting the requirements of the Global Ocean Acidification Observing Network (GOA-ON) for “weather” goals (permitting a maximum pH uncertainty of 0.02). The vSEA–pH system was successfully applied for on-site pH measurements in coastal seawater and coral systems. The performance of the vSEA–pH system was validated using different real-world samples, and t-test results showed that the vSEA–pH system was consistent with pH measurements obtained using a state-of-the-art benchtop spectrophotometer ($t = 1.986$, $p = 0.7949$). The vSEA–pH system is applicable to different types of smartphone devices, making it possible for vSEA–pH to be widely promoted for public citizen use. The vSEA–pH system offers a simple, accurate, and applicable method for the on-site measurement of seawater pH, assisting the large-scale monitoring of ocean acidification by allowing the contribution of citizen science-based data collection.



基于智能手机的便携式pH分析系统

Ocean Acidification Observations Using Smartphone Devices

以上工作于2023年发表于*ANALYTICAL CHEMISTRY*期刊，博士生李杭茜为第一作者，马剑教授为通讯作者。

Reference： Li H., Zheng S., Tan Q-G., Zhan L., Martz T., Ma J. Toward Citizen Science-Based Ocean Acidification Observations Using Smartphone Devices. *ANALYTICAL CHEMISTRY*. 2023. 95. 41. 15409-15417.

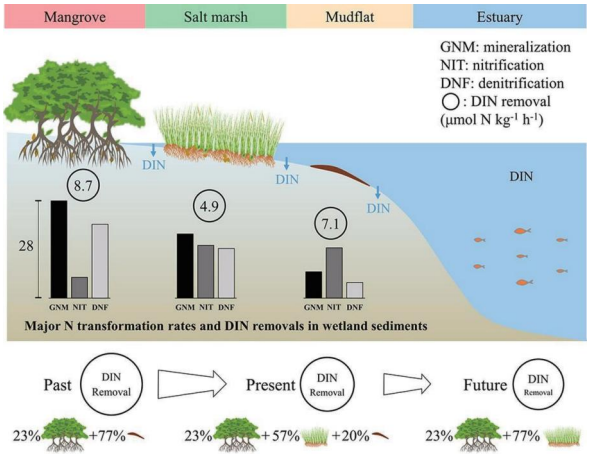
盐沼扩张导致河口红树林湿地沉积物的脱氮能力下降

Salt marsh expansion into estuarine mangrove mudflats reduces nitrogen removal capacity

我国南方滨海湿地普遍存在盐沼（互花米草）入侵或扩张现象。互花米草由于具有较高的耐盐和耐缺氧能力、较强的繁殖和竞争力等特性，可扩张进入原生红树林湿地系统，从而形成红树林-盐沼生态交错带（如福建漳江口湿地）。人类活动增加了营养物质的向海输送量，红树林湿地常被认为是氮汇，可通过沉积物中反硝化和厌氧氨氧化过程将水中无机氮转化为氮气，有利于降低氮污染导致的近海富营养化风险。然而，目前对于盐沼扩张对原有红树林湿地系统氮循环过程，特别是对沉积物的脱氮能力（本研究定义为：无机氮产生过程与消耗过程速率之差，即氮的净累积或净去除量）及水质净化功能的影响，尚缺乏针对性研究。

本研究依托福建台湾海峡海洋生态系统国家野外科学观测研究站于2020-2021年春夏秋冬四个季节在红树林、盐沼和滩涂三个区域采集约50cm深的柱状沉积物，利用15N同位素示踪技术开展室内培养实验，定量氮的矿化、同化、硝化、反硝化、厌氧氨氧化和异化还原等沉积物主要氮循环过程的转化速率，结合氮功能基因分析、情景模拟分析等结果进行综合研究。结果表明：（1）矿化、同化、硝化和反硝化是三个湿地区域沉积物主要的氮转化过程；（2）与红树林沉积物相比，盐沼沉积物有较弱的矿化和反硝化过程、较强的硝化过程；滩涂沉积物硝化速率与盐沼接近，而矿化和反硝化速率在三个区域沉积物中最小。沉积物中碳氮底物浓度、有机碳组分、功能基因丰度是氮转化过程的主要控制因子；（3）盐沼扩张会潜在降低红树林湿地沉积物的脱氮能力；（4）进一步基于未来盐沼扩张情景模拟分析发现，假设未来盐沼覆盖面积持续增加，整个漳江口红树林湿地沉积物的脱氮能力将呈现降低趋势。此外，互花米草治理等生态修复工程如何影响湿地碳氮循环有待进一步深入研究。

Salt marsh (*Spartina alterniflora*) has been rapidly encroaching into mangrove wetlands worldwide. However, the potential effects of salt marsh expansion on coastal nitrogen cycling and ecosystem function remain unclear. In this study, sediment cores were seasonally collected from mangroves, salt marshes and mudflats from 2020 to 2021 to assess their nitrogen cycling. Nitrogen transformation rates of mineralization, immobilization, nitrification, denitrification, anaerobic ammonium oxidization (anammox), and dissimilatory nitrate reduction to ammonium (DNRA) were determined using 15N isotope tracer techniques. Rate measurements were paired with analysis of physicochemical properties, carbon isotopes, and nitrogen functional genes. The results showed that compared to mangrove sediments, salt marsh sediments mostly exhibited lower mineralization and denitrification rates but higher nitrification rates. Mudflat sediments had the lowest mineralization and denitrification rates among the studied habitats, while the nitrification rates were close to those of salt marshes. The differences in carbon quantity and source, nitrogen gene abundances, and carbon and nitrogen substrate availabilities controlled the variations in nitrogen transformation rates. The balance of these rates was used to indicate the net nitrogen retention or removal capacity of the three habitats. On an annual scale, salt marshes exhibited ammonium (NH_4^+-N) removal while mangroves had net NH_4^+-N retention. Nitrate (NO_3^--N) was removed both in salt marsh and mangrove sediments with larger removal capacity in mangroves. Salt marsh sediments had lower NH_4^+-N removal but higher NO_3^--N removal levels than mudflat sediments. In summary, salt marsh invasion decreased the overall nitrogen removal levels in the mangrove-mudflat wetland. The future scenarios of increasing salt marsh coverage suggest a decreased removal of nitrogen loads, which has important implications for mitigating coastal eutrophication.



盐沼扩张对河口红树林湿地沉积物氮转化及脱氮能力的影响

Impact of salt marsh expansion into estuarine mangrove mudflats

以上工作于2023年8月发表于*Catena*期刊，博士生王芬芳为第一作者，陈能汪教授为通讯作者。

Reference： Wang F., Lu Z., Tobias C., Wang Y., Xiao K., Yu Q., Lin J., Huang G., Chen N. Salt marsh expansion into estuarine mangrove mudflats reduces nitrogen removal capacity. *Catena*. 2023. 232： 107459.

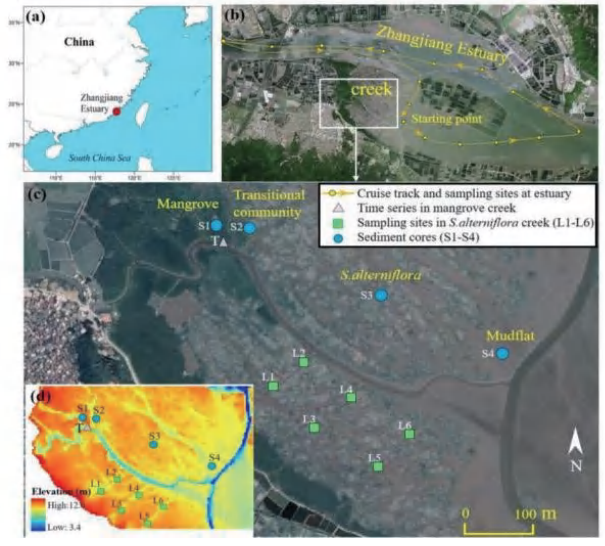
盐沼入侵降低红树林湿地惰性碳库但增大无机碳的横向输出

Salt marsh invasion reduces recalcitrant organic carbon pool while increases lateral export of dissolved inorganic carbon in a subtropical mangrove wetland

红树林是海岸带重要的“蓝碳”生态系统之一，拥有极高的固碳与储碳“超能力”。我国南方滨海湿地普遍存在互花米草入侵红树林湿地现象。截至目前，关于互花米草入侵如何改变红树林湿地沉积物碳循环形态和无机碳横向输出，还缺乏清晰的认识。

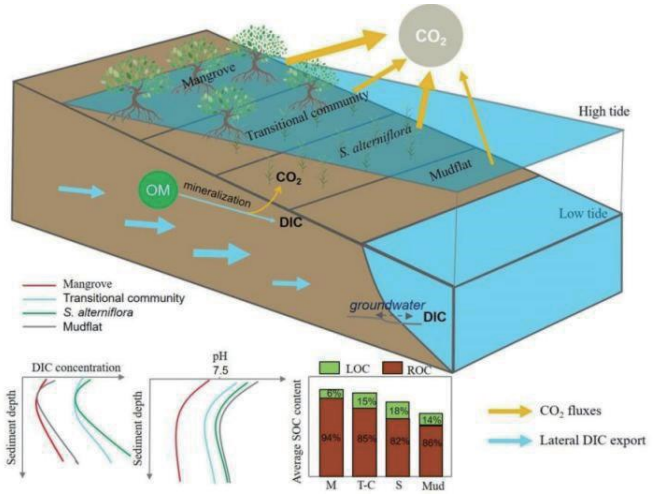
本研究依托福建台湾海峡海洋生态系统国家野外科学观测研究站通过2020-2021年不同季节湿地潮沟与河口表层水的大面观测以及沉积物剖面的精细观测，综合应用同位素示踪技术、培养实验和多学科方法进行定量分析，结果表明：（1）与红树林生境相比，互花米草入侵区域的沉积物中活性有机碳的含量增加，但惰性碳的占比降低；（2）来自互花米草植被的有机碳主要集中在表层沉积物且多为活性有机碳（79%），而来自红树林植被的有机碳则有相对更多的惰性有机碳（25%-36%），说明红树林湿地更有利于碳的长期埋藏；（3）互花米草生境碱性的沉积物环境和更多的活性有机碳输入，使得沉积物孔隙水中含有更高浓度的溶解性无机碳，互花米草入侵原生红树林湿地，大大增加了这类滨海湿地无机碳的横向输出。该研究初步揭示了互花米草入侵对红树林湿地沉积物碳形态和无机碳横向输出的影响机制，可为滨海湿地生态修复与增汇路径选择提供科学依据。

Mangrove wetlands are one of the most productive ecosystems and store large amounts of organic carbon (blue carbon). However, mangrove wetlands have been invaded by *S. alterniflora*-dominated salt marsh globally, the understanding of how this ecological invasion affects carbon cycling in mangroves remains limited. In this study, we conducted intensive investigations and measurements in a subtropical mangrove wetland (S.E. China) to evaluate the impacts of *S. alterniflora* invasion on sediment organic carbon (SOC) pools, sources, stability, and dissolved inorganic carbon (DIC) export. Results showed that *S. alterniflora* invasion increased sediment labile organic carbon (LOC) content and decreased the proportion of recalcitrant organic carbon (ROC) compared with other habitats (e.g., mudflat, mangrove, and marsh-mangrove transitional community). The $\delta^{13}C$ values showed that mangroves can provide more SOC and ROC than *S. alterniflora*. The SOC provided by *S. alterniflora* mostly consisted of LOC, which was unstable and easily transformed, leading to the higher anaerobic mineralization rate and CO_2 production. Different from the acidic environment of mangrove sediment, the alkaline environment of *S. alterniflora* sediment preserves more CO_2 in the form of DIC in porewater, which could be transported during the movement of tides. Thus, *S. alterniflora* potentially exported more DIC to the estuary than mangroves. These findings suggested that *S. alterniflora*-dominated salt marsh invasion can substantially perturb the mangrove wetlands by reducing ROC pool and potentially increasing the lateral export of DIC.



漳江口红树林-盐沼-河口系统水与沉积物采样站位布设

Map of study areas in Fujian Province, China (a), sampling sites along Zhangjiang Estuary (b), sampling sites around a main tidal creek (c) and the relative surface elevation (d) in Yunxiao National Mangrove Reserve



互花米草入侵红树林湿地对不同生境沉积物碳形态和无机碳横向输出影响

Schematic model showing various SOC pools and lateral DIC export in different habitats including mangrove (M), transitional community (T-C), *S. alterniflora* (S) and mudflat (Mud)

以上工作于2023年9月发表于*Geoderma*期刊，博士生路则洋为第一作者，陈能汪教授为通讯作者。

Reference： Lu Z., Xiao K., Wang F., Wang Y., Yu Q., Chen, N. Salt marsh invasion reduces recalcitrant organic carbon pool while increases lateral export of dissolved inorganic carbon in a subtropical mangrove wetland. *Geoderma*. 2023. 437:116573.

全球性入侵植物互花米草入侵和原产种群的性状间相关性存在明显差异

Altered trait covariances between invasive and native ranges of a global plant invader

越来越多的研究证据表明入侵种群能够快速适应新的环境，快速适应新环境的能力取决于可遗传的性状变异和性状间的相关性。然而，针对入侵种群和原产种群性状间相关性的研究仍然十分有限。此类研究不仅有助于全面解析历史因素和适应进化如何塑造外来入侵物种的入侵能力，还有助于预测未来的入侵动态。

本研究发现，低纬度同质园中的植株比在高纬度同质园中开花更早，长得更矮小，结实更少，并且植株的生长和遗传表达的水平可能受到了高温的限制。因此只有在高纬度同质园中，入侵地和原产地种群的首开花时间才都显示出渐变群格局，但植株高度和种子结实率只在原产地或入侵地种群中显示出渐变群格局。原产地种群的首开花时间和植株高度间存在负相关关系，但在入侵地种群中则不存在相关性；入侵地种群的首开花时间和结实率间存在负相关关系，但在原产地种群中则不存在相关性。

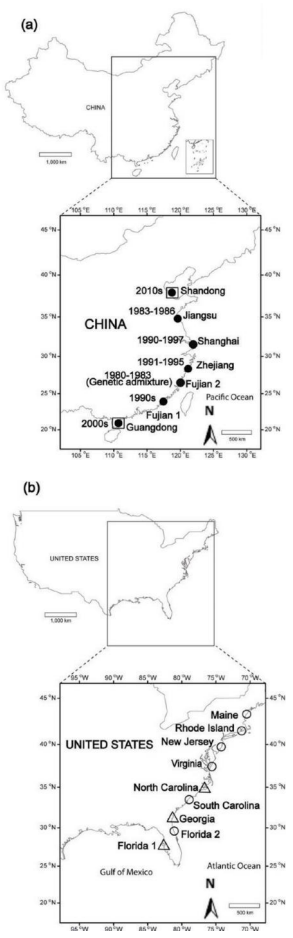
以上结果表明，在40年的入侵过程中，互花米草经历了对局域环境条件的快速适应。这种地理尺度的快速适应很可能得益于此前已被证实的遗传混合，这种遗传混合解除了性状间的相关性。同时该研究强调将完整地理分布范围的调查与引种历史相结合的重要性，这样的调查有助于理解入侵过程中性状进化的潜力和机制。

Increasing evidence suggests that invasive populations adapt to the novel environments rapidly, and the ability of rapid adaptation depends on genetically-based trait variation and covariation. However, few studies have investigated the trait covariance in the native and invasive ranges. Such investigation will give a more comprehensive picture of how historical contingency and adaptation shape invasiveness, contributing to the prediction of future invasion dynamics.

Here, we collected seven and nine populations alongside latitudes from invasive and native ranges of a global invasive plant, *Spartina alterniflora*, and planted them in two common gardens at the southernmost and northernmost sites of the invasive range. We measured plant traits, including the first flowering time, plant height, and seed set, and analyzed how these traits varied with garden sites and populations' origin latitudes and how their covariance changed between ranges.

We found that plants flowered later, grew taller, and set more seeds in the high-latitude garden than the low-latitude one. The growth and expression of genetic variation of traits appeared to be limited by high ambient temperature in the low-latitude garden. In the high-latitude garden, the flowering time of populations showed clinal variation for both invasive and native populations, whereas the plant height and seed set showed clinal variation only for native or invasive populations. From the native to the invasive range, the flowering time and seed set developed negative genetic covariance, and flowering time and plant height changed from negative genetically correlated to uncorrelated.

Our results suggested that *S. alterniflora* has experienced rapid adaptation to clinal and local conditions over the 40-year invasion. Such geographic-scale rapid adaptation appeared to have benefited from previously identified genetic admixture that has released the trait covariance. Our study highlights the importance of integrating full-range geographical surveys with introduction history to understand the potential and mechanisms of trait evolution during invasion.



研究地点地图

Map of study sites

以上工作于2023年2月发表于*FUNCTIONAL ECOLOGY*期刊，博士后陈欣淙为第一作者，张原野副教授和张宜辉教授为共同通讯作者。

Reference : Chen, X., Liu, W., Zhang, Y.-Y., Zhang, Y.-H. Altered trait covariances between invasive and native ranges of a global plant invader. *FUNCTIONAL ECOLOGY*. 2023. 37(5):1280-1290.

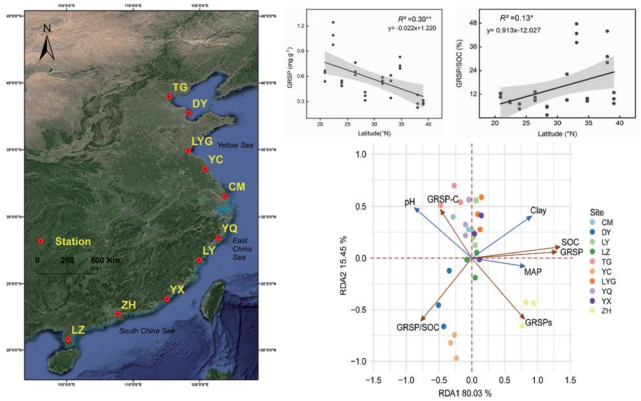
球囊霉素相关土壤蛋白沿亚热带和温带蓝碳区的纬度梯度变化

Change in glomalin-related soil protein along latitudinal gradient encompassing subtropical and temperate blue carbon zones

球囊霉素相关土壤蛋白（GRSP）是一种与丛枝菌根真菌来源相关的微生物衍生产物。在陆地生态系统中，GRSP广泛分布，是土壤有机碳的重要组成部分，并通过改善土壤团聚体结构等促进土壤固碳。GRSP可通过雨水淋溶、土壤侵蚀等方式进入河流，输送并积累至滨海湿地生态系统。尽管对陆地生态系统中不同时空尺度下GRSP的储量进行了大量研究。然而，GRSP在大规模海岸带环境中的沉降尚未被揭示，这阻碍了对GRSP储藏模式和环境控制的深入理解，这一知识差距成为理解GRSP作为海岸带蓝碳组分的生态功能的关键不确定性之一。因此，揭示滨海湿地中GRSP的分布与碳汇效应有助于深入理解丛枝菌根真菌来源的碳在滨海湿地中的生物地球化学过程。

研究团队通过对中国东部沿海跨越不同温度带，超过2500km的10个盐沼湿地GRSP含量分析。结果表明GRSP含量介于0.29mg·g^{-1}到1.10mg·g^{-1}之间，且随着纬度的增加而降低（R^2=0.30, $p < 0.01$）。盐沼的中GRSP对土壤碳的贡献在4%到43%之间，其碳贡献受到背景有机碳总量的限制。在盐沼湿地，降水、粘土含量和pH值是影响GRSP储存的主要因素，且各个气候区的主要因素对GRSP的相对贡献存在差异。在亚热带区域（20°N<34°N）盐沼的土壤特性，如粘土含量和pH值，对GRSP影响显著；而在暖温带盐沼（34°N<40°N），降水则显著影响GRSP分布。这些发现为沿海盐沼环境中GRSP的分布和碳汇功能提供了新见解。

本研究将GRSP的分布和碳贡献模式扩展到了滨海生态系统，并证实了它们对维持蓝碳功能的贡献。这项研究观察到的GRSP模式和驱动因素将为蓝碳模型提供新的见解，从而更好地预测全球碳预算。



中国盐沼湿地GRSP的纬度分布及其环境响应

Latitudinal distribution of GRSP in Chinese salt marsh wetlands and its environmental response

Glomalin-related soil protein (GRSP), an abundant and eco-friendly bioproduct associated with arbuscular mycorrhizal fungi (AMF), contributes significantly to the soil particle aggregation and carbon sequestration. Although much research has been conducted on the storage of GRSP at different spatio-temporal scales in terrestrial ecosystems. However, the deposition of GRSP in large-scale coastal environments has not been revealed, which hinders an in-depth understanding of GRSP storage patterns and environmental controls, and this knowledge gap has become one of the key uncertainties in understanding the ecological functions of GRSP as blue carbon components in coastal environments. Therefore, we conducted large-scale experiments (spanning subtropical and warm temperate climate zones, coastlines over 2500 km) to test the relative contributions of environmental drivers that shape unique GRSP storage. In salt marshes of China, we found that the abundance of GRSP ranges from 0.29 mg·g^{-1} to 1.10 mg·g^{-1}, and its concentration decreases with increasing latitude (R^2 = 0.30, $p < 0.01$). The GRSP-C/SOC of salt marshes ranged from 4 % to 43 % and increased with the increase in latitude (R^2 = 0.13, $p < 0.05$). The carbon contribution of GRSP does not follow the trend of increasing abundance, but is limited by the total amount of background organic carbon. In salt marsh wetlands, precipitation, clay content and pH are the main factors influencing GRSP storage. GRSP is positively correlated with precipitation (R^2 = 0.42, $p < 0.01$) and clay content (R^2 = 0.59, $p < 0.01$), but negatively correlated with pH (R^2 = 0.48, $p < 0.01$). The relative contributions of the main factors to the GRSP differed across climatic zones. Soil properties, such as clay content and pH, explained 19.8 % of the GRSP in subtropical salt marshes (20°N < 34°N), however, in warm temperate salt marshes (34°N < 40°N), precipitation explained 18.9 % of the GRSP variation. Our study provides insight into the distribution and function of GRSP in coastal environments.

以上工作于2023年6月发表于*SCIENCE OF THE TOTAL ENVIRONMENT*期刊，硕士生陈向文为第一作者，卢豪良教授为通讯作者。

Reference： Chen X., Su M., Wu S., He L., Zhang B., Zhang Y., Huang X., Liu J., Yan C., Liu W., Lu H. Change in glomalin-related soil protein along latitudinal gradient encompassing subtropical and temperate blue carbon zones. *SCIENCE OF THE TOTAL ENVIRONMENT*. 2023. 895:165035.

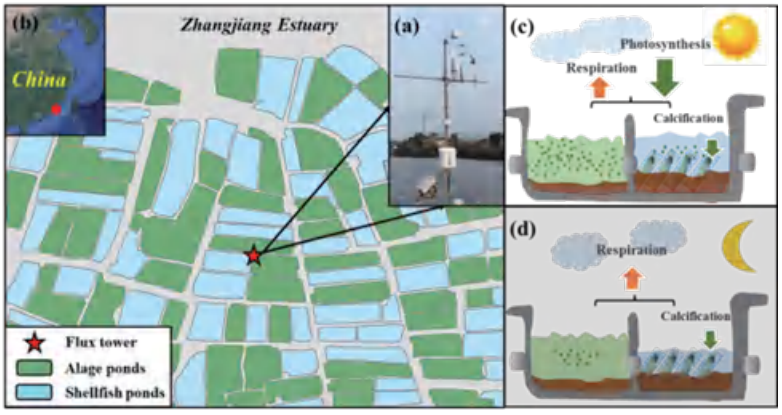
海水养殖塘水-气界面二氧化碳通量的昼夜变化特征与调控机制

Strong diurnal variability of carbon dioxide flux over algae-shellfish aquaculture ponds revealed by eddy covariance measurements

海水养殖塘是二氧化碳（CO_2）源汇研究的热点区域。在自然与人为作用双重调控下，其水-气界面CO_2通量（NEE）具有极强的时间动态性，如从短时的昼夜变化到季节变化及年际变化等。由于难以实现时间上的高频连续观测，基于漂浮箱等传统通量观测法的海水养殖塘碳收支评估可能存在较大的不确定性。利用涡度相关法开展海水养殖塘NEE高频连续观测可以弥补上述不足，揭示NEE的多尺度时间变化特征，量化在不同养殖和管理阶段之间NEE大小及昼夜变化的差异性。

研究团队利用涡度相关法在中国东南沿海福建漳江口贝藻类海水养殖塘（缢蛏-虾蟹季节轮养）开展为期两年半（2020年1月~2022年6月）的NEE高频连续观测，获得如下科学认识：（1）养殖塘NEE昼夜变化显著，白天为大气CO_2的汇，夜间为大气CO_2的源，二者分别受控于光合有效辐射与温度；（2）养殖塘在缢蛏与虾蟹养殖时期均表现为大气CO_2的汇，而在排水时期则表现为大气CO_2的源；（3）CO_2汇的大小在缢蛏养殖的不同阶段也存在差异，缢蛏养殖后半阶段具有“白天汇-夜间近零”的通量特征，其CO_2汇比缢蛏养殖前半阶段大很多（约16倍）；（4）与其它水生系统相比，该类型养殖塘NEE具有更大的昼夜变化幅度，且变化幅度与气温呈现一定的正相关。研究结果表明，以往基于白天非连续通量测定计算全天NEE的做法可能会使碳收支估算出现较大偏差。该研究也证实了开展高频连续碳通量观测在贝藻类海水养殖塘碳收支评估中的重要性和必要性。

研究依托福建台湾海峡海洋生态系统国家野外科学观测研究站的海水养殖塘通量观测平台，开展贝藻类海水养殖塘NEE及其环境因子的连续观测，揭示了不同养殖与管理阶段NEE的昼夜变化特征及其调控机制，为评估海水养殖塘碳收支与源汇格局提供了科学依据。



福建台湾海峡海洋生态系统国家野外科学观测研究站海水养殖通量观测平台

Mariculture eddy flux observation platform at National Observation and Research Station for the Taiwan Strait Marine Ecosystem

Aquaculture ponds represent a biogeochemical hotspot of the global carbon cycle. However, accurate estimations of their carbon budgets are hindered by a limited understanding of the temporal variability of carbon fluxes across time scales. In this study, the eddy covariance (EC) approach was applied to quantify net ecosystem CO_2 exchange (NEE) over algae-shellfish aquaculture ponds (razor clam cultivation) in Zhangjiang Estuary of Southeast China from January 2020 to June 2022, aiming to assess the diurnal variability of NEE during various management periods. The EC-based NEE over the ponds showed strong diurnal variations with daytime sink and nighttime source, mainly controlled by photosynthetically active radiation and air temperature, respectively. The ponds acted as a net sink system during razor clam (daily mean flux of −0.42μmol m^{-2} s^{-1}) and shrimp-crab (−0.50μmol m^{-2} s^{-1}) farming periods with a stronger daytime sink than a nighttime source, while it was the opposite during the drainage period acting as a net source (0.40μmol m^{-2} s^{-1}). The strength of sink/source also differed between the early and late stages of the razor clam farming period, with much larger (-16 times) net carbon uptake in the late stage as a result of the strong daytime sink and near-neutral nighttime flux. The diurnal variability of NEE over the ponds was overall larger than other aquatic ecosystems and tended to increase with air temperature. Previous estimates of daily NEE from discrete daytime-only samplings might have biased the actual carbon budgets if no diurnal correction was applied in the temporal aggregation. The confirmed strong temporal variability of NEE across time scales highlighted the importance and necessity of continuous and high-frequency flux measurements in assessing the carbon budgets of algae-shellfish aquaculture ponds.

以上工作于2023年6月发表于*AGRICULTURE, ECOSYSTEMS AND ENVIRONMENT*期刊，硕士生张一萍为第一作者，朱旭东副教授为通讯作者。

Reference：Zhang Y., Guo X., Zhu X. Strong diurnal variability of carbon dioxide flux over algae-shellfish aquaculture ponds revealed by eddy covariance measurements. *AGRICULTURE, ECOSYSTEMS AND ENVIRONMENT*. 2023. 348:108426.

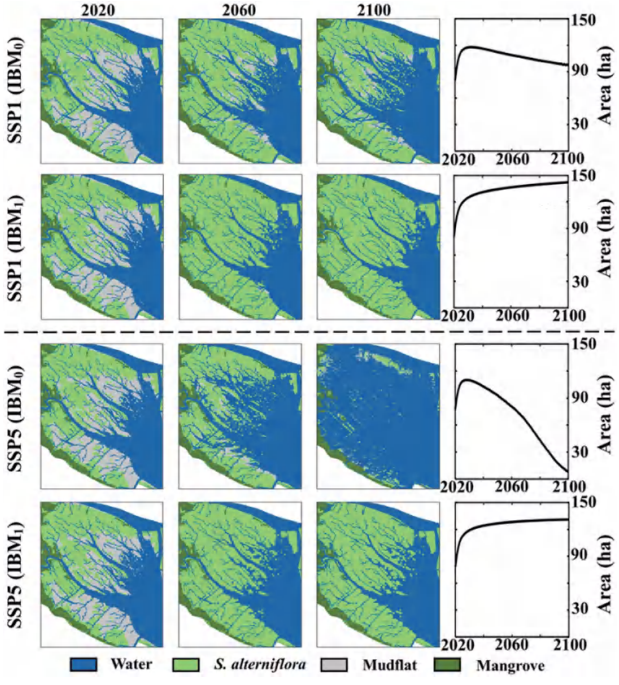
全球变暖减弱了低纬度潮汐盐沼抵御海平面上升的能力

Warming-Induced Growth Inhibition Weakens the Resilience of Low-Latitude Tidal Marshes to Sea-Level Rise

潮汐盐沼湿地可以提供很多重要的生态系统服务，包括海岸带保护、生物多样性维持和生态碳汇等，但在气候变化驱动下潮汐盐沼的生存正面临着巨大挑战。海平面上升和全球变暖是影响潮汐盐沼生存的两个关键驱动因子。海平面上升在加剧潮汐盐沼植物淹水胁迫的同时，沉积作用可以抬高滩面高程来缓解淹水胁迫，而全球变暖对潮汐盐沼植物生长的调控又使得上述反馈过程更加复杂。在低纬度地区，全球变暖可能使得未来气温超过潮汐盐沼植物的最佳生长温度，因而，相对于高纬度地区，低纬度潮汐盐沼滩面的抬升速度更可能赶不上海平面的上升速度。以往很多研究利用模型手段评估潮汐盐沼对海平面上升的适应能力，但存在一些不足：一是多数模型模拟未明确考虑潮汐盐沼植物的生活史特征，无法准确反映植物生长与沉积作用之间的生物物理反馈过程；二是模型模拟很少考虑全球变暖对植物生长本身的调控作用，缺乏这一生理反馈过程可能严重影响模型对潮汐盐沼抵御海平面上升的评估能力。

研究团队以福建台湾海峡海洋生态系统国家野外科学观测研究站漳江口互花米草盐沼湿地为研究对象，通过在种群扩散模型中集成互花米草生活史特征并同时考虑生物物理反馈与生理反馈过程，开展互花米草种群空间扩散的模型模拟与情景分析研究。发现：（1）考虑生物物理反馈的模型可以更好地模拟互花米草种群扩散动态；（2）在高排放情景下是否考虑生物物理反馈对模型预测结果影响巨大；（3）升温带来的植物生长抑制加剧了低纬度互花米草盐沼的生存危机。改进的模型预测更合理地反映了互花米草盐沼抵御海平面上升的能力，研究为定量评估滨海湿地对气候变化的适应能力提供了科学依据。

Sea-level rise (SLR) is expected to suppress the growth of tidal marshes due to prolonged inundation, but this can be compensated by increasing surface elevation with SLR. Warming-induced growth regulation could make it more complicated. We applied a spatially explicit individual-based model (IBM) with dynamic parameterization to predict the range expansion of *Spartina alterniflora* by 2100 over a low-latitude wetland, under one low-emission scenario (Shared Socioeconomic Pathway 1 [SSP1]: 0.28 m SLR and 0.55 °C warming) and one high-emission scenario (SSP5: 1.01 m and 3.55 °C). The results showed that (a) the simulations of an IBM with life-history-mediated biophysical feedbacks (IBM_1) better tracked the actual range expansion of *S. alterniflora* over 2014 to 2017 (90.1% accuracy) than that without the feedbacks (IBM_0) (83.0%); (b) under SSP1, most marshes were predicted to survive SLR by 2100 in both IBM_0 and IBM_1, while, under SSP5, the marshes were predicted to disappear much more in IBM_0 (93.2% drowned) than IBM_1 (31.9%); and (c) warming-induced growth inhibition of *S. alterniflora* leads to exacerbated disappearance and even collapse of the marshes under SSP5 in IBM_1. This study highlights the importance of life-history-mediated biophysical and physiological feedbacks in regulating the response of tidal marshes to climate change. Warming-induced growth inhibition weakens low-latitude tidal marsh resilience to SLR.



不同模拟情景下福建漳江口地表覆盖类型的时空演变及互花米草面积变化

Temporal evolutions of land cover and tidal-marsh area in Zhangjiang Estuary of Fujian under different simulation scenarios

以上工作于2023年4月发表于*ECOSYSTEM HEALTH AND SUSTAINABILITY*期刊，硕士生蔡秀龙为第一作者，朱旭东副教授为通讯作者。

Reference：Cai X., Zhang Y., Zhu X. Warming-induced growth inhibition weakens the resilience of low-latitude tidal marshes to sea-level rise. *ECOSYSTEM HEALTH AND SUSTAINABILITY*. 2023. 9. 0054.

我国海岸带地区全氟和多氟烷基物质在海洋生物中的富集态势

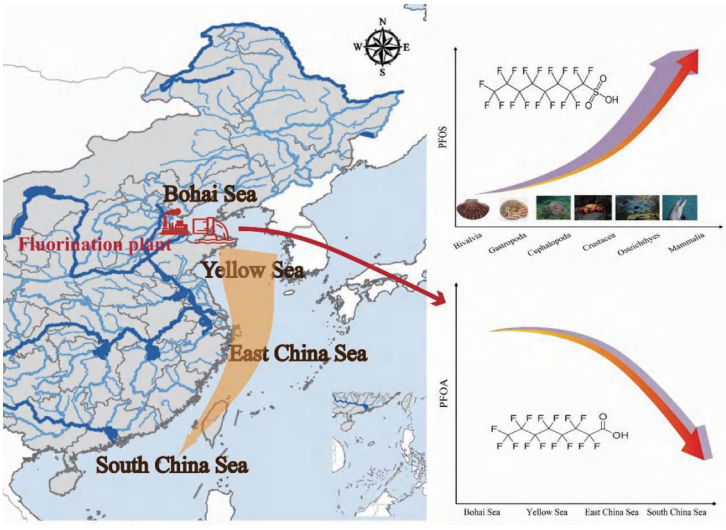
Per- and polyfluoroalkyl substances (PFAS) in marine organisms along the coast of China

我国海岸带地区分布有大量的氟化工生产和应用行业，其产生的以全氟辛酸（PFOA）和全氟辛烷磺酸（PFOS）等新污染物为代表的全氟和多氟烷基物质（PFAS）的排放形式严峻。同时海岸带地区人口密集，生活源也是重要的排放源。PFAS经干湿沉降、污水排放、河流输运等途径输送至海洋环境，PFAS的特性使得其易在生物体内富集，产生潜在的生态风险和食用水产品的人群健康风险。近年来，关于海岸带水生生物对PFAS富集的研究逐步增多，然而相关研究涉及不同的PFAS物质、海洋生物物种、地理区域，尚缺乏对海岸带地区整体趋势的综合性研究。

研究团队整理汇总了2002年至2020年中国海岸带海洋生物PFAS暴露的数据，重点讨论了双壳纲、腹足纲、头足纲、甲壳纲、硬骨鱼纲和哺乳纲六个分类群生物对PFAS的富集水平。研究结果表明，PFOS 和 PFOA 是大多数生物体内主要的PFAS，然而随着管控措施的推进，其替代物F-53B和HFPO-DA以及前驱物等的检出率不断上升；在海洋生物体内 PFOA 浓度呈现由北到南的下降趋势，主要受渤海莱州湾小清河上游大型氟化工厂 PFOA 排放输入的影响；海洋生物体内 PFOS 浓度则呈现由低营养级到高营养级生物上升的趋势，尤其是在哺乳纲生物体内 PFOS 浓度显著高于其他纲生物，体现了生物营养级放大效应。

PFAS一直受到国际社会的广泛关注，其代表性物质也被列入我国2023年重点管控新污染物清单。本研究针对我国海岸带地区海洋生物对PFAS富集的系统总结，一方面有助于提升对PFAS污染态势的整体把握，也对未来新污染物管控提供了重要的科学依据。

Per- and polyfluoroalkyl substances (PFASs) are a large and complex class of synthetic chemicals widely used in industrial and domestic products. This study compiled and analyzed the distribution and composition of PFASs in marine organisms sampled along the coast of China from 2002 to 2020. Perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) were dominant in bivalves, cephalopods, crustaceans, bony fish and mammals. PFOA in bivalves, crustaceans, bony fish and mammals gradually decreased from north to south along the coast of China, and the PFOA contents of bivalves and gastropods in the Bohai Sea (BS) and the Yellow Sea (YS) were higher than those of PFOS. The increased production and use of PFOA have been detected by biomonitoring temporal treads in mammals. For the organisms in the East China Sea (ECS) and the South China Sea (SCS), which were less polluted by PFOA compared to BS and YS, PFOS was universally higher than PFOA. The PFOS of mammals with high trophic levels was significantly higher than that of other taxa. This study is conducive to better understanding the monitoring information of PFASs of marine organisms in China and is of great significance for PFAS pollution control and management.



我国海岸带海洋生物中主要PFAS物质PFOS和PFOA在物种中和地理空间上的分布趋势

Distribution trends of PFOS and PFOA, the main PFAS substances, in marine organisms in China's coastal zones, among species and in geographical space

以上工作于2023年6月发表于*SCIENCE OF THE TOTAL ENVIRONMENT*期刊，博士生解兴伟为第一作者，吕永龙教授为通讯作者。

Reference：Xie X., Lu Y., Wang P., Lei H., Liang Z. Per- and polyfluoroalkyl substances in marine organisms along the coast of China. *SCIENCE OF THE TOTAL ENVIRONMENT*. 2023. 876:162492.

典型河流-红树林河口-海湾系统中全氟和多氟烷基物质赋存特征及迁移传输研究

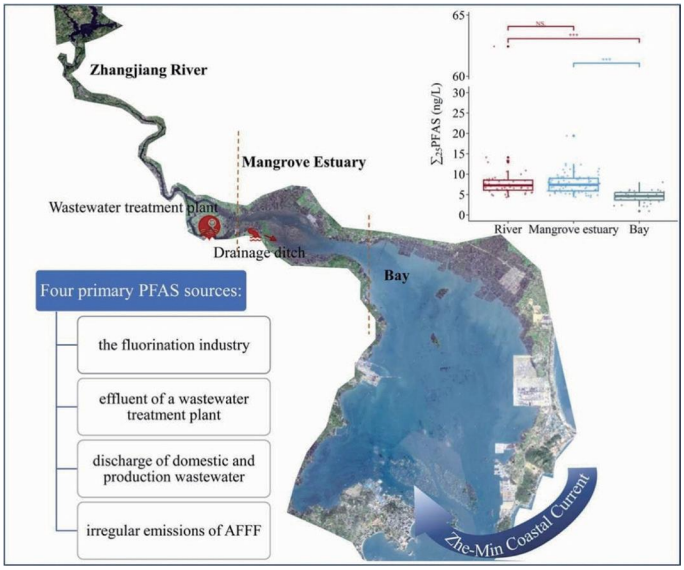
Per- and polyfluoroalkyl substances in a subtropical river-mangrove estuary-bay system

红树林作为重要的陆海过渡带生态系统，对于稳定海岸线、维持生物多样性具有重要的意义。全氟和多氟烷基物质（PFAS）是一类目前受到广泛关注的持久性有机污染物，主要排放到水环境中，具有生物毒性，能够在生物中富集和传递，并通过食物链/网产生生物放大效应，对生态系统产生危害。红树林河口是众多水生生物栖息、繁殖和觅食的场所，然而目前缺乏针对红树林河口生态系统 PFAS 污染的系统研究。

福建漳江口是典型的亚热带红树林河口，研究团队以其为研究区域，对漳江口及其上游河流和下游海湾进行了 6 个季度的航次采样，系统分析了典型红树林河口生态系统 PFAS 的赋存规律和季节变化。结果表明，PFAS整体污染较轻，呈现河流-河口-海湾逐渐下降的分布趋势，说明主要受陆源污染影响；在浙闽沿岸流的影响下，受氟化工业源污染的北方海水入侵东山湾，导致了海湾区 PFAS 的季节分布呈现秋冬季高于夏春季的趋势；红树林潮沟受潮汐作用的影响，生活和生产污水排放主要在退潮低水位时排水，此时的PFAS污染输入明显增加；沉积物中 PFAS 的分布不仅受污染输入来源的影响，也存在盐析效应，说明红树林能够对 PFAS 进行截留。

红树林河口生态系统作为陆地输入海洋污染物的直接承载缓冲系统，随着城市化和工业化进程的推进，所面临的环境压力也日益增加。本研究填补了红树林河口系统 PFAS 污染研究的匮乏，有助于更全面的了解PFAS的生态环境效应。

Mangrove estuaries are one of the most economically valuable and biologically diverse coastal ecosystems. However, knowledge of emerging pollutants in mangrove estuaries is limited. This study provided insight into the PFAS in a river (Zhangjiang River, ZR)-mangrove estuary (Zhangjiang River Estuary, ZRE)-bay (Dongshan Bay, DSB) continuous system in Fujian Province, China. The Σ_{25}PFAS (sum of 25 PFAS) concentrations (0.94 ~ 62.44 ng/L) showed a declining trend from the river to bay. The Zhe-Min Coastal Current (ZMCC) can transport an abundance of PFAS, especially PFOA, from the northern sea to southern bays, which can affect the seasonal distribution of PFAS concentrations in the DSB and result in PFOA/Σ_{25}PFAS with a decreasing trend in the DSB (28.08%), ZRE (21.15%), and ZR (14.13%), respectively. The primary PFAS sources in this area determined by the positive matrix factor model mainly contained the effluent of the wastewater treatment plant neighboring the R2 site, discharge of domestic and production wastewater, irregular emissions of aqueous film-forming foams, and fluorochemistry industry wastewater transmitted from the ZMCC. The PFAS pollution in the mangrove creek was mainly affected by the discharge of domestic and production wastewater and presented a significant point source pollution, especially during the rainy season.



漳江口河流-红树林河口-海湾系统PFAS的赋存特征和源解析

Occurrence and source of PFAS in Zhangjiang river-mangrove estuary-bay system

以上工作于2023年6月发表于 *JOURNAL OF HAZARDOUS MATERIALS*期刊，博士生解兴伟为第一作者，吕永龙教授为通讯作者。

Reference : Xingwei Xie, Yonglong Lu*, Pei Wang, Hoajie Lei, Nengwang Chen, Zian Liang, Xudong Jiang, JialongLi, Zhiwei Cao, Jieming Liao, Kongming Li. Per- and polyfluoroalkyl substances in a subtropical river-mangrove estuary bay system. *JOURNAL OF HAZARDOUS MATERIALS*, 2023, 464, 132937.

滨海湿地中聚乙烯塑料表面铁膜形成及其性质变化：非生物因素和细菌群落

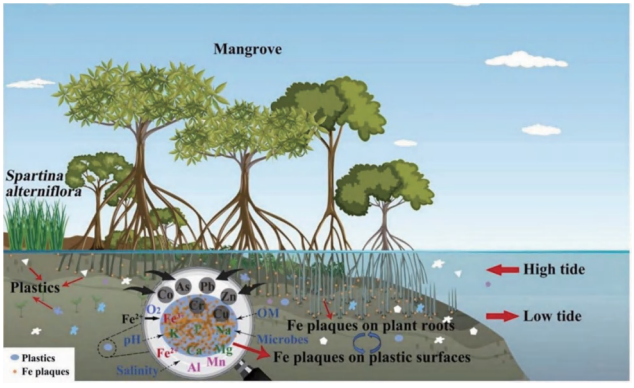
Iron plaque formation and its influences on the properties of polyethylene plastic surfaces in coastal wetlands: Abiotic factors and bacterial community

滨海湿地位于陆地与海洋之间，是陆地和海洋塑料沉积的汇。沉积的塑料可进一步被破碎成为微塑料，对湿地生态环境造成威胁。湿地中铁含量丰富，早在20世纪六七十年代，就观测到滨海湿地植物根系表面铁氧化物的形成。后来有学者观察到塑料容器表面附着氧化铁，尽管在塑料表面自然形成的氧化铁引起了学者们的关注，但铁膜的形成特征、驱动因素以及相关关系等数据仍然缺乏。因此，本文采取多技术联合解析塑料表面形成铁膜的特征，阐明铁膜形成的驱动力，揭示可能的环境影响，为滨海湿地塑料暴露特征及生态效应提供数据支持。

研究团队通过室内模拟培养实验，结合多种表征方法和微生物分析，研究了滨海湿地(红树林和互花米草)中低密度聚乙烯塑料表面铁膜的形成特征及其与环境因子的相关关系。结果表明，塑料表面铁膜的形成，促使塑料表面的黏附力增加了3.6倍，并促进塑料表面氧化。铁膜的形成受到盐度、铁含量、pH、氧气调控。低盐、弱碱性、以及厌氧环境更有利于塑料铁膜的形成；铁膜与某些重金属(i.e., As, Mn, Co, Cr, Pb, Zn)的吸附量呈显著正相关。此外，塑料铁膜的形成与微生物有显著相关关系，其中与*Nitrospirae*呈显著正相关关系，与*Verrucomicrobia*和*Kiritimatiellaeota*呈显著负相关关系。这些结果有助于更好地理解塑料诱导的铁膜的关键作用，并揭示铁膜对滨海湿地污染的潜在生态风险。

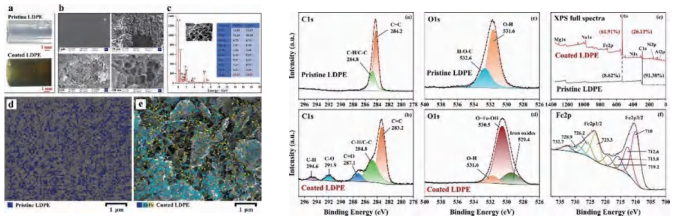
这项工作证明了铁膜可以通过改变塑料表面性质来增强塑料在污染物迁移转化中的作用，为滨海湿地塑料界面行为和潜在的生态效应提供了新的视角。

Iron (Fe) plaques in coastal wetlands are widely recognized because of their strong adsorption affinity for natural particles, but their interaction behaviors and mechanisms with plastics remain unknown. Through laboratory incubation experiments, paired with multiple characterization methods and microbial analysis, this work focused on the characteristics of Fe plaques on low-density polyethylene plastic surfaces and their relationship with environmental factors in coastal wetlands (Mangrove and Spartina alterniflora soil). The results showed that iron plaques increased the adhesive force of the plastic surface from 65.25 to 300 nN and promoted the oxidation of the plastic surface. Fe plaque formation was stimulated by salinity, anaerobic conditions, natural organic matter, and a weak alkaline scenario (pH 8.0–8.3). The Fe content showed a stable positive correlation with heavy metals loading (i.e., As, Mn, Co, Cr, Pb, and Zn). Furthermore, we revealed that Fe plaque was positively regulated by *Nitrospirae* through 16S rRNA high-throughput sequencing analysis. Meanwhile, *Verrucomicrobia* and *Kiritimatiellaeota*. may act as depressants by consuming salt. This work illustrated that iron plaques could enhance the role of plastics in contaminant migration by altering their adsorption performance, providing new insights into plastic interface behavior and potential ecological effects in coastal wetlands.



塑料在滨海湿地中的暴露行为

Exposure behavior of plastics in coastal wetlands



塑料暴露在湿地环境中的表面性质变化

Surface properties of plastics exposed to wetland environment

以上工作于2023年9月发表于*JOURNAL OF HAZARDOUS MATERIALS*期刊，博士生张晓婷为第一作者，卢豪良教授为通讯作者。

Reference：Zhang X., Lin L., Li H., Liu S., Tang S., Yuan B., Hong H., Su M., Liu J., Yan C., Lu H. Iron plaque formation and its influences on the properties of polyethylene plastic surfaces in coastal wetlands: Abiotic factors and bacterial community. *JOURNAL OF HAZARDOUS MATERIALS*. 2023. 461:132585.

皱纹盘鲍饲料添加不同来源抗氧化剂（虾青素）效果的综合比较研究

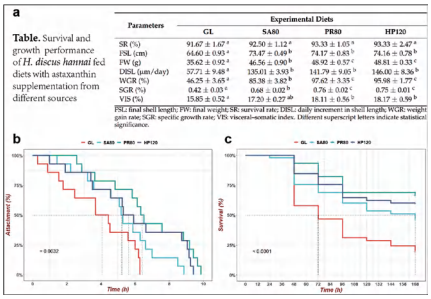
Comprehensive Comparison of Effects of Antioxidant (Astaxanthin) Supplementation from Different Sources in Haliotis *discus hannai* Diet

虾青素以其非凡的抗氧化活性而闻名，远远超过其它抗氧化剂。大量报道表明，虾青素在水生动物的生殖健康、卵子质量、生长、存活、免疫、胁迫耐受性和抗病性方面具有优异的表现，其在水产养殖业中被认为是一种环保的功能性饲料添加剂。皱纹盘鲍是我国重要的养殖经济贝类，目前我国的养殖产量已超20万吨。与其它水产动物一样，虾青素也开始被应用于鲍配合饲料中以期发挥其多重的生物功能，最终实现进一步提升鲍的生产表现和提高其环境抗逆性（耐热和抗病等）的目标。目前市场上主要以工业合成虾青素为主，但随着需求的快速增长，工业合成虾青素的安全性问题备受争议，绿色的雨生红球藻和红发夫酵母逐渐成为虾青素经济有效的替代来源。然而，由于不同来源虾青素的异构体差异及其与化合物的关联将导致生产性能存在差异，即便在天然来源的虾青素之间也是如此。因此，有必要了解皱纹盘鲍饲料中虾青素的最佳添加形式。

研究团队首先通过前期实验解决了不同来源虾青素的最佳添加量问题。然后对饲喂添加不同来源虾青素（以最佳添加量添加）饲料的皱纹盘鲍的生长性能、免疫力、抗氧化能力、耐热性、抗病性和肠道微生物生态系统等方面进行比较分析，结果表明：与天然饵料龙须菜组相比，摄食添加工业合成虾青素、雨生红球藻和红发夫酵母的皱纹盘鲍的存活、生长、免疫应答、抗氧化活性、耐热性和抗病性等方面均表现更好。在成活和生长性能方面，添加天然来源的虾青素（雨生红球藻和红发夫酵母）组比工业合成来源组具有更好的表现。在耐热性和抗病性方面，摄食添加红发夫酵母来源的虾青素饲料的皱纹盘鲍表现出最强的抵抗力。总体而言，建议在鲍配合饲料中以红发夫酵母来补充虾青素（以80mg/kg虾青素的添加量添加），以达到更有效和全面的效果。

本研究将鲍配合饲料添加虾青素的效果最大化，实现鲍配合饲料添加剂的精细、准确添加。这项研究将为鲍配合饲料生产中虾青素的添加方案提供指导，最大化虾青素的生物功能，进而有助于提高鲍生产效率，促使鲍养殖业实现经济效益最大化。

Dietary antioxidant supplementation, especially astaxanthin, has shown great results on reproductive aspects, egg quality, growth, survival, immunity, stress tolerance, and disease resistance in aquatic animals. However, the effects of dietary astaxanthin supplementation from different sources are still unknown. A comprehensive comparison of survival, growth, immune response, antioxidant activity, thermal resistance, disease resistance, and intestinal microbial structure was conducted in dietary antioxidant supplementation from the sources of *Gracilaria lemaneiformis* (GL), industrial synthetic astaxanthin (80 mg/kg astaxanthin actual weight, named as group 'SA80'), *Phaffia rhodozyma* (80 mg/kg astaxanthin actual weight, named as group 'PR80') and *Haematococcus pluvialis* (120 mg/kg astaxanthin actual weight, named as group 'HP120') at their optimal supplementation amounts. According to our results, the SA80, PR80, and HP120 groups performed better in all aspects, including survival, growth, immune response, antioxidant activity, thermal resistance, and disease resistance, compared with the GL group. Besides, the PR80 and HP120 group had a better growth performance than the SA80 group. In terms of heat stress and bacterial challenge, abalone in the PR80 group showed the strongest resistance. Overall, 80 mg/kg astaxanthin supplementation from *Phaffia rhodozyma* was recommended to obtain a more effective and comprehensive outcome. This study contributes to the discovery of the optimum dietary astaxanthin supplementation source for abalone, which is helpful to improve the production efficiency and economic benefits of abalone. Future research can further explore the action mechanism and the method of application of astaxanthin to better exploit its antioxidant role.



皱纹盘鲍饲喂添加不同来源虾青素饲料后的存活和生长表现（a），耐热性表现（b），攻毒后存活率表现（c）

The survival and growth performance (a), heat resistance performance (b), and survival rate after bacterial challenge (c) of H. discus hannai fed the diets with different sources of astaxanthin supplementation

以上工作于2023年8月发表于*ANTIOXIDANTS*期刊，博士生邹伟广为第一作者，柯才焕教授和骆轩高级工程师为共同通讯作者。

Reference：Chen X., Su M., Wu S., He L., Zhang B., Zhang Y., Huang X., Liu J., Yan C., Liu W., Lu H. Change in glomalin-related soil protein along latitudinal gradient encompassing subtropical and temperate blue carbon zones. *SCIENCE OF THE TOTAL ENVIRONMENT*. 2023. 895:165035.

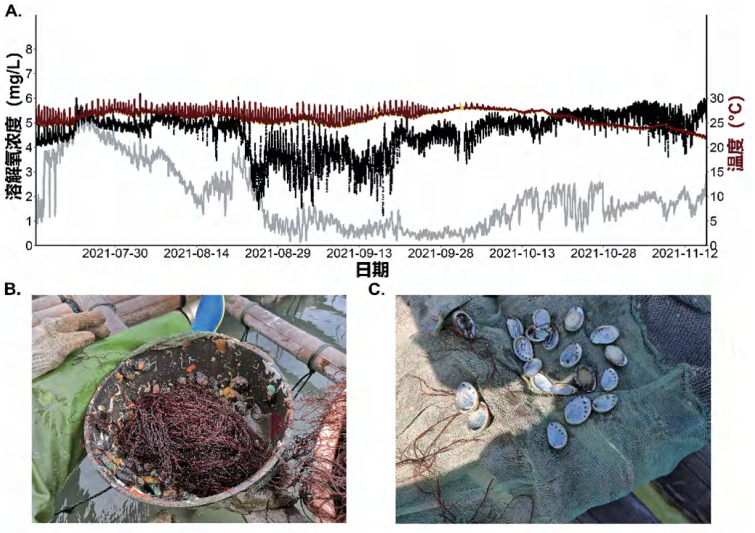
水生动物低氧耐受性差异的机制综述及其对水产养殖的启示

An overview of the mechanisms underlying hypoxia tolerance differences in aquatic animals and their inspirations for aquaculture

自20世纪中期以来，由于全球变暖和富营养化废水的过度排放，开阔大洋和沿岸海水的溶解氧浓度持续降低，这是海洋中发生的最重要的变化之一，极大地影响了海洋生物的生存、丰度、发育、代谢、生长和繁殖。过去，海水养殖为人类提供了丰富的“蓝色食品”，但沿岸海水低氧区域近年来不断扩散，并且海水养殖系统的特殊微环境进一步导致低氧事件的频繁发生，最终造成严重的经济和生态损失。培育低氧耐受品种和品系是海水养殖可持续发展的迫切需求，而现在此类尝试尚少。

这篇综述就水生动物低氧耐受性的生理机制、低氧耐受性差异的遗传和表观遗传来源等方面的研究进展进行了梳理和讨论，这将帮助我们解析海水养殖动物低氧耐受性的形成机制，并通过现代育种技术培育出具有优良耐低氧性状的养殖品种和品系。我们期望通过这篇文章，让人们深刻理解低氧对海水养殖系统的负面影响，明确缓解低氧问题的可能途径，同时鼓励未来的研究将海水养殖系统作为研究环境低氧和水生生物低氧反应和适应过程的一个模型，最终推动海水养殖物种的性状改良和种质创新。

The decline in dissolved oxygen concentrations has been one of the most important changes occurring in the oceans, greatly impacting the survival, abundance, development, metabolism, growth, and reproduction of aquatic organisms. Aquaculture has suffered from coastal seawater deoxygenation, and the micro-environments of aquaculture systems also contribute to the frequent occurrence of hypoxic events. The cultivation of hypoxic-tolerant species and varieties will be urgent for the sustainable development of aquaculture. In this review, the current and ongoing research topics on hypoxia tolerance of aquatic animals were summarized and discussed, including the physiological mechanisms of hypoxia tolerance and the genetic and epigenetic sources of hypoxia tolerance differences in aquatic animals. Understanding the results of these two aspects will allow us to shape aquatic animals' tolerance to hypoxia and create hypoxia-tolerant aquaculture species and varieties by cutting-edge breeding techniques. This will help us alleviate the ecological damage and economic losses brought on by hypoxia occurrences. We urge those working in the aquaculture field to understand the negative effect that hypoxia has on aquaculture systems. We also encourage future research that uses aquaculture systems as ones of the models for studying environmental hypoxia and biological hypoxia responses and adaptation.



（A）2021年夏季福建东山海区，鲍养殖笼内（灰：溶解氧，红：温度）和笼外（黑：溶解氧，黄：温度）的溶解氧浓度（mg/L）和温度（℃）变化；（B）养殖笼具内的鲍和投喂的大型海藻；（C）鲍易受低氧危害而死亡

(A) Records of seawater dissolved oxygen concentration (DO, mg/L) and temperature (°C) in (grey: DO, red: temperature) and out (black: DO, yellow: temperature) of an abalone cage in the aquaculture area (Dongshan, China) in 2021. (B) The abalones and large algae in an abalone cage. (C) Abalone is vulnerable to hypoxia events

以上工作于2023年7月发表于*FISH BIOLOGY AND FISHERIES*期刊，博士后沈雅威为第一作者，柯才焕教授为通讯作者。

Reference：Shen Y., You W., Luo X., Lu Y., Huang M., Ke C. An overview of the mechanisms underlying hypoxia tolerance differences in aquatic animals and their inspirations for aquaculture. *REVIEWS IN FISH BIOLOGY AND FISHERIES*. 2023. 33(4). 1223-1236.

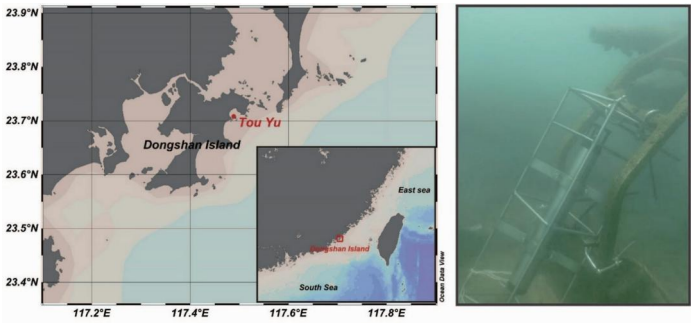
鼓虾发声行为及环境因子关联性研究

Snapping shrimp sound production patterns at Dongshan and their relationships to environmental factors

鼓虾发声为整个海洋声景的重要组成部分，其发声可以引导鱼类、牡蛎一些以声音为媒介的海洋生物到适宜的栖息地定居、可以为一些鲸豚类的觅食及避碰行为进行导航，因此鼓虾及其声信号在海洋生态系统中有着重要的生态意义。此外，鼓虾的发声特性受到海水酸化、海水温度变化、光照变化、噪声变化等环境因素的影响，因此可以通过其声信号进行生态系统的监测。

通过对东山湾珊瑚礁保护区进行长期声学以及环境因子监测，同时充分利用东山实验场天气观测系统所测得的风速，建立声学-环境因子联合监测系统，获得鼓虾发声率以及温度、盐度、浑浊度、叶绿素、风速等环境因子的变化数据。通过分析可得，鼓虾发生行为受到温度-盐度、浑浊度-风速两对环境因子的联合作用影响：（1）随着温度上升，鼓虾发声率增高，但存在一个温度临界点，在临界值之后鼓虾发声率会下降。并且此临界值随着盐度的升高而降低。（2）随着浑浊度升高，鼓虾发声率降低；且风速的增加一定情况下会导致浑浊度增高。

对东山湾一鱼排进行长期声学监测。通过观察发现在白天尤其中午左右，鱼排附近渔船作业频率增加，故通过此现象探究船舶噪声对鼓虾发声特征的影响。探究发现：船舶经过时，鼓虾发声率明显增加，增加量可达39.2%。鼓虾声信号声压级总体提高0.17dB。此外，鼓虾声信号时长存在明显升高，且峰值频率和-3dB带宽有所下降。



东山珊瑚礁保护区声学监测

Acoustic monitoring in the Coral Reef Protection area at Dongshan Bay

The snaps emitted by the invertebrate snapping shrimp (Alpheidae) are important contributions to the overall soundscape in the ocean. Research shows that whales and dolphins may rely on the sound of snapping shrimp to orient themselves along the coast and to meal, and diverse soundscapes help attract fish, shellfish, and coral larvae to appropriate settling sites. In addition, ecology monitoring also can be done through the effects of ocean acidification, temperature variations, light change, and noise on the acoustic properties of the snaps.

Long-term acoustic and environmental factors monitoring was conducted in the Coral Reef Protection area at Dongshan Bay. A joint acoustical and environmental factors monitoring system was established by fully utilizing the wind speed measured by the weather observation system at D-SMART to obtain data on changes in the snap rate and environmental factors, including temperature, salinity, turbidity, chlorophyll, and wind speed. The investigation indicates that the combined impacts of temperature, salinity, turbidity, and wind speed on environmental parameters affect snap shrimp's acoustic behavior: (1) The snap rate rises as temperature rises, but there is a temperature threshold beyond which the vocal rate of drum shrimp falls. Additionally, as salinity rises, the critical value falls. (2) The snap rate dropped as turbidity increased. Additionally, in some situations, an increase in wind speed will result in an increase in turbidity.

Long-term acoustic monitoring was produced at a fish platoon in Dongshan Bay. By observation, it is discovered that the number of fishing boats close to the fish row increases during the day, particularly at midday, and it is via this occurrence that the impact of ship noise on the acoustic characteristics of snap shrimp is investigated: The snap rate clearly increases as the ship passes by; in fact, the increase can reach 39.2%. The snap's sound pressure level rose by 0.17 dB. Furthermore, the snap's duration increased dramatically while the peak frequency and -3dB bandwidth decreased.

以上工作于2023年1月发表于*FRONTIERS IN MARINE SCIENCE*期刊，博士后宋忠长为第一作者，张宇教授为通讯作者。

Reference： Song Z., Ou W.,Su Y., Li H., Fan W., Sun S., Wang T., Xu X., Zhang Y. Sounds of snapping shrimp (*Alpheidae*) as important input to the soundscape in the southeast China coastal sea. *FRONTIERS IN MARINE SCIENCE*. 2023. 10:1029003.

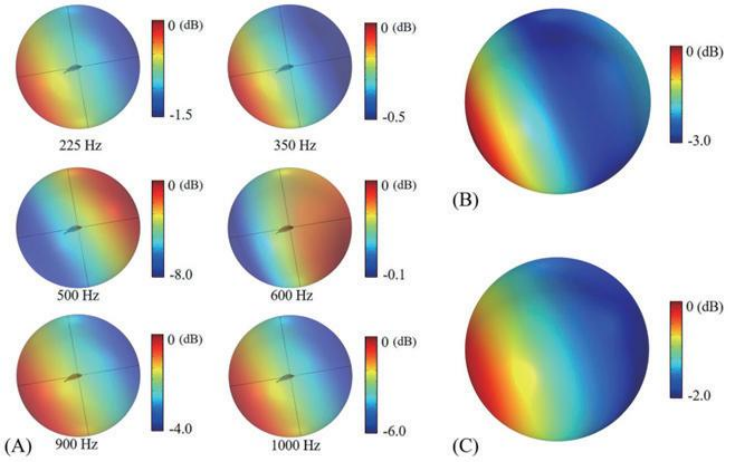
石首鱼繁殖季节发声特性及其指向性研究

Research on vocal characteristics and directivity of Sciaenid species during reproduction season

石首鱼科鱼类主要生活在浑浊的沿海和河口地区，作为渔业渔获物和副渔获物的主要组成部分，该物种具有很高的商业和保护价值。由于其发声行为，石首鱼家族通常被称为“croakers”和“drummers”。尽管几个世纪以来，渔民们一直利用这种能力来定位和捕捉这些动物，但在298种石首鱼中，只有24种能够发声。石首鱼主要通过声肌的收缩和鱼鳔膨胀产生的振动来产生其特有的声信号，其发出的声音与生命活动与行为环境显著相关，包括繁殖、通讯、定位等。因此，鉴于石首鱼野外丰度已明显下降的事实，通过数值模拟与被动声学监测技术为石首鱼繁殖季节的发声特性研究提供了一种无创、低成本的有效工具，有助于未来的养殖管理和渔业种群保护。

作为我国重要的水产养殖物种，大黄鱼繁殖季节的声学特性需要更深入地探讨。通过在一个水产养殖设施中部署被动声学监测装置来记录繁殖过程中大黄鱼的声信号，并将收集到的声学数据信息结合计算机断层扫描（CT）与数值模拟技术探究大黄鱼声信号的声辐射与指向性以及鱼鳔对声辐射的影响，研究表明：（1）大黄鱼的声辐射不是全向的，而是随频率变化的，在将每个频率（20个频率）的权重分配给各自的声学模式并将这些模式合并后，两种类型呼叫的总体声辐射场在反向方向上显示出更高的振幅。（2）将模拟扩展到鱼鳔尺寸对整体传输方向的影响，对于两种类型的声信号，在类型I和类型II中，辐射场具有很强的向后指向性。当鱼鳔的相对尺寸减小到0.8时，I型鸣叫的前向仍以后向传输为主，而前向则出现了较强的旁瓣。声辐射场表明，鱼鳔的大小会影响鱼声的定向传播。

The investigation of the large yellow croaker (*Larimichthys crocea*) deserves more attention due to its high commercial value as an important aquaculture fish species. This study was initiated by deploying a passive acoustic monitoring device to record the calls from the L. crocea during the spawning process in an aquaculture facility. The subsequent analysis suggested the croakers produced at least two types of calls with considerable energy distributed up to 1000 Hz. The acoustic data and the computed tomography scanning of an adult croaker were used to develop a numerical model to address the directivity of the calls at frequencies up to 1000 Hz. The radiation patterns at all frequencies were assigned with respective weights and then combined to estimate an overall acoustic radiation pattern for both types of the calls. The backward transmission was greater for both types of calls by 1.85 dB on average. The reduction of size by 20% in the swim bladder resulted in a stronger sidelobe in the frontal direction, indicating its influence on call directivity. These results provided information on the directivity of the croaker calls and understanding of fish acoustics.



(A)全鱼鳔鱼模型在不同频率下的声辐射场 (B)呼叫类型I的整体声学模式 (C)呼叫类型II的整体声学模式
色带给出了以分贝为单位的相对振幅范围

(A) Acoustic radiation field of the fish model with a full swim bladder at various frequencies. (B) The overall acoustic pattern of call type I. (C) The overall acoustic pattern of call type II. the color bar gives the relative amplitude range in decibel.

以上工作于2023年6月发表于*JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA*期刊，硕士研究生苏英楠为第一作者，张宇教授为通讯作者。

Reference : Su Y., Song Z., Li H., Zhang Y., Xiang W., Hui J., Sun S., Xiao Z., Zhang Y. Call properties of the large yellow croaker (*Larimichthys crocea*) during reproduction with insight into directivitya. *JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA*. 2023. 153. 3192-3200.

红树植物在逆境中的隐性节水策略：夜间树干液流对水分亏缺的补偿作用

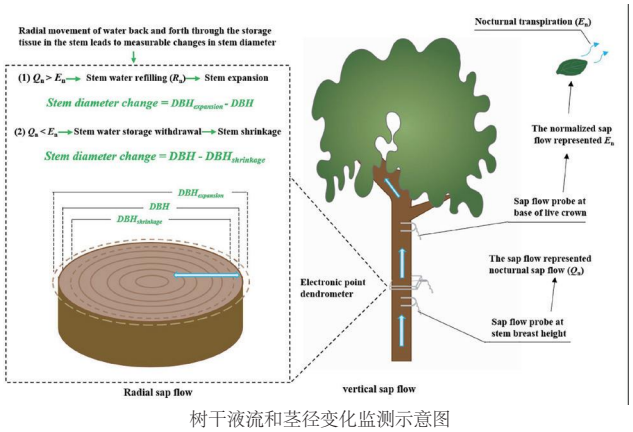
Nocturnal sap flow as compensation for water deficits: an implicit water-saving strategy used by mangroves in stressful environments

红树林是一类生长在热带和亚热带海岸潮间带的耐盐植物。健康的红树林具有很高的生态系统服务价值，如维持高度的生物多样性、调节区域气候和水平衡等。然而，潮间带高盐的生境导致红树植物受到很高的水分压力，维持水分平衡一直是红树植物的生理挑战。红树植物保守的水分利用策略被普遍认为是它们适应高盐生境的关键因素。

本研究利用树干液流监测系统（Sap Flow）、结合树干直径微变化监测，以及叶片气体交换法在中国东南沿海福建漳江口国家红树林自然保护区内对三种生长在同一生境中的红树植物（秋茄、白骨壤和桐花树）开展为期一年（2019年1月~2020年1月）的树干液流连续监测。研究获得以下结论：（1）在监测期间，三种红树植物夜间液流持续存在，并贡献了全天液流的5.5%~24.0%，三种红树植物的夜间树干液流均与夜间蒸腾和夜间茎干补水两个生理过程密切相关。（2）秋茄和桐花树的茎干补水主要发生在日落之后，高盐生境促进了较高的夜间液流；而白骨壤的茎干补水主要发生在白天，高盐生境抑制了其夜间液流；茎干补水模式的多样性和对高盐环境下液流的不同响应是红树植物种间夜间树干液流对全天液流贡献差异的主要原因。（3）秋茄和桐花树叶片严格控制气孔开放程度，以减少夜间的水分流失；而夜间茎干补水受白天缺水后茎干补水需求和盐度变化的驱动，成为夜间液流的主要贡献者；不同的是，白骨壤在饱和水汽压差的驱动下保持较低的夜间液流、并将其用于夜间蒸腾，其通过限制夜间水分耗散来适应高盐环境。

本研究揭示了生长在同一生境中的三种红树植物物种（秋茄、白骨壤和桐花树）具有不同的水分利用策略，而多样的夜间树干茎流模式是它们躲避生理脱水、适应高盐生境的方法之一。这一在红树植物物种中新发现的策略为它们在日间节水策略之外的夜间补水机制提供了证据。

As part of the plant water-use process, plant nocturnal sap flow (Q_n) has been demonstrated to have important ecophysiological significance to compensate for water loss. The purpose of this study was to explore nocturnal water-use strategies to fill the knowledge gap in mangroves, by measuring three species co-occurring in a subtropical estuary. Sap flow was monitored over an entire year using thermal diffusive probes. Stem diameter and leaf-level gas exchange were measured in summer. The data were used to explore the different nocturnal water balance maintaining mechanisms among species. The Q_n existed persistently and contributed markedly over 5.5%~24.0% of the daily sap flow (Q) across species, which was associated with two processes, nocturnal transpiration (E_n) and nocturnal stem water refilling (R_n). We found that the stem recharge of the *Kandelia* obovata and *Aegiceras corniculatum* occurred mainly after sunset and that the high salinity environment drove higher Q_n while stem recharge of the *Avicennia marina* mainly occurred in the daytime and the high salinity environment inhibited the Q_n. The diversity of stem recharge patterns and response to sap flow to high salinity conditions were the main reasons for the differences in Q_n/Q among species. For *Kandelia obovata* and *Aegiceras corniculatum*, R_n was the main contributor to Q_n, which was driven by the demands of stem water refilling after diurnal water depletion and high salt environment. Both of the species have a strict control over the stomata to reduce water loss at night. In contrast, Avicennia marina maintained a low Q_n, driven by vapor pressure deficit, and the Q_n mainly used for E_n, which adapts to high salinity conditions by limiting water dissipation at night. We conclude that the diverse ways Q_n properties act as water-compensating strategies among the co-occurring mangrove species might help the trees to overcoming water scarcity.



树干液流和茎径变化监测示意图

Schematic diagram of monitoring of sap flow and stem diameter change

以上工作于2023年5月发表于*Frontiers in Plant Science*期刊，硕士生伍思攀为第一作者，陈鹭真教授为通讯作者。

Reference：Wu S., Gu X., Zheng Y., Chen L. Nocturnal sap flow as compensation for water deficits: an implicit water-saving strategy used by mangroves in stressful environments. *FRONTIERS IN PLANT SCIENCE*. 2023. 14:1118970.

Data Management

数据管理

2023年，厦门大学海洋监测与信息服务中心暨台海站数据中心围绕数据中心的总体建设框架和任务，持续推进台海站数据库建设、数据管理与数据应用服务。同时，开发上线了厦门大学海洋云暨台海站数据中心门户网站，进一步提升资源开放与共享服务能力。

数据库建设和数据管理方面，在完善数据资源目录、元数据编制规范以及数据汇交制度的基础上，进一步完善建设覆盖台湾海峡-海湾-河口-湿地-流域的生态环境数据库，开发了“海岸带遥感数据库系统”和“生态环境数据共享服务平台”，分别于并于2023年3月和11月投入试运行，目前系统注册用户60个，服务校内外20个课题组，提供了38批次的数据共享服务。

数据应用服务方面，进一步升级了漳江口滨海湿地碳汇观测数据可视化系统，通过产学研合作，设计开发了“三沙湾大黄鱼养殖数字孪生系统”和“厦门湾数字孪生系统”，并在“2023年数字孪生海洋国际峰会”上展示，积极推进数字孪生海洋技术的发展和应用。

In 2023, the Marine Monitoring and Information Service Center of Xiamen University (MMIS), which also serves as the Data Center of T-SMART, persistently advanced database construction, data management, and data application services within the overall framework and tasks. At the same time, Marine Monitoring and Information Service Cloud System (Marine Cloud), also the portal website for Data Center of T-SMAR, was developed and launched, which significantly enhanced service capabilities in resource access and sharing.

Expanding upon improvements to the data resource catalog, metadata preparation standards, and data exchange system, the ecological environment database covering the Taiwan Strait-Gulf-estuary-wetland-watershed has been further enriched. In addition, we also developed the “Ecological Environment Data Query, Display, and Sharing Service System” and “Coastal Remote Sensing Database” that were trialed in March and November 2023, respectively. At present, the system caters to 60 registered users, serves 20 research groups within and outside the university, and provides 38 batches of data sharing services.

Regarding data application services, the Visualization System of Carbon Sink Observation data in Zhangjiang Estuary has been further upgraded. The “Digital Twin System for Large Yellow Croaker Farming of Sansha Bay” and “Digital Twin System for Disaster Prevention and Reduction of Xiamen Bay” have been developed through industry-research cooperation and displayed at the “International Digital Twins of the Ocean 2023”, promoting the development and application of digital twin technology of the ocean.

台海站数据中心门户网站

Portal Website for Data Center of T-SMART

2023年9月，厦门大学海洋云暨台海站数据中心门户网站（mcloud.xmu.edu.cn）正式上线，从数据汇聚、数据资源、分析平台、产品中心和应用案例等全方位展示数据中心的资源和应用服务能力。

In September 2023, Marine Monitoring and Information Service Cloud System（Marine Cloud）which is also the portal website for Data Center of T-SMART (mcloud.xmu.edu.cn) was officially launched, providing resources and application service in data aggregation, data sharing, data analysis, data product and data application cases.

台海站数据中心门户网站界面

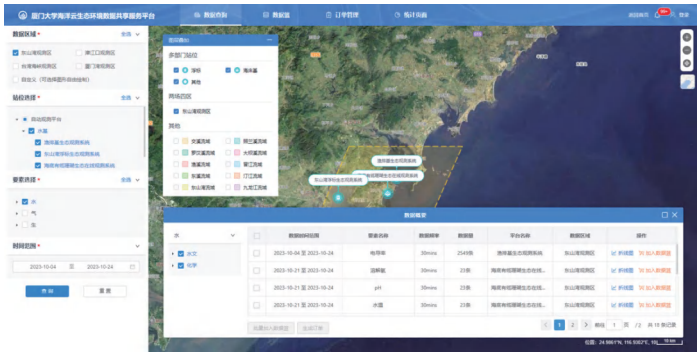
The web page of the Portal website for Data Center of T-SMART

生态环境数据共享服务平台

Ecological Environment Data Query, Display, and Sharing Service System

“生态环境数据查询共享服务平台”整合了台海站两场三区观测数据资源，可实现数据的在线查询、申请、审批、上传、下载等功能，用户通过该系统能够在线申请数据，实现分级审批，保障了数据权利人、生产者、管理者等利益相关者的权益，从而达到高效服务、共建共享、权限分级，提升了数据管理水平和数据价值。

Ecological Environment Data Query, Display, and Sharing Service System integrates the observation data resources of tT-SMART, which allows online query, request, approval, upload and download of data. Users can apply for data online through the system. Through hierarchical approval, rights and interests of stakeholders such as data rights holders, producers and managers are protected. This rights classification, co-construction and sharing improve the level of data management and data value.



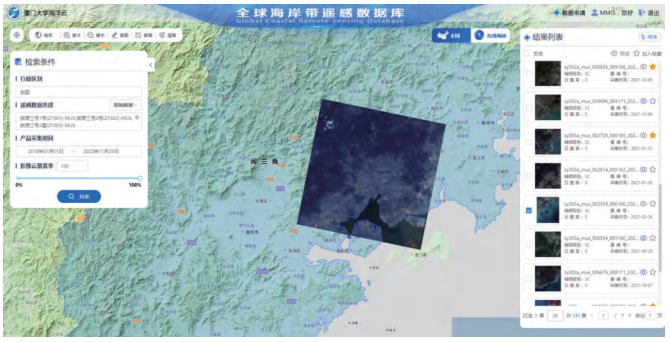
生态环境数据共享服务平台界面

The web page of Ecological Environment Data Query, Display, and Sharing Service System

海岸带遥感数据库系统

Coastal Remote Sensing Database

“海岸带遥感数据库”融合多源遥感数据（包括资源卫星、高分卫星、海丝1号、海丝2号卫星等）和专业算法，形成动态更新的长时序高分辨率遥感产品。入库数据涵盖中国和全球海岸带区域，包括全国海岸带高分辨率数据与常见遥感产品，涉及土地利用、滨海湿地、岸线变化、水质生态、物理海洋等专业应用。目前该系统已拥有近10T影像数据，实现各类遥感数据和遥感产品的科学管理与共享服务。



海岸带遥感数据库系统界面

The web page of coastal remote sensing database

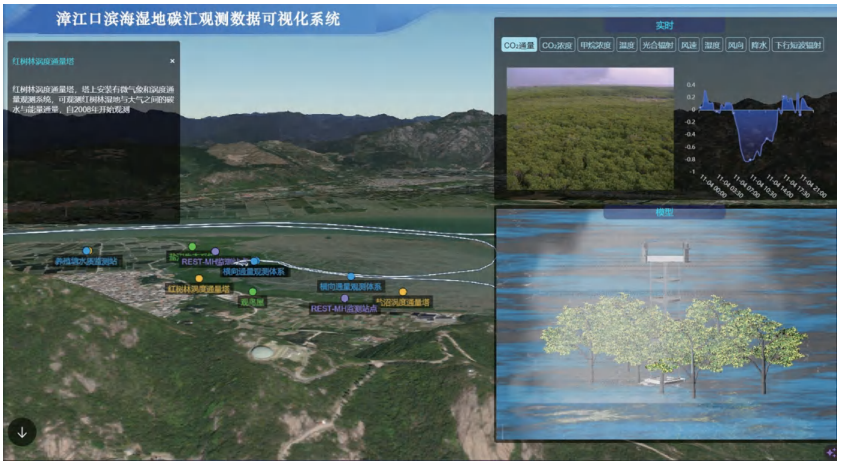
The "Coastal Remote Sensing Database" integrates multi-source remote sensing data (including resources satellite, Gaofen satellite, Hi sea-1 satellite, Hi sea-2 satellite, etc.) and professional algorithms to form dynamically updated long-term high-resolution remote sensing products. The database covers China and the global coastal zones, including national coastal zone high-resolution data and common remote sensing products, such as land use, coastal wetlands, coastline varation, water quality, aquatic ecology, marine physics and other professional applications. At present, the system has collected image data nearly 10 T, achieving scientific management and sharing service of remote sensing data and products.

漳江口滨海湿地碳汇观测数据可视化系统

The Visualization System of Zhangjiang Estuary Coastal Wetland Carbon Sink Observation Data

在台海站可视化大屏基础上升级建设漳江口滨海湿地碳汇观测数据可视化系统，支持三维全景地图的观测点位与航线图查看，实现各类观测数据与视频监控影像的实时接入，并能查看过去24小时的数据变化趋势及其详细数据；同时可以对通量塔观测数据进行实景拟真，包括天气，二氧化碳通量等。

The visualization system for monitoring the carbon sink in the Zhangjiang Estuary coastal wetland has been enhanced and developed based on T-SMART large visual screen. This system enables users to explore three-dimensional panoramic maps of observation points and voyage routes. Real-time access to diverse observation data and video surveillance images is facilitated, allowing for the visualization of data trends and detailed information from the past 24 hours. Additionally, the system can simulate real-life observation data from the flux tower, covering parameters such as weather conditions and carbon dioxide flux.



漳江口滨海湿地碳汇观测数据可视化系统界面

The web page of monitoring the carbon sink in the Zhangjiang Estuary coastal wetland

数字孪生海湾

Digital Twins of the Bay

近年来，数字孪生技术在海洋环境领域的应用得到越来越多的关注，数字孪生海洋（DTO）是通过来自真实海洋的观测与模型、数据科学和人工智能相结合，去创建适应现实世界变化的数字孪生体，数字孪生海洋对于气候变化应对和可持续发展具有重要意义。基于台海站多年积累的数据，数据中心尝试开展数字孪生海洋技术的应用，以三沙湾和厦门湾为例，通过产学研合作，分别与厦门凤凰创壹软件有限公司、上海申届云信息科技有限公司合作设计开发了“三沙湾大黄鱼养殖数字孪生系统”和“厦门湾数字孪生系统”示范应用系统。

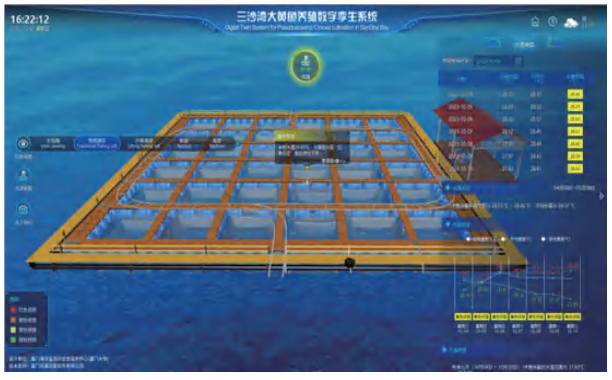
“三沙湾大黄鱼养殖数字孪生系统”利用XR数字孪生技术平台，构建全空间、全过程和全要素的三沙湾高精数字孪生底座，结合水温、盐度预测模型，实现数字孪生智慧养殖模式，增强渔业养殖抗风险能力。“厦门湾数字孪生系统”利用大模型AI等应用赋能海洋数字化，实现对台风、风暴潮等海洋灾害进行高精度预测与预警，提高防灾减灾能力。

In recent years, the utilization of digital twin technology in the Marine environment sector has garnered increasing attention. Digital Twin Ocean (DTO) integrates real ocean observations with models, data science, and artificial intelligence to construct a digital twin that dynamically adapts to changes in the real world. DTO holds significant importance for responding to climate change and fostering sustainable development.

Leveraging the wealth of data amassed by T-SMART over the years, the data center strives to apply digital twin Marine technology. Taking Sanshawan and Xiamen Bay as case studies, collaborative efforts between academia, industry, and research partners have led to the design and development of the “Sansha Bay Digital Twin System” and “Xiamen Bay Digital Twin System” in conjunction with Xiamen Phoenix Creative One Software Co., Ltd., and Shanghai Shenjiyun Information Technology Co., Ltd.

The “Sansha Bay Digital Twin System for large yellow croaker aquaculture” harnesses XR digital twin technology to establish a comprehensive, high-precision digital twin base for Sanshawan, encompassing all spatial locations, processes, and factors. By integrating a water temperature and salinity prediction model, this system enables an intelligent farming model in the digital twin realm, thereby enhancing the resilience of fishery aquaculture against risks.

On the other hand, the “Xiamen Bay Digital Twin System” capitalizes on AI-driven large-scale modeling applications to drive Marine digitalization, enabling precise prediction and early warning of Marine disasters such as typhoons and storm surges. This empowers authorities to enhance disaster prevention and mitigation capabilities effectively.



三沙湾大黄鱼养殖数字孪生系统
Sansha Bay Digital Twin System for large yellow croaker aquaculture

厦门湾数字孪生系统
Xiamen Bay Digital Twin System

Personnel

团队人员

台海站现有固定人员73人，其中研究人员62人，由43名教授、1名教授级高工、16名副教授、2名助理教授组成，其中中国科学院院士2人，欧洲科学院/俄罗斯科学院/发展中国家科学院院士1人，国家杰出青年科学基金获得者5人，国家优秀青年科学基金获得者5人，国家高层次人才1人；技术人员和管理人员共11名，由4名高级工程师、2名工程师、3名助理工程师、1名驻站科学家、1名秘书组成。

2023年，新增固定人员8人，包括2名教授，2名副教授，1名助理教授，1名工程师，2名助理工程师。陈鹭真入选厦门大学南强重点岗位教授，郭香会晋升为厦门大学教授，戴民汉获厦门大学“南强杰出贡献奖”。焦念志获自然资源部2022年度“海洋人物”荣誉称号；焦念志、张瑶团队参与合作的科研成果“海洋人工上升流技术及应用”获浙江省技术发明奖一等奖；江毓武参与合作的研究成果“潮间带贝类地理分布格局及适应机制研究”获2022年海洋科学技术奖一等奖；游伟伟获第一届中国科技青年论坛最佳策论奖。

There are 73 permanent staff in the station, including 62 research people and 11 technical personnel. Among the regular research people, there are two academicians of the Chinese Academy of Sciences, one academician of the Academy of Sciences for Developing Countries/European Academy of Sciences/Russian Academy of Sciences, 10 winners of National Science Fund for distinguished and excellent scientists, 43 professors, 1 professorate senior engineer, 16 associate professors and 2 assistant professor. Our technical staff consists of 4 senior engineers, 2 enginners, 3 assitant engineers, 1 residential scientist, and 1 secretary.

In 2023, there are 8 new members including 2 associate professors, 1 assistant professor, 1 engineer, and 2 assistant engineer. Luzhen Chen was made a Nanqiang Chair Professor of Xiamen University; Xianghui Guo was promoted to Professor; Minhan Dai was given the XMU Nanqiang Distinguished Contribution Award; Nianzhi Jiao was elected an "Ocean Figure 2023" by the Ministry of Natural Resources of China; Co-research on the “Application of Marine artificial upwelling technology” joined by team of Nianzhi Jiao and Zhang Yao won the Zhejiang Province 1st Class of Science and Technology Progress Award; Co-research on the "Geographical Distribution Pattern and Adaptation Mechanism of Shellfish in the Intertidal Zone" joined by Yuwu Jiang won the 1st Class of Marine Science and Technology Award, 2022 by the Chinese Society for Oceanography. Weiwei You won the best theroy award in the first China Science and Technology Youth Forum.

New Members

张　宇
博士 教授

Dr. Yu Zhang
Professor
E-mail:yuzhang@xmu.edu.cn

2000年获南京大学理学博士学位。2009年入职厦门大学，于2023年加入台海站。研究方向为海洋仿生、海洋生物声学、仿生探测与通信、海洋人工智能、海洋物理等。

Dr. Yu Zhang received his PhD in Science from Nanjing University in 2000. He was employed by Xiamen University in 2019, and joined T-SMART in 2023. His research interests are marine bionics, marine biological acoustics, marine artificial intelligence, marine physics.

王新红
博士 教授

Dr. Xinhong Wang
Professor
E-mail：xhwang@xmu.edu.cn

2001年获厦门大学工学博士学位，2010年入职厦门大学，于2023年加入台海站，研究方向为持久性有机污染物的生物地球化学、生态毒理学。

Dr. Xinhong Wang received her PhD in Engineering from Xiamen University in 2001. She joined Xiamen University in 2010 and T-SMART in 2023. Her research interests are biogeochemistry of persistent organic pollutants and ecotoxicology.

郑　越
博士 副教授

Dr. Yue Zheng
Associate professor
E-mail：yzheng@xmu.edu.cn

2019年获中国科学院城市环境研究所博士学位，2021年入职厦门大学，于2023年加入台海站，研究方向为滨海湿地系统的甲烷生物氧化机制及其调控、微生物碳氮耦合过程。

Dr. Yue Zheng received his PhD from Institute of Urban Environment, CAS in 2019. He was then employed by Xiamen University in 2021, and joined T-SMART in 2023. His research interests are biological oxidation mechanism and regulation of methane in coastal wetland system and microbial carbon and nitrogen coupling process in coastal wetland system

潘　峰
博士 副教授

Dr. Feng Pan
Associate professor
E-mail：fengpan@xmu.edu.cn

2019年获厦门大学海洋地质学博士学位，2020-2023年在厦门大学从事博士后研究。2023年入职厦门大学并加入台海站，研究方向为磷和重金属环境地球化学、沉积物孔隙水监测与分析技术、全球变化下的滨海湿地环境过程与生态效应。

Dr. Feng Pan received his PhD from Xiamen University in 2019, and moved to Xiamen University as a postdoc before she was employed by Xiamen University in 2023 and joined T-SMART. His research interests are environmental geochemistry of phosphorus and heavy metals, monitoring and analysis techniques of sediment pore water, environmental processes and ecological effects of coastal wetlands under global change.

洪华龙
博士 助理教授

Dr. Hualong Hong
Assistant professor
E-mail：honghl@xmu.edu.cn

2017年获厦门大学水生生物学博士学位，2018-2021年在厦门大学从事博士后研究。2021年入职厦门大学，于2023年加入台海站。研究方向为痕量金属的生物效应及污染风险评价、人类活动的环境印迹。

Dr. Hualong Hong received his PhD in hydrobiology from Xiamen University in 2017, and continued his research at Xiamen University as a postdoc. He was then employed by Xiamen University in 2021, and joined T-SMART in 2023. His research interests are biological effects and pollution risk assessment of trace metals, environmental imprinting of human activities.

方许闻
工程师

Xuwen Fang
Engineer
E-mail：xwfang@xmu.edu.cn

2018年获河海大学港口、海岸及近海工程硕士学位，2023年入职厦门大学并加入台海站，从事海洋环境模型研发、航次组织、海洋环境监测、水文仪器管理等研究工作。

Xuwen Fang received his master degree in port, coastal and offshore engineering from Hohai University in 2018. He was employed by Xiamen University and mainly work for T-SMART in 2023. He mainly works on marine environment model development, voyage organization, marine environment monitoring, and hydrological instrument management.

郑泽琦
助理工程师

Zeqi Zheng
Assistant egineer
E-mail：zeqizheng@xmu.edu.cn

2022年获中国海洋大学环境科学硕士学位。2023年入职厦门大学并加入台海站，从事浮游动物生态学等研究。

Zeqi Zheng received his master degree in environmental science from Ocean University of China in 2022. He was then employed by Xiamen University and joined T-SMART in 2023. He mainly works on zooplankton ecology research.

赵小雨
助理工程师

Xiaoyu Zhao
Assistant egineer
E-mail：zhaoxiaoyu@xmu.edu.cn

2023年获厦门大学环境科学硕士学位。2023年入职厦门大学并加入台海站，从事海洋大型底栖动物生态学和分类学等研究工作。

Xiaoyu Zhao received her master degree from Xiamen University in 2023 and then was employed by Xiamen University in 2023 and joined T-SMART. Her mainly works on ecology and taxonomy of Marine macrobenthos.

Education

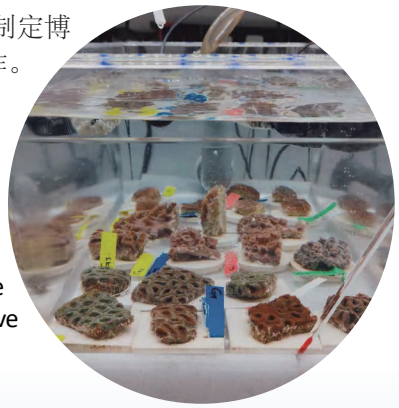
人才培养

2023年，依托台海站培养博士后1名，博士研究生10名，硕士研究生43名，在东山实验场和漳江口实验场开展珊瑚保育与河口红树林湿地相关研究达3254人天。来自厦门大学海洋与地球学院、环境与生态学院，以及生命科学学院的本科生在站内开展生产实习活动达517人天。

In 2023, T-SMART provided training for one post-doctoral student, 10 doctoral students, and 43 master's students. The research on coral conservation and estuarine mangrove wetlands conducted at the D-SMART and M-ECORS amounted to a total of 3,254 person-days. Additionally, undergraduates from the College of Ocean and Earth, the College of Environment and Ecology, and the College of Life Sciences at Xiamen University engaged in production practice activities at the station for a total of 517 days.

外籍博士生Mohamed驻站开展低温对东山珊瑚群落影响的研究，已制定博士课题研究计划，后续将由驻站科学家刘迟迟博士指导该研究的现场工作。目前已完成系统搭建，三个石珊瑚种类的样品采集和断枝分离等工作。

Mohamed, a foreign doctoral student, is stationed to conduct research on the impact of low temperature on the coral community in Dongshan. He has made a doctoral research plan, and Dr. Chichi Liu, a scientist stationed in the station, will guide the field work of the research. At present, the system construction, sample collection of three stony coral species and the separation of broken branches have been completed.



珊瑚实验

Coral experiment

Outreach & Social Services

公众教育与社会服务

建设完善科普服务平台
Building outreach platforms

2023年，东山珊瑚省级自然保护区服务中心联合台海站东山实验场挂牌成立科普宣教基地。基于野外调查及项目执行过程中搜集整理的图片、视频等素材，制作了东山海域水下漫游视频、东山海域造礁珊瑚生态系统生物多样性VLOG、珊瑚保护宣传册、珊瑚讲座课件、珊瑚及典型生物样品三维重构视频等6种不同类型的科普宣教作品。

台海站漳江口实验场在9月浙江温州举行的第十届全国红树林学术研讨会上，与北京市企业家环保基金会签署红树林科普服务合作备忘录，双方发挥各自的优势，开展公益性的红树林科普活动。全国红树林科普服务平台建设正在积极推进中，并落实了第一笔20万的建设经费。

珊瑚宣教中心
Coral popularization and education base

In 2023, Dongshan Coral Provincial Nature Reserve Service Center and D-SMART collaborated to establish a science popularization and education base. Leveraging imagery, videos, and field research materials, the project has made a diverse range of educational materials such as underwater roaming videos, vlogs highlighting the biodiversity of the reaf-building coral ecosystem in Dongshan Bay, coral protection brochures, lecture courses, and 3D reconstruction videos featuring coral and typical biological samples.

During the 10th National Mangrove Academic Seminar in Wenzhou, Zhejiang Province, M-ECORS and the Beijing Entrepreneurs Environmental Protection Foundation signed a memorandum of cooperation to advance mangrove science popularization services. Both parties will capitalize on their strengths to conduct outreach activities aimed at promoting mangrove science awareness. At the same time, efforts to establish a national mangrove science popularization service platform have been actively pursued, with the initial construction fund of 200,000 yuan already put into effect.

台海站东山实验场建立海洋开放日制度，与东山县人民政府、东山县自然资源局，福建东山城投集团有限公司、共青团东山县委员会、东山珊瑚省级自然保护区服务中心、华为技术有限公司、福建城投生态环境等政府部门与企业举办5场专题公众科普活动，活动丰富多彩，包括专题讲座、对话沙龙、动手实验、VR水下漫游等形式，反响热烈。为公众提供全面了解海洋科学的窗口。同时台海站积极参与厦门大学海洋开放日活动，利用VR水下漫游、VR红树林漫步、显微镜观察浮游动物、照片与海报科普等形式，促进公众对于珊瑚与红树林了解，增强了公众的保护意识。

D-SMART also established the Marine Open Day system, and hold 5 outreach events with government departments and enterprises such as Dongshan County People's Government, Dongshan County Natural Resources Bureau, Dongshan Coral Provincial Nature Reserve Service Center, Huawei Technology Company, and etc. These events engaged the public through special lectures, dialogue salons, hands-on experiments, VR underwater roaming and other forms, to promote the understanding of marine science between the audience. T-SMART also participated in Ocean Open Day activities of Xiamen University, promoted public understanding of corals and mangroves, and enhance public awareness of protection using VR underwater roaming, VR mangrove walking, microscope observation of zooplankton, photos and posters.

活动现场照片
Photos of Ocean Open Day

第七届全国净滩公益活动东山分会场

The 7th National Beach Cleaning Activity

2023年10月12日，由中国海洋发展基金会主办，东山县海洋保育志愿者协会承办，台海站东山实验场、漳州市海有爱文化科技有限公司共同协办的第七届全国净滩公益活动（东山分会场）在东山金銮湾海滩顺利举行。东山实验场驻站技术人员孙圣垚、蔡其思及驻站研究生共同参与该活动。

On Octorber 12, 2023, sponsored by China Oceanic Development Foundation, organized by Dongshan County Volunteer Association, co-organized by D-SMART and Zhangzhou Love sea cluture Technology company, the seventh National Beach Cleaning Activity (Dongshan parallel sessions) was successfully held at Dongshan Jinluan Bay Beach. Our members Shengyao Sun and Qisi Cai, joined this acitivity with graduate students from Xiamen University.

第二十八届全国大学生绿色营——“红树林蓝碳与气候变化主题营”

The 28th National Green Camp for College Students - "Mangrove, Blue Carbon and Climate Change"

2023年8月17-25日，第二十八届全国大学生绿色营活动在漳江口实验场举行。来自全国不同高校不同专业的23名大学生参与了本次活动。台海站固定研究人员陈鹭真教授和漳江口实验场高级工程师张雅棉参与了开营仪式，并分别为营员们带来“红树林生态系统与蓝碳方法学”和“红树林生态修复”的课程。漳江口实验场博士生张林带来了题为“红树林生态监测与科研工作交流”的分享。

From August 17 to 25, 2023, the 28th National Green Camp for College Student was held in M-ECORS. Twenty-three college students from different universities and majors across the country participated in this activity. Prof. Luzhen Chen and senior engineer Yamean Zhang participated gave lessons on "Mangrove ecosystem and Blue carbon Methodology" and "Mangrove ecological restoration" to the campers respectively in the opening ceremony of the camp. Lin Zhang, a

第八届MEL研究生论坛科普专场

The 8th MEL Graduate Forum

2023年7月22日上午，第八届MEL研究生论坛科普专场在东山实验场成功举办。论坛特别邀请了福建省东山第二中学50位高一学生来到东山实验场，论坛结合专题讲座与科普摊位游园方式进行公众科普。内容涉及海洋生物、海洋物理、海洋化学和海洋地质四个方向。通过引导同学们亲身体验，感受海洋环境科学的魅力，激发对海洋的关注和热爱。

On July 22, 2023, the 8th MEL Graduate Forum was successfully held at D-SMART. The forum featured special lectures and interactive science booths, showcasing disciplines including marine biology, marine physics, marine chemistry, and marine geology. A group of 50 senior high school students from Dongshan No. 2 Middle School were invited to visit D-SMART, where they had the opportunity to immerse themselves in the world of Marine environmental science. Through hands-on experiences and engagements, the students were inspired to develop a deeper appreciation and affection for the ocean.

厦门大学-槟榔中学2023暑假夏令营“滨海湿地红树林暑期研学活动”

2023 Summer Research activity of Xiamen University-Binglang Middle School "Coastal Wetland and Mangrove Summer Research"

2023年7月8-10日，厦门大学-槟榔中学2023年暑期研学活动在漳江口实验场举行。本期活动以“滨海湿地红树林保护”为主题，由漳江口实验场、滨海湿地生态系统教育部重点实验室和厦门市槟榔中学联合举办，漳江口红树林国家级自然保护区协办。本次研学活动共举办了3场科学报告、3场野外调研，以及科学小实验、小组讨论、海报展示等。通过三天的课程学习和野外实践，学生们对红树林、红树林鸟类和底栖动物以及互花米草除治有了进一步的认识，增强了师生对红树林生态系统的保护意识。

活动现场合照

Group photo of the patrol activity

The 2023 Summer Research activity of Xiamen University-Binglang Middle School took place in M-ECORS from July 8-10, 2023. With the theme "Protect Coastal Wetland Mangrove Forest", this camp was jointly organized by M-ECORS, Key Laboratory of Coastal Wetland Ecosystem of the Ministry of Education, and Xiamen Binglang Middle School, co-organized by Zhangjiangkou Mangrove National Nature Reserve. It included 3 scientific reports, field investigations, scientific experiments, group discussions, and poster display. Through this three-day program and field practice, students gained a deeper understanding of mangroves and their associated wildlife such as birds and benthos. They also learned about *spartina alterniflora* control while raising awareness among teachers and students about the importance of protecting mangrove ecosystems.

2023年少年蓝色先锋培养计划

2023 Junior Blue Pioneers Training Program

2023年7月18-28日，由桃花源生态保护基金会、中华环境保护基金会联合发起的海洋教育重点项目，依托厦门大学近海海洋环境科学国家重点实验室、70.8海洋媒体实验室及台海站共同举办的“少年蓝色先锋培养计划”顺利进行。20位来自全国各地的少年们，集结漳江口和东山实验场，完成海洋人才培养之旅。本次活动中，台海站邀请加拿大英属哥伦比亚大学（UBC）海洋与渔业研究所教授Daniel Pauly为同学们开设国际讲师专题，漳江口实验场高级工程师张雅棉、东山实验场驻站科学家刘迟迟担任科学导师，漳江口实验场助理工程师泽郑琦、东山实验场工程师孙圣垚和助理工程师蔡其思，以及台海站秘书薛锦华均参与了本次活动。

黄邦钦向Pauly教授赠送少蓝学员画作

Bangqin Huang presents Prof. Pauly with a painting painted by students from Junior Blue Pioneers Training Program

"Junior Blue Pioneers Training Program" was successfully concluded at the D-SMART from July 18th to 28th, 2023. It is a key marine education project, jointly launched by theThe Paradise International Foundation and the China Environmental Protection Foundation, relied on the State Key Laboratory of Marine Environmental Science (Xiamen University), 70.8 Media Lab, and T-SMART. 20 youngsters from all over the country gathered at the M-ECORS and D-SMART to complete their journey for marine talent cultivation. T-SMART invited Daniel Pauly, professor of the Institute of Ocean and Fisheries of the University of British Columbia (UBC), Canada, to gave an international lecturer topic for the students; Senior engineer Yamian Zhang, and resident scientist of D-SMART Chichi Liu were joined as scientific tutors; Assistant engineer Zeqi Zheng, Qisi Cai, engineer Sun Shengyao, and T-SMART secretary Jinhua Xue all participated in this activity.

福建省第27届世界湿地日宣传活动

Promo-activities for the 27th World Wetlands Day in Fujian Province

2023年2月2日，“福建省第27届世界湿地日宣传活动”专家讲座在漳江口实验场综合楼举办，近50名嘉宾参与了本次讲座。台海站副站长王文卿教授作为主讲专家为参会嘉宾介绍了红树林修复和生物多样性保护，并在漳江口红树林湿地修复示范区为环保志愿者和学生现场讲解红树林种植。

On February 2, 2023, the expert lecture of "The 27th World Wetland Day Publicity Activity in Fujian Province" was held in M-ECORS, with nearly 50 guests participating. As the main lecturer, Wenqing Wenqing, associate director of T-SMART, introduced mangrove restoration and biodiversity protection to the guests, and explained mangrove planting for environmental volunteers and students in the Zhangjiang Estuary mangrove wetland restoration demonstration area.

海洋传感器——海洋主题科普艺术展

Ocean sensors - Marine theme science exhibition

经前期与台海站东山实验、厦门大学近海海洋环境科学国家重点实验室和70.8媒体实验室的交流探讨，2023年9月15日—10月29日，中央美术学院联合厦门大学策划的“海洋传感器——海洋主题科普艺术展”在北京展出。本次展览由中央美术学院实验艺术与科技艺术学院、中央美术学院科技艺术研究院、近海海洋环境科学国家重点实验室、厦门大学海洋与地球学院、厦门大学环境与生态学院、厦门大学科考船运行管理中心、福建台湾海峡海洋生态系统国家野外科学观测研究站及70.8海洋媒体实验室共同主办。

张宇在开幕式上讲话

Yu Zhang spoke at the opening ceremony

马剑作科普讲座

Jian Ma gave a lecture

9月15日下午展览开幕并开设第一场科普讲座，台海站站务委员会委员、厦门大学海洋与地球学院副院长张宇教授在开幕式上讲话，台海站东山实验场副站长、厦门大学环境与生态学院副院长马剑教授作主题为“海洋观测的末梢——海洋传感器”的讲座。10月16日，第二场科普讲座上，东山实验场驻站科学家刘迟迟作“东山站的日与夜——珊瑚守护者的日常”的分享，进一步普及珊瑚保育相关知识。此次展览促进了公众对海洋科研工作的了解，同时结合科学技术与艺术文化，提升公众的海洋意识。

After preliminary discussions with the D-SMART, MEL, and the 70.8 Media Lab, the "Ocean Sensors -- Science & Art Exhibition for Ocean" planned by the Central Academy of Fine Arts and Xiamen University was exhibited in Beijing from September 15 to October 29, 2023. The exhibition is co-sponsored by the School of Experimental Art and Scientific Art of the Central Academy of Fine Arts, the Institute of Scientific Art of the Central Academy of Fine Arts, MEL, the School of Ocean and Earth Sciences of (COE, Xiamen University), the School of Environment and Ecology (CEE, Xiamen University), the research vessel TAN KAH KEE, the T-SMART and the 70.8 Marine Media Lab.

On the afternoon of September 15, the exhibition opened and the first science lecture was held. Prof. Yu Zhang, member of T-SMART and vice president of COE, spoke at the opening ceremony. Jian Ma, deputy director of D-SMART and vice president of CEE, gave a lecture with the theme of "The Ending of Ocean Observation -- Ocean Sensors". On October 16, the second science lecture was held, and Chichi Liu, the station scientist of D-SMART, shared the “Day and Night of D-SMART -- The Daily Life of Coral Guardians" to further appealing coral conservation. The exhibition promotes the public's understanding of marine scientific research while combining science and technology with art and culture to enhance the public's awareness of the ocean.

蓝碳生态系统碳汇交易撬动生态资源价值化

Leverages the value of ecological resources: blue carbon ecosystem carbon sink trading

近年来，台海站固定研究人员陈鹭真教授团队依据我国滨海蓝碳生态系统长期观测数据和特征参数，有序开发红树林、滨海盐沼等滨海蓝碳方法学，达到了可监测、可报告、可核查的要求，完成了蓝碳增汇价值的量化，凸显了红树林和滨海盐沼生态增汇、综合生态服务功能和应对气候变化能力的协同提升。团队于今年5月完成《福建省修复红树林碳汇项目方法学》备案公开；9月完成了《滨海盐沼生态修复项目碳汇计量与监测方法》备案公开。为蓝碳生态产品价值实现和蓝碳交易提供了技术依据，对助力"双碳"目标等具有重要现实意义。

9月26日上午，江苏盐城珍禽国家级自然保护区和腾讯公司顺利完成江苏盐城滨海盐沼生态修复碳汇项目蓝碳生态系统碳汇交易签约仪式。该项目中盐沼修复产生的净碳汇量测算依托《滨海盐沼生态修复项目碳汇计量与监测方法》开展。此次签约顺利达成我国首笔盐沼碳汇交易，标志着我国盐沼蓝碳交易"零的突破"，实现了生态系统价值的可持续发展，具有先行示范作用。该项目落户盐城世界自然遗产地，凸显滨海湿地生态系统的保护和修复成效，对于减缓气候变暖、保护生物多样性和维持生态系统健康发展具有积极意义。

In recent years, Luzhen Chen's team at T-SMART has developed a comprehensive coastal blue carbon methodology focusing on mangroves and coastal salt marshes.This methodology, based on long-term observation data and characteristic parameters of China's coastal blue carbon ecosystem, fulfills the requirements for monitoring, reporting, and verification. By quantifying the incremental value of blue carbon, the team showcases the synergistic enhancement of the ecological sink provided by mangroves and coastal salt marshes, as well as their integrated ecological service function and climate change mitigation capabilities. The team achieved significant milestones this year, including the completion of the "Fujian Province Mangrove Carbon Sink Restoration Project Methodology" in May and the filing and publicizing of the "Carbon Sink Measurement and Monitoring Method of Coastal Salt Marsh Ecological Restoration Project" in September. These achievements lay a technical foundation for realizing the value of blue carbon ecological products and facilitating blue carbon trading, aligning with the goal of reducing carbon emissions.

A noteworthy event took place on September 26, when Jiangsu Yancheng Rare Birds National Nature Reserve and Tencent signed a landmark agreement on blue carbon ecosystem carbon sink trading for the Jiangsu Yancheng Coastal Salt Marsh ecological restoration project. This project, guided by the "Carbon Sink Measurement and Monitoring Method of Coastal Salt Marsh Ecological Restoration Project," marked China's first salt marsh carbon sink trade, signaling a significant advancement in blue carbon trading and promoting the sustainable development of ecosystem values. Situated in the Yancheng World Natural Heritage Site, the project underscores the importance of protecting and restoring coastal wetland ecosystems. It plays a crucial role in combating climate change, preserving biodiversity, and fostering the healthy development of ecosystems. Overall, these initiatives have practical significance in achieving the "double carbon" goal and setting an example for future conservation efforts.

"生态产品价值实现平台"滨海盐沼生态修复项目碳汇计量与监测方法
CEEX: Carbon Sink Measurement and Monitoring Method of Coastal Salt Marsh Ecological Restoration Project

签约双方与见证人合影
Photo of signing

日本囊对虾“闽海2号”新品种选育

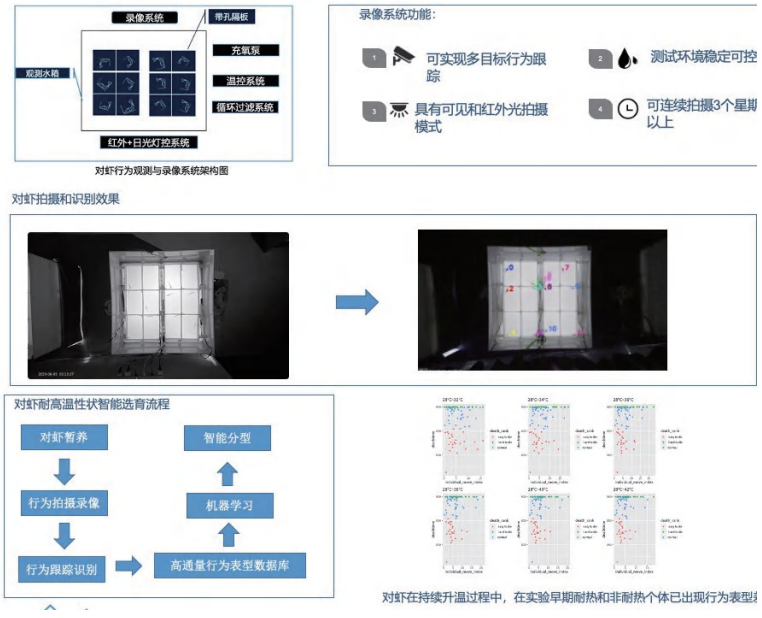
Precise and intelligent phenotypic evaluation technologies for shrimp have been continuously developed and applied to the selective breeding of the new variety *M. japonicus* "Minhai No. 2".

该研究通过引入计算机视觉技术到对虾的表型测量过程中，避免了人工测量精准度低、耗时长和无法大规模测评等问题，通过多种视觉算法可获取对虾组织、生理、形态和行为高通量表型，建立了一整套对虾表型精准智能测评技术，可以自动识别对虾尾部组织蜕皮时期、对虾心率、对虾活体体长、对虾运动行为和摄食行为等多种表型数据，建立了多维高通量表型数据库，通过引入机器学习等人工智能算法，以及数据建模及可视化，该技术已经成功应用于日本囊对虾“闽海2号”耐高温新品种选育工作。

台海站自建站以来，已在东山实验场建立了对虾表型智能检测与精准测评技术中心，通过联合日本囊对虾东山育种基地，已经形成了完整的日本囊对虾分型-育种技术流程，通过该技术流程，构建了“闽海2号”耐高温家系52个，其中，耐高温品系“闽海2号”能够完全耐受37℃的高水温，该项目立足于东山实验场，获得了东山县委县政府的全面重视，已成为东山走出“蓝色粮仓”“芯”路径的重点推广项目之一，最为立足于东山的养殖技术产-学-研重点项目，该项目的成功将会为福建省对虾养殖带来极大的经济效益。

By incorporating computer vision technology into the phenotypic measurement process of shrimp, this study effectively addresses issues such as low accuracy, time consumption, and the inability to conduct large-scale evaluations associated with manual measurements. Through a range of visual algorithms, the study achieves high-throughput phenotyping of shrimp tissue, physiology, morphology, and behavior, establishing a precise intelligent evaluation technology for shrimp phenotypes. It enables automatic identification of various phenotypic data, including the molting period of shrimp tail tissue, heart rate, body length, locomotion behavior, and feeding behavior, while creating a multidimensional high-throughput phenotypic database. Moreover, by integrating artificial intelligence algorithms like machine learning, data modeling, and visualization, this technology has been successfully applied to the selective breeding work of the new high-temperature-tolerant *Marsupenaeus japonicus* variety “Minhai No. 2”.

Since its establishment, the T-SMART has set up a Shrimp Phenotype Intelligent Detection and Precision Evaluation Technology Center at the D-SMART. A comprehensive technical process for typing and breeding *M.japonicus* has been developed in collaboration with the Dongshan Shrimp Breeding Base. Utilizing this technology, 52 high-temperature-tolerant families of "Minhai No. 2" were developed, with the strain fully tolerating water temperatures up to 37°C. This project, based at the T-SMART, has garnered significant attention from the Dongshan County Party Committee and local government, emerging as a key initiative in propelling Dongshan beyond its traditional agricultural focus towards new economic opportunities. The success of this endeavor is poised to deliver substantial economic benefits to shrimp farming in Fujian Province, heralding a positive shift in the regional aquaculture landscape.



对虾精准智能测评耐高温性状及选育方法

Accurate and intelligent evaluation of high temperature tolerance traits and breeding methods of shrimp

福建罗源红树林科普及全国红树林生态养殖培训

Mangrove science popularization in Luoyuan, Fujian and national mangrove ecological restoration training

为兼顾红树林修复和社区居民增收，在中国香港恒生银行和北京市企业家环保基金会的支持下，厦门大学在福建罗源县罗源湾成功种植红树林100亩，并通过设立科普宣传栏、举办科普讲座和生态养殖培训班、生态养殖考察等，希望能引导社区居民发展生态养殖，增加收入。

2023年6月3-4日，在罗源县松山镇巽屿村举办了以福州市及罗源县林业干部、乡镇村干部、养殖户和恒生银行员工为对象的科普讲座。2023年11月，由王文卿带队，带领罗源县领导、林业局干部、乡镇村干部和养殖户代表对广西和浙江沿海地区红树林生态养殖进行了专题考察。试图寻找一种红树林友好的养殖模式，旨在不破坏红树林生态系统的结构和功能前提下，最大限度地提高红树林的经济效益，探索红树林修复与利用的新模式，达到对红树林资源“在保护中利用，在利用中保护”的目的，为可持续经营提供依据。

考察广西红树林研究中心竹林基地鱼塘生态养殖
Investigate the ecological aquaculture of fish pond in bamboo forest base of Guangxi Mangrove Research Center

Through the generous support of Hang Seng Bank of Hong Kong, China, and the Beijing Entrepreneurs Environmental Protection Foundation, Xiamen University has successfully initiated a mangrove reforestation project spanning 100 hectares in Luoyuan Bay, Luoyuan County, Fujian Province. This endeavor aims to restore mangrove ecosystems while enhancing the livelihoods of local residents. The project aspires to encourage community members to engage in sustainable aquaculture practices by leveraging educational initiatives such as informative displays, scientific lectures, training workshops on ecological aquaculture, and regular inspections to boost income opportunities.

On June 3-4, 2023, a public lecture on environmental science was organized in Xunyu Village, Songshan Town, Luoyuan County, targeting forestry officials, local government officers, farmers, and Hang Seng Bank employees from Fuzhou and Luoyuan County. In November 2023, under the leadership of Wang Wenqing, a team comprising officials from Luoyuan County, forestry bureau personnel, local government representatives, and farmers conducted a comprehensive investigation on mangrove ecological practices along the coasts of Guangxi and Zhejiang. The objective was to develop a sustainable and mangrove-friendly aquaculture model that maximizes economic returns from mangrove resources while preserving the ecosystem’s integrity and functionality.

This initiative aims to pioneer a new approach towards mangrove restoration and utilization, emphasizing the principle of “using for protection and protecting for utilization.” By exploring innovative strategies for mangrove resource management, the project endeavors to establish a blueprint for sustainable practices that uphold the delicate balance between conservation and economic prosperity in the realm of mangrove ecosystems.

科技助力东山珊瑚保护

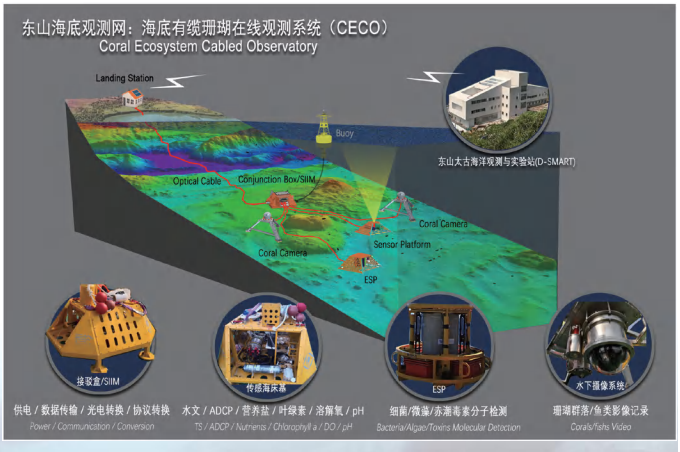
Enhancing coral conservation in Dongshan Bay through technological support

东山实验场技术团队以自主研发的水下高清摄像头为核心部件，在东山珊瑚省级自然保护区核心区布放海底有缆珊瑚生态在线观测系统（Coral Ecosystem Cabled Observatory，简称“CECO”）实现了典型造礁珊瑚群落生长状态、水动力、水质、生物多样性等参数的实时监测。2023年团队还结合社会经济状况、海域开发利用和保护、现状调查数据和历史资料，开展珊瑚群落物种多样性、健康状态影响因素、变化趋势等分析工作，对东山珊瑚生态系统健康进行评估，编制完成《东山海域造礁石珊瑚资源历史数据整编报告》，向保护区管理部门提供管理建议措施。

驻站科学家刘迟迟受聘为漳州蓝碳司法特约研究员、驻站工程师孙圣垚受聘为东山县人民检察院“公益诉讼观护员”，协助在保护区管理部门在保核心区设立岸基视频监控系统、界址标识、海上警戒线、警示标语牌等设备，用于日常监管，特别是严防渔业生产活动（下锚、底拖网）和旅游活动（潜水、赶海、盗采、误采等）进入保护区核心区，对造礁珊瑚造成破坏，并为海洋生态保护公益诉讼案件提供线索。

With the proprietary underwater high-definition camera serving as the central component, the technical team at D-SMART has established the Coral Ecosystem Cabled Observatory (CECO) within the core area of the Dongshan Coral Provincial Nature Reserve. CECO enables real-time monitoring of vital parameters including the growth status of typical reef-building coral communities, water dynamics, water quality, biodiversity, and other ecological indicators. In 2023, the team conducted an in-depth analysis of coral community species diversity, factors influencing their health, and emerging trends in conjunction with social and economic factors, as well as the development, utilization, and protection of the sea area. This analysis was based on survey data, historical data, and an assessment of the health of the Dongshan coral ecosystem, resulting in the compilation of a comprehensive report on the historical data of reef-building coral resources in the Dongshan Sea Area, along with management recommendations for the protected area management department.

Furthermore, Our resident scientist, Chichi Liu, was appointed as a specialresearcher of Zhangzhou Blue Carbon Judiciary, providing technicaladvisory services for the judicial work of blue carbon at DongshanCounty Court. Our technical personnel, Shenyao Sun, was designated asthe 'observer for public interest litigation' of Dongshan County Procura-torate. They are tasked with supporting the conservation area management department in establishing a shore-based video surveillance system, demarcating boundary sites, implement-ing maritime warning technology, and installing warning signs and other equipment within the core area for daily supervision. Of particular impor-tance is the stringent prevention of activities such as anchoring and bottom trawling related to fishery production, as well as tourism-related activities like diving, sea driving, illegal mining, and unauthorized extraction from entering the core area of the reserve, thereby safeguarding against damage to reef-building corals and providing evidence for public interest litigation cases related to marine ecological preservation.



东山海底观测网

Underwater Observation System in Dongshan

Exchange & Collaboration

合作交流

第十届“海峡两岸海洋环境监测及预报技术研讨会”

The 10th Symposium on Marine Environment Monitoring and Forecasting Technologies

2023年11月1日，第十届“海峡两岸海洋环境监测及预报技术研讨会”在厦门大学召开。会议由台海站、台湾海洋大学海洋工程科技中心、台湾“中央”大学水文与海洋科学研究所、福建省海洋预报台、闽江学院物理与电子信息工程学院等单位联合主办，台海站承办。

会议采用线上线下同步的方式进行，来自海峡两岸二十多家科研院所、政府部门、企业单位的一百余名人员参会交流。两岸专家学者纷纷发表感言，表达了希望能够继续加强两岸在海洋环境监测及预报等领域的合作交流，进一步拓展研究领域，共同推动两岸观测技术发展，提高学术成果应用能力，为海上安全尤其是防灾减灾方面作出贡献。两岸学者共同期盼2025年在北京召开的第十一届会议上重逢相聚。

On November 1, 2023, the 10th Symposium on Marine Environment Monitoring and Forecasting Technologies was held in Xiamen University. The conference was jointly sponsored by T-SMART, Marine Engineering Science and Technology Center of Taiwan Ocean University, Institute of Hydrology and Marine Science of Taiwan “Central” University, Fujian Ocean Forecast Station, College of Physics and Electronic Information Engineering of Minjiang University and other units.

The meeting was conducted online and offline simultaneously. More than 100 personnel from more than 20 scientific research institutes, government departments and enterprises participated in the exchange. Experts and scholars have made speeches, expressing the hope that can continue to strengthen the cooperation and exchanges in the field of marine environmental monitoring and forecasting, further expand the research field, jointly promote the development of cross-strait observation technology, improve the application of academic achievements, and make contributions to maritime safety, especially disaster prevention and reduction. Scholars look forward to meeting again at the 11th Congress to be held in Beijing in 2025.

台湾海峡及周边海域关键海洋过程学术研讨会

Symposium on Critical Marine Processes in the Taiwan Strait and Surrounding Waters

2023年5月17日，台湾海峡及周边海域关键海洋过程学术研讨会在厦门召开。会议由自然资源部第三海洋研究所（简称“海洋三所”）和厦门大学联合主办，台海站协办。来自海峡两岸的三十多家涉海高校和科研院所160名专家学者和研究生参会交流。会议围绕台湾海峡及周边海域海洋生物生态、海洋地质、海洋动力、海洋生物地球化学循环等四个主题展开研讨，台海站站长黄邦钦教授作“台湾海峡及邻近海域浮游生物群落演变及其对多尺度物理过程的响应”大会特邀报告，现场交流气氛活跃。

黄邦钦作大会特邀报告

Bangqin Huang presented a keynote speech

On May 17, 2023, Symposium on Critical Marine Processes in the Taiwan Strait and Surrounding Waters was held in Xiamen. The conference was jointly sponsored by the Third Institute of Oceanography under the Ministry of Natural Resources (Three Ocean Institutes) and Xiamen University, with the support of T-SMART. More than 160 experts, scholars, and postgraduates from over 30 sea-related universities and research institutes on both sides of the Taiwan Straits convened at the event. The primary focus of the meeting revolved around four key themes: marine biology ecology, marine geology, ocean dynamics, and marine biogeochemical cycles within the Taiwan Strait and its surrounding waters. Prof. Bangqin Huang, the director of T-SMART, presented a special keynote address on the “Evolution and response of plankton communities to multi-scale physical processes in the Taiwan Strait and its adjacent waters” during the conference.

2023年数字孪生海洋国际峰会

International Digital Twins of the Ocean 2023

11月10日，2023年数字孪生海洋国际峰会（International Digital Twins of the Ocean 2023, DITTO Summit 2023）在厦门国际会议中心酒店开幕。本次会议由“数字孪生海洋”（DITTO）国际大科学计划发起主办，福建海洋创新实验室（筹）和近海海洋环境科学国家重点实验室（厦门大学）共同承办，台海站协办。来自19个国家和地区450名海洋领域知名专家、学者及业界各方代表参会。本次峰会围绕感知、模拟、可视等主题，邀请全球专家学者共同参与，并通过组织产学研用研讨会、“数字化深海典型生境”国际大科学计划启动研讨会、青年海洋科学家论坛以及系列卫星活动（Satellite Events）等方式开展多层次、多元化、跨界合作的深入探讨。

柴扉做大会报告
Fei Chai presented at the conference

On November 10, the International Digital Twins of the Ocean 2023 (DITTO Summit 2023) commenced at the Xiamen International Convention Center Hotel. The summit was hosted by the “Digital Twin Ocean” (DITTO) international Big Science program, with co-sponsorship from the Fujian Marine Innovation Laboratory and the State Key Laboratory of Offshore Marine Environmental Science at Xiamen University, in collaboration with T-SMART. A total of 450 distinguished experts, scholars, and industry representatives from 19 countries and regions gathered for the conference. The summit placed a strong emphasis on the themes of perception, simulation, and visualization, inviting global experts and scholars to actively participate. Furthermore, the event featured industry-university-research seminars, the “Digital Deep Sea Typical Habitat” international Big Science program launch seminar, a young Marine scientists forum, and a series of Satellite Events designed to facilitate in-depth discussions and foster multi-level, diversified, cross-border cooperation.

第九届全国稳定同位素生态学学术研讨会暨中国生态学学会稳定同位素生态专业委员会2023年学术年会

The 9th National Symposium on Stable Isotope Ecology - 2023 Annual Conference of Stable Isotope Ecology Committee of the Chinese Ecological Society

2023年11月25日至27日，第九届全国稳定同位素生态学学术研讨会暨中国生态学学会稳定同位素生态专业委员会2023年学术年会在厦门召开。本次会议由中国生态学学会稳定同位素生态专业委员会、厦门大学主办，厦门大学环境与生态学院、滨海湿地生态系统教育部重点实验室承办，清华大学地球系统科学系、深圳海关食品检疫中心、台海站协办。来自稳定同位素研究与应用领域的100多所高校、科研院所和企事业单位近400位专家学者、业界代表齐聚厦门互动交流，是历届线下参会规模最大的会议。

会后，参会代表实地考察了福建台湾海峡生态系统国家野外科学观测研究站的漳江口实验场和东山实验场、厦门大学近海海洋环境科学国家重点实验室“大型仪器与技术服务中心”、以及厦门大学八闽园滨海湿地全球变化温室群。

From November 25 to 27, 2023, the 9th National Symposium on Stable Isotope Ecology and the 2023 Annual Conference of the Stable Isotope Ecology Committee of the Chinese Ecological Society was held in Xiamen. The conference was organized by the Professional Committee of Stable Isotope Ecology of the Chinese Ecological Society and Xiamen University, with support from the College of Environment and Ecology (CEE, Xiamen University) and the Key Laboratory of Coastal Wetland Ecosystem of the Ministry of Education. Additionally, the Department of Earth System Science (Tsinghua University), the Food Quarantine Center of Shenzhen Customs, and T-SMART served as co-organizers. The event successfully brought together nearly 400 experts, scholars, and industry representatives from over 100 universities, research institutes, enterprises, and institutions specializing in stable isotope research and application, making it the largest offline conference of its kind.

参会代表考察台海站漳江口实验场和东山实验场
Participants visiting M-ECORS and D-SMART

Following the conference, participants visited the M-ECORS and D-SMART, the “Large Instrument and Technical Service Center” of the State Key Laboratory of Offshore Marine Environmental Science at Xiamen University, as well as the Global Change Warming Chamber Group of Coastal Wetlands in Bamin Garden at Xiamen University.

台海站第一届学术委员会第二次会议

The Second Meeting of the First Academic Committee

12月1日上午，由傅伯杰院士主持的台海站第一届学术委员会第二次会议在台海站漳江口实验场召开。与会专家肯定了台海站2023年的工作，台海站在科学观测和实验、科学研究、学术交流与示范服务中均取得显著成果，进一步聚焦的观测目标与区域有助于台海站开展长期的、可持续的科学观测与实验，产出系统性科研成果。同时，专家们为台海站的建设发展提出了建设性意见建议，他们希望台海站进一步提升观测系统性和原位智能观测能力，整合团队，系统性研究典型生态系统生态过程，形成重大科研成果，从科学的角度为政府决策提供科技支撑，进一步提高成果转化和示范能力。

会议线上合影

Photo of the Conference

The second meeting of first Academic Committee was held on December 1, 2023. T-SMART reported the achievements in scientific observation and experiment, scientific research, academic exchange and demonstration services in 2023, which affirmed by members of Academic Committee. They believe the further focused observation targets and regions will help T-SMARTcarry out long-term and sustainable scientific observation and experiment, and produce systematic scientific research results. They also put forward constructive suggestions on the construction and development of T-SMART. They aim for the station to enhance its systematic observation and in-situ intelligent observation capabilities, foster team integration, conduct systematic research on the ecological processes of typical ecosystems, generate significant scientific research outcomes, offer scientific and technological support for government decision-making based on a scientific standpoint, and enhance the ability to effectively transform and demonstrate research findings.

2023年全国红树林保护与修复研讨会

Conference on Mangrove Protection and Restoration

现场考察图片

Photo of the conference

2023年12月3日至6日，“2023年全国红树林保护与修复研讨会”在厦门大学漳江口红树林基地顺利举办。本次会议以“红树林修复与互花米草除治的耦合”为主题，由国家林业和草原局湿地管理司、中国湿地保护协会、福建省湿地保护中心主办，红树林基金会（MCF）与厦门大学福建台湾海峡海洋生态系统国家野外科学观测研究站（以下简称台海站）承办，滨海湿地生态系统教育部重点实验室（厦门大学）、中国生态学学会红树林生态专业委员会、漳江口红树林国家级自然保护区管理局、福建省滨海湿地保护与生态恢复工程技术研究中心、福建省生态学会、中国生态学学会科普基地（福建漳江口）共同协办。来自全国各省市自然资源、林草相关部门，各红树林保护地、相关科研院所和企业单位100余人参与了本次活动。本次会议提高了我国各省市自然资源、林草相关部门，红树林保护地管理人员，以及一线工作者对红树林有效保护修复以及互花米草防治的认识，同时增进了公众对红树林的了解和保护意识。

On December 3-6th, the Conference on the Mangrove Protection and Restoration was successfully held with the theme of "The Coupling of Mangrove Restoration and *Sparsparia alterniflora* Control". The conference was hosted by the Department of Wetland Management of National Forestry and Grassland Administration, China Wetland Conservation Association and Fujian Wetland Conservation Center, and hosted by Mangrove Wetland Conservation Foundation (MCF) and T-SMART. Co-organized by Key Laboratory of Coastal Wetland Ecosystem of Ministry of Education (Xiamen University), Ecological Society of China, Zhangjiangkou Mangroves National Nature Reserve, Fujian Coastal Wetland Protection and Ecological Restoration Engineering Technology Research Center, and etc. Over 500 people from mangrove reserve, relative institutes and enterprises participated in this activity and raised the awareness of effective mangrove conservationand restoration and *Sparsparia alterniflora* Control.

野外台站交流

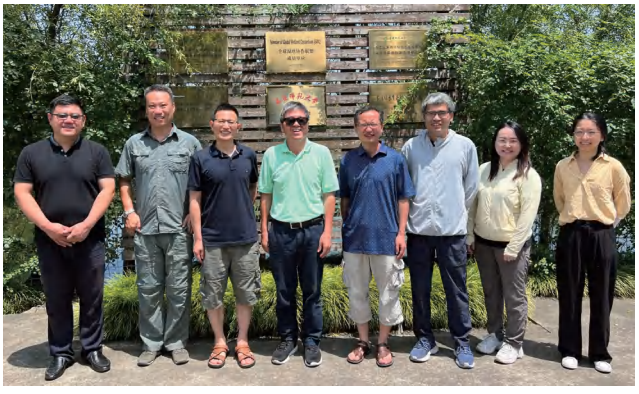
Exchange with other field stations

2023年7月3-5日，台海站黄邦钦、江毓武、王文卿、马剑等带队前往“太湖湖泊生态系统国家野外站（中科院地湖所）”、“长江河口湿地生态系统国家野外站（复旦大学）”，“长江三角洲河口湿地生态系统教育部野外站（华东师范大学）”对野外站场地与实验室、观测设施与实验设备进行实地考察，并就野外站运行管理、人员配置、成果统计等方面开展座谈交流，共同探讨野外站建设与发展的难点与解决途径。

在江苏太湖湖泊生态系统国家野外科学观测研究站合照

Group photo at National Observation and Research Station for the Tai Lake Ecosystem

From July 3-5, 2023, Professor Bangqin Huang, Yuwu Jiang, Wenqing Wang, and Jian Ma, along with a team from T-SMART, visited the“National Observation and Research Station for the Tai Lake Ecosystem (Institute of Geomecnology, Chinese Academy of Sciences)”, the “National Observation and Research Station for the Yangtze River Estuary Wetland Ecosystem (Fudan University)”and the“Field Station for the Yangtze River Delta Estuarine Wetland Ecosystem of the Ministry of Education (East China Normal University)”. The team explored the site, laboratory, observation facilities, and experimental equipment of these field stations. They also engaged in discussions and exchanges on the operation and management of the field station, personnel allocation, and results statistics, with the aim of collaboratively addressing challenges and identifying solutions to improve the construction and development of the field station.



在长江三角洲河口湿地生态系统教育部野外科学观测站合照

Group photo at Field Station for the Yangtze River Delta Estuarine Wetland Ecosystem of the Ministry of Education

在长江河口湿地生态系统国家野外科学观测研究站合照

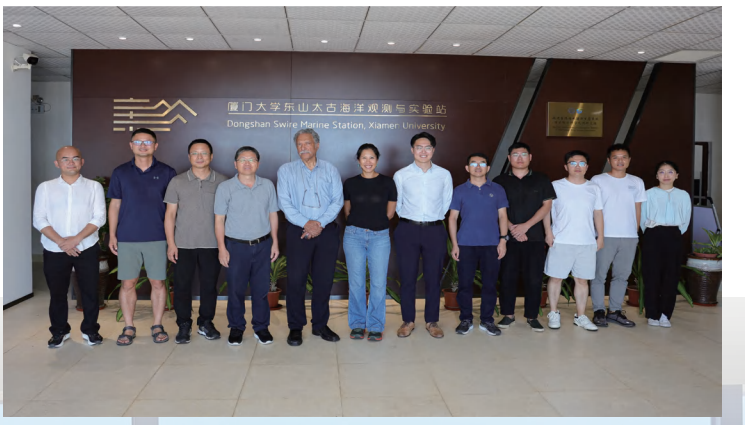
Group photo at National Observation and Research Station for the Yangtze River Estuary Wetland Ecosystem

太古集团慈善信托基金来访

Visit from the Swire Group Charitable Trust

2023年4月20日，太古基金公益事务总监陈婷婷来访考察台海站东山实验场与漳江口实验场，了解站内建设运行情况。同年7月24日，陈婷婷总监与太古基金科学顾问、英属哥伦比亚大学（UBC）海洋与渔业研究所Daniel Pauly教授一同访问台海站东山实验场与漳江口实验场，就新一轮合作进行深入探讨。

On April 20, 2023, Tina Chan, Head of Philanthropy for the Swire Group Charitable Trust, visited T-SMART to gain insights into the station's construction and operation. Later, on July 24 of the same year, Tina Chan, along with Prof. Daniel Pauly of the Institute of Ocean and Fisheries at the University of British Columbia (UBC) and Scientific Advisor to Swire Trust, visited the T-SMART for in-depth discussions regarding a new phase of collaboration.



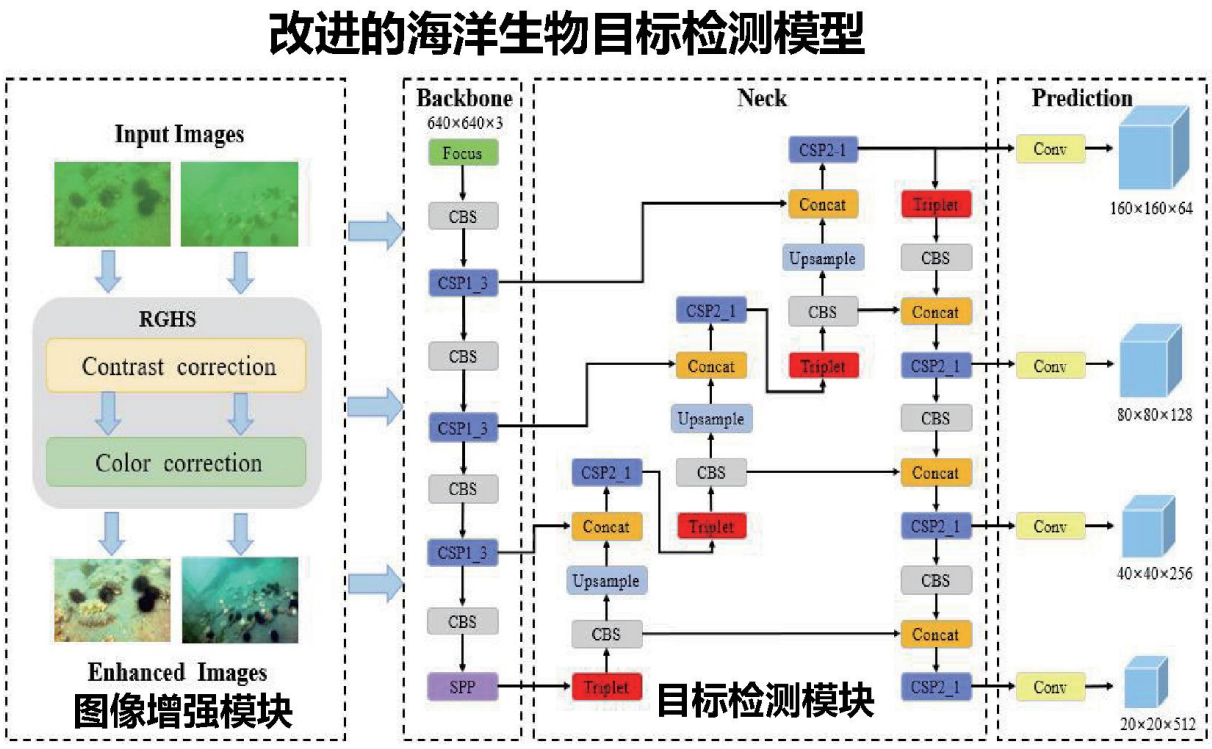
漳江口实验场（左）与东山实验场（右）现场合照
Group photo at M-ECORS (left) and D-SMART (right)

与中国科学院沈阳自动化研究所合作项目进展

Progress of the project collaborated with Shenyang Institute of automation, CAS

2023年，台海站团队完成东山珊瑚群落常见鱼类数据标定工作，沈自所团队利用该数据集对模型进行训练和优化，并部署到边缘计算模块中，沈自所团队访　问台海站东山实验场，在珊瑚观测系统岸基节点实现边缘计算模块试运行。此外，团队还利用少年蓝色先锋科创活动，培训学员进行人工视频判定，对人工智能的结果进行评估，为模型的优化提供参考。

In 2023, T-SMART team successfully completed the calibration of common fish data within the Dongshan coral community. Subsequently, the team from Shenyang Institute of Automation (SIA), Chinese Acedemy of Sciences utilized this dataset to train and optimize their model, which was then deployed to the edge computing module. A visit to the D-SMART enabled the SIA team to conduct trial operations of the edge computing module at the shore-based node of the coral observation system. Moreover, through engaging the Junior Blue Pioneers Program, students were trained to perform artificial video assessments, evaluate artificial intelligence outcomes, and offer insights to aid in model optimization.



改进的海洋生物目标检测模型

Improved marine species detection model

专著与期刊专辑

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