



◎ 广西合浦县养殖塘侵占红树林生境

保护海洋蓝碳生态系统， 保护人类与海洋和谐共生

撰文、摄影 / 朱祖浩

物理学有云：运动是绝对的，静止是相对的。是动是静，主要取决于参照系的不同。也就是说，我们所处的自然环境，大到宇宙中的天体，小到矿泉水瓶里的水分子，都是无时无刻处于运动状态。地球的气候，也不例外。

全球变暖形势紧迫

地球自诞生至今，其气候大致在有规律地变化着，即冰期、间冰期不断交替。其中冰期约持续 10 万年，间冰期约持续 1 万年。科学家根据在极地和冰川上钻取的冰芯中封存的 CO₂ 的浓度，反演出了地球历史上大气中 CO₂ 的浓度，从而发现了地球气候冰期和间冰期交替与大气 CO₂ 浓度变化之间存在一致性。表明地表温度和大气 CO₂ 浓度存在关联，即当地球气候处于温度相对较高的间冰期时，大气中 CO₂ 浓度也更高。

然而，地球大气中的 CO₂ 浓度与地表温度究竟有何种关系？这里不得不介绍一下 CO₂ 的“绝技”：吸收长波辐射。地球稠密的大气层就像一层厚厚的被子，被子里以 CO₂ 为主的气体就像棉花一样，吸收了地球以长波辐射散发的热量。在太阳辐射不断的前提下，地球不断增温。因此，以 CO₂ 为首的能够吸收长波辐射的气体，便成了“温室气体”。千百年来，地球气候一直这么规律地变化着。

人类诞生百万年，有历史记载的人类文明几千年。然而人类真正主宰地球不过始于 18 世纪爆发的工业革命。以化石燃料为能源的工业革命极大地解放了生产力，在推动人类工业文明快速向前的同时，向大气中排放了越来越多化石燃料燃烧所产生的 CO₂。人类突然贡献给大气的大量 CO₂，很快便产生了温室效应——自工业

革命以来，地球平均气温逐渐升高——与大气中 CO₂ 浓度升高趋势一致。目前大气中 CO₂ 浓度已达到 80 万年来的最高值，而地球上一次大气 CO₂ 出现这么高浓度时，人类尚未存在。与此同时，自工业革命以来，地球平均气温已升高 1℃，按目前的趋势将在 2030 至 2052 年间升温达到 1.5℃。因此，遏制气候变暖是全世界面临的严峻挑战。

蓝色碳汇助力减缓气候变暖

大气中的 CO₂ 时刻处于一个动态过程。含 C 物质燃烧、氧化以及动植物的呼吸作用产生 CO₂ 释放至大气，大气中 CO₂ 又能通过光合作用和一系列复杂的生物地球化学反应，被固定在土壤和沉积物中。被固定下来的 CO₂，成了“碳汇”。陆地上的植物通过光合作用吸收并固定大气中的 CO₂，称之为“绿碳”。而在海洋中通过海洋生物吸收，如“微生物泵”和复杂的海洋过程，固定储存在深海和沉积物中的 CO₂，则被称为“蓝碳”。

地球实际上是名副其实的“水球”，地表 70.8% 的面积被海洋覆盖。因此海洋是吸收大气 CO₂ 的主体，吸收并储存了大气中约 93% 的以 CO₂ 为主的温室气体。自工业革命以来，海洋吸收了人类排放温室气体总量的一半。毋庸置疑，海洋是地球上最大的碳库。

在海洋中，有这么一群典型海洋蓝碳生态系统：红树林、海草床和滨海盐沼生态系统，因为有着发达的根系和极高的生产力，能够快速将 CO₂ 吸收转化并埋藏在沉积物中，有着极大的固碳效率，近年来受到越来越多的关注。

红树林、海草床和滨海盐沼三大蓝碳生态系统，面积不到全球海床的 0.5%，



◎ 海南东寨港红树林



◎ 浙江杭州湾芦苇湿地

植物生物量也只有陆地植物生物量的0.05%，但是其碳储量却超过海洋碳储量的50%。因此，2009年，联合国相关机构联合发布《蓝碳：健康海洋固碳作用的评估报告》，确认了红树林、海草床、盐沼典型蓝碳生态系统在全球气候变化和碳循环过程中的重要作用。2013年，政府间气候变化专门委员会（IPCC）发布了《2006国家温室气体清单指南2013增补：湿地》，蓝碳损失和增加被纳入国家温室气体清单工作中，成为温室气体排放和减排的一项内容。

蓝碳生态系统的生态价值

以红树林、海草床和盐沼为代表的蓝碳生态系统，在高效固碳、抵御风暴和海平面上升、防止水土流失、调节海水水质、提供生物栖息地以及美化景观等方面，具有不可估量的生态价值，对于构建可适应气候变化、具有生态弹性的海岸带不可或缺。

蓝碳生态系统是固碳能手。与陆地生态系统中储存的“绿碳”类似，蓝碳在相对较短的时间内被封存在蓝碳生态系统植

物生物量中；而与陆地生态系统不同的是，被封存在沿海土壤中的碳则会在几百年到几千年时间内被大范围封存，从而使得蓝碳生态系统拥有大量的碳储量。

总的来说，蓝碳生态系统中碳汇主要来自于两个方面：一是蓝碳植物通过光合作用从大气或海水吸收 CO_2 ，并将其转化为植物组织以增加植物生物量。蓝碳植物生物量的很大一部分在根部，在厌氧条件下分解非常缓慢，从而将碳储存在沉积物中。二是蓝碳生态系统水动力条件较好，在海浪、潮汐和海流的作用下，大量沉积物和含碳碎屑被蓝碳植物发达的根系捕获，从而以沉积物碳汇得以埋藏。

滨海生态系统是海岸卫士。以红树林和盐沼植物为代表的滨海生态系统，凭借其茂密的地上生物量和发达的根系，成为抵御台风、风暴潮和海浪侵蚀的海岸长城，是内陆的天然屏障。红树林和盐沼植物还可以在固沙促淤、巩固岸线的同时，将海滩面积不断扩大和抬升，抵消海平面上升对岸线后方的威胁。在我国南疆，与越南交界的广西北仑河口红树林，在几代护林员的守护下，担负起了绝不让祖国丢失一寸领土的神圣使命。净化水质，提供

生物栖息地。作为人类居住陆地与海洋之间的过渡带，海岸带不仅要承载潮汐的影响，还要承载人类活动的影响。因此，生长在海岸带的蓝碳生态系统会直接受到人类排放污染物的影响。生活在高盐环境中的蓝碳生态系统具有较强的抗污染能力。例如红树林体内的单宁酸能降低重金属的毒性，包含细菌、藻类、浮游动物和底栖生物在内的多样性生物群落结构使得蓝碳生态系统能够有效地吸附和降解污染物，从而净化水体。蓝碳生态系统还是众多海洋生物的产卵场和栖息地。例如红树林生

态系统中，动植物种类相较于其它生态系统更加丰富。我国共有红树植物 37 种，其构建的生态系统中涵养着约 873 种浮游动物、游泳动物、底栖动物、两栖类和爬行类动物等，以及约 421 种鸟类，此外还有种类和数量众多的微生物。红树林不仅营造了相对稳定的栖息环境，其产生的凋落物还是动物的饵料。此外，成片的红树林和盐沼还是鸟类的理想栖息地和候鸟迁徙中转场所。

海岸带红树林和盐沼植物是海岸带独有的自然地理景观。例如在辽宁盘锦的红

◎ 红树林湿地里的弹涂鱼和招潮蟹



◎ 广西合浦儒艮国家级自然保护区内互花米草侵蚀红树林生境





海滩 5A 级景区，其主角就是盐沼植物碱蓬，绵延数十公里的红色碱蓬滩涂为游人营造了绝佳的观赏胜地。红树林则因为其生物多样性更具观赏价值，作为“海上森林”，红树林或以单一树种独自成林，或多种红树混杂而生，树叶、树枝、树干以及根系千姿百态，各有千秋，随着潮涨潮落，呈现出别样的色彩美和动态美。而其涵养的多种生物如白鹭、招潮蟹、弹涂鱼等更是彰显了整个生态系统的野性之美。

我国蓝碳生态系统现状

我国蓝碳生态系统丰富。我国滨海湿地总面积约为 1738 ~ 3965km²，是世界上为数不多的同时具有红树林、海草床、滨海盐沼三大蓝碳生态系统的国家。其中，红树林面积约 300km²，分布于浙江以南海域；海草床面积约 231km²，分布在我国除江苏、上海、浙江和福建以外的沿

海；滨海盐沼面积约 1207 ~ 3434km²，在全国沿海范围内广泛分布。据估计，我国蓝碳生态系统的碳年固定量为 0.349 ~ 0.835Tg. C，其中，滨海盐沼约占 80%，主要是因为滨海盐沼面积最大且固碳速率相对较高。

然而，自 20 世纪 60 年代以来，我国相继经历了四次大规模围填海浪潮，约 21900km² 滩涂消失，导致红树林、海草床、滨海盐沼面积大幅缩小，近海环境污染加剧了这一趋势。这不但导致年碳汇量减少，也造成被埋藏的碳暴露在大气或水中而重新释放回大气。与 1950 年相比，超过 80% 的海草床消失；我国红树林面积历史上曾达 2500km²，2013 年仅为 250km²，与此同时红树林种群还存在低矮化和单一化的趋势；20 世纪 50 年代，我国滨海沼泽面积曾达 7650km²，而到 2012 年消失面积已超过 50%。此外，还有其他自然或人为因素严重影响蓝碳生态系统的发育。如互花米草入侵，所到之地海草床绝迹，

红树林和滨海盐沼植物生境逐渐被互花米草蚕食；沿海渔民赶海，严重破坏表层沉积物生境，导致海草床退化，并威胁到红树林和滨海盐沼的生长。有研究表明，滨海植被的退化和消失有可能扰动到1米深度的土壤碳，使其矿化为CO₂，释放到大气，使得滨海生态系统成为碳源，加剧温室效应。

蓝碳增汇， 助力“双碳”战略，贡献中国智慧

气候变化对生态环境的负面影响日益显现，以全球变暖为代表的气候变化已深深影响到世界上每一个角落，严重威胁着人类的发展和生存。世界各国已达成通过节能减排遏制全球变暖的共识，降低大气CO₂浓度则成为世界各国关注的焦点。作为负责任的大国，我国提出了“人类命运共同体”的理念，并于2020年9月明确提出2030年我国CO₂排放量达到峰值、

2060年我国CO₂排放量与固碳量达到平衡实现中和，即碳达峰碳中和“双碳”战略。为实现这一目标，不仅要推进绿色能源取代传统化石能源，还要努力提高CO₂的固定能力。

与陆地植树造林增加绿碳碳汇相比，利用蓝碳生态系统高效的固碳效率增加蓝碳碳汇是十分有效的选择。蓝碳是应对全球气候变化、生物多样性保护和可持续发展等全球治理热点领域的汇聚点。我国同时拥有红树林、海草床和盐沼三大海洋蓝碳生态系统，发展蓝碳碳汇的潜力巨大。2021年10月，国务院发布了两份“双碳”指引文件，均将发展海洋蓝碳碳汇纳入其中。事实上，我国早已在增加蓝碳碳汇方面部署了相关工作。“十三五”期间，我国开展了“南红北柳”“蓝色海湾”“生态岛礁”“海洋牧场”等海洋生态建设项目实施，涉及的红树林、海草床和滨海盐沼生态系统修复工作增加了大量的蓝碳碳汇。“十四五”以来，我国又陆续开展了“海



岸带保护与修复”“红树林营造”等海洋生态修复工程项目，为实现我国“双碳”目标开好局。

开展红树林、海草床和盐沼生态系统保护与修复，是增加蓝碳碳汇的主要途径。为保护红树林生态系统蓝碳增汇潜力及其生态价值，我国已建立了38个以红树林为主要保护对象的自然保护地，超过75%的天然红树林被纳入保护地范围，远远超过25%的世界平均水平。海草床和盐沼植物也被直接或间接地纳入各级保护区保护范围。通过编制有效的生态修复实施方案，在红树林、海草床和盐沼退化区有效降低人类活动干扰、推动自然恢复并辅以人工修复，能够在短时间内迅速恢复。在围填海等毁灭性开发场地，通过退塘还海、退养还滩、拆除非法构筑物，使受损蓝碳植物生境地形地貌在潮汐、海流的作用下可较快恢复到原始状态，通过人工修复也能较快构建蓝碳生态系统。

在发展蓝碳经济、保护修复滨海蓝碳

生态系统、增加蓝碳碳汇等方面，我国已走在世界前列。近年来，相关从业者已在蓝碳资源调查、监测和评估等方面开展我国蓝碳增汇潜力研究，并从蓝碳交易实施机制方面摸索蓝碳产品价值实现的路径。通过实施各项海洋生态修复项目，我国已积累了多项海洋生态修复相关技术、方法和标准。例如，2021年6月“湛江红树林造林项目”已通过核证碳标准开发和管理组织的评审，标志着我国首个红树林碳汇项目和首个蓝碳（海洋碳汇）交易项目的完成。

然而，推动蓝碳碳汇有效支撑我国“双碳”战略，还需要在蓝碳工作顶层设计、国际合作与交流、蓝碳市场建立等方面继续努力。可以预见，随着我国推动蓝碳基础研究和示范应用，将提升我国在全球气候变化领域的话语权，形成的一系列可推广应用的技术、方法和标准，将为全世界开发蓝碳资源、减缓气候变化，贡献中国智慧。■



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8 文明回眸 | Civilization Glimpse

Better Forests and Grasslands Contribute to Better Ecological Environment and More Prosperous Civilization: An Overview of Forest and Grassland Ecosystem Development Since the 18th National CPC Congress

The 18th National CPC Congress incorporated for the first time the concept of ecological civilization into the “Five-sphere Integrated Plan”, the overall plan for building socialism with Chinese characteristics, and set “Building a Beautiful China” as the ambitious goal. The 19th National CPC Congress clearly define the guiding principles and practical actions for ecological civilization development, and deliver China’s solemn pledge to the world that it would honor its commitments on both global environmental governance and emission reduction. The CPC Central Committee, led by President Xi Jinping, takes ecological civilization as one of foundations for China’s great rejuvenation and sustainable development, and bring up a series of important views including “lucid water and lush mountains are invaluable assets” and “mountains, rivers, forests, farmlands, lakes, grasslands and deserts are a community of shared life”. Over the past decade, China has experienced the historical and holistic change in its ecoenvironment protection along with the quantum leap in building a beautiful China.

Progress Towards Achieving Success in Green Development and Saihanba Spirit Shaping

Saihanba Mechanized Forest Farm, located at the southern edge of the Inner Mongolia Plateau and Hunshandak Sandy Land, covers a land of 933 square kilometers. Thanks to three generations’ effort in afforestation for over 60 years, the barren land has been turned into a green land, home to the largest artificial forest in China and even in the world. With unwavering loyalty to the Community Party, the undaunted spirit to overcome difficulties and long-held firm belief in success, the people working there have relentlessly pursued green development by building a green great wall that wards Beijing and Tianjin from sand, replenishes water sources of Liaoning, Tianjin and Hebei, produce more resources for Hebei, and generates incomes for Inner Mongolia. In their practices in the natural environment protection and restoration, they have shaped and forged the Saihanba Spirit.

34 理论视点 | Theoretical Views

Reflection on Ecological Values

Living creatures, environment and the entire ecosystem are carriers of ecological values whose market value must be recognized. In terms of value attribute, the ecological elements that comply with the laws of nature have objective relevance and subjective preference, and transcends the Taoism. The systematic values of ecosystems and the community of shared life go far beyond the market scope of a certain group or a country. Therefore, the whole global community should make efforts to build a community of shared life by refraining from extravagance and waste of ecological products. We should also assume our due responsibilities to maintain the balance, stability and prosperity of the community so as to satisfy our sense of being and morality, among other spiritual needs.

42 特别策划 | Special Focus

What Global Commitments to Carbon Neutrality and Carbon Peaking Goals Inspire China?

Global warming has pushed humans into more frequent extreme weather events and propelled more and more countries to be aware of the importance of emission reduction. Some 70 countries have set the “net-zero” targets, which will contribute to about 76% of total global emission. China has taken upon itself the daunting task to achieve carbon peaking by 2030 and carbon neutrality by 2060. By analyzing and summarizing the actions, strategies, practical experience and cutting-edge technologies made by various countries in their addressing climate change, the paper contributes China’s wisdom to fulfilling the pledge on nationally determined contributions, promoting global climate governance and achieving the goal of limiting the global temperature rise.

Tapping Forest Carbon Sinks Potentials to Achieve Goal of Carbon Neutrality and Carbon Peaking

Forests, as the largest carbon sink in terrestrial ecosystems, play an important role in mitigating global climate change and achieving China’s target to achieve carbon peaking and neutrality. China is now facing new challenges in expanding new afforested area, improving forest quality, protecting forest resources, processing forest products, and enhancing science-based monitoring and accounting. forest carbon sink should meet the demands and standards of China’s carbon peaking and neutrality goals, strengthen sci-tech innovation in terms of scientific greening, resource protection, quality improvement, wood and bamboo substitutes, investigation and monitoring, carbon sink trading and talent training. Thus, the potential of forest carbon sinks can be fully unleashed to help achieve the goal of carbon peaking and carbon neutrality.

Enhancing Planted Forest Carbon Sinks to Achieve Carbon Peaking and Neutrality Goals

In this new era, we should strengthen the protection of forest resources and sustainable and multi-functional forest management, increase the total stocking volume of planted forests while improving the quality and efficiency of planted forest ecosystem to help achieve carbon peaking and neutrality goals. The only way to achieve high-sequestration carbon sink forestry is to keep the forest ecosystems in the most ideal state for maximum growing stock volume and the highest carbon sequestration, and maintain a forestry development model that could maintain a high capture of carbon sink in the long term.

A “Bamboo + n” Compound Management Mode

As the second forests in China, bamboo forests provide a large number of production and living materials for national economic development. The full understanding of the governing law behind biodiversity, and the reasonable use of the growth time and space characteristics of organisms will benefit the exploration of a scientific compound management mode with bamboo as the main carrier and the establishment of spatially vertical plant-animal-microbe compound management mode. This helps build a “bamboo + n” compound management mode that integrates ecological, economic and social benefits, which falls in the development trend of modern agriculture, modern forestry and their compound management. It is of great significance to implement the concept of “lucid water and lush mountain are valuable assets”, realize carbon peaking and neutrality goals, implement the “rural revitalization” strategy and materialize the four roles of forests as the source of water, grains, assets and carbon sinks.

Utilizing Soil Carbon Sinks to Achieve Carbon Peaking and Neutrality Goals

Plants fix CO₂ through photosynthesis and enter the soil layer in the form of dead leaves, dead roots or their secretions, which are transformed into organic matters by animals, microorganisms and enzymes and stored in the soil, thus forming soil carbon sink. Climate and human activities are the main factors affecting soil carbon storage and the function of forest soil carbon sequestration. Forest land preparation, harvest intensity, rotation management, mixed multi-species plantation, disease and pest control and fire control can effectively reduce soil carbon emissions and thus increase the carbon sink function.

Protecting Blue Carbon Ecosystems for Harmonious Human-Ocean Coexistence

Blue carbon is the focal point of global governance hotspot areas such as climate change, biodiversity conservation and sustainable development. China is rich in blue carbon ecosystems with a total area of coastal wetlands about 1738-3965 km², and is one of the few countries in the world that simultaneously boast three blue carbon ecosystems, namely mangrove, seagrass bed and coastal salt marsh. Blue carbon ecosystems are of inestimable ecological values in terms of efficient carbon sequestration, resistance to storms and sea level rise, prevention of soil and water loss, regulation of seawater quality, provision of wildlife habitats and landscape beautification.

Virtual Power Plant: Energy Digitalization in the Emission Reduction Era

Since the slash-and-burn period, human beings have never stopped exploring and utilizing energy. Thanks to the skyrocketing development of information technology, the Internet provides a new and effective means to refine the use, respond to the demands, and tap the potentials of energy. Against this backdrop, the concept of virtual power plants was born. Equipped with digital technology, we can flexibly adjust customer-side load, coordinate power-generating resources, and solve the conflict, and reach a balance between safe operation of the power system and the demand for energy at a smaller cost, thus realizing the digital transformation of the energy industry.

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Illuminating Rural Revitalization with “Light”: “PV+” Green Development in Changxing County

Huzhou in Zhejiang Province is the place where President Xi Jinping came up with the concept of “lucid water and lush mountains are invaluable assets”. In recent years, Changxing County of Huzhou has been implementing the concept by fully exploiting local solar energy resources, and striving to do well in the green development of “photovoltaic +”, which has effectively achieved energy conservation and carbon emission reduction while greatly improving the efficiency and modernization of agriculture, fishery and animal husbandry. The county has successfully developed the “photovoltaic+” industry to get rid of poverty, and provided a practical example to help achieve net-zero emission and rural revitalization. All rights reserved. <http://www.cnki.net>