

**Abstracts of Session 6 of the 1st International
Biopetrological Congress (Shijiazhuang, China,
Sept. 22-25, 2023): Structures of modern reef
systems and their interaction with environments**

--Edited by Ke-Fu Yu

Publisher: IBA

Journal: Biopetrology, 3(6): 1-28.

Prepublished date: Sept. 21, 2023

Revised: Oct. 10, 2023

Contents

Late Pleistocene sedimentary record during the past 60 kyr from the slope of one isolated coral atoll in southern South China Sea	1
Gang Li, Wanqiu Zhou, Xiaowei Zhu, Wen Yan	1
Orbital-insolation controlled Porites coral $\delta^{13}\text{C}$ seasonality variations since the mid-Holocene in the northern South China Sea	3
Hao Wang, Kefu Yu, Tao Han, Shendong Xu, Shichen Tao, Shaohua Dang, Xiaopeng Yu.....	3
Integrating transcriptome and physiological analyses to reveal the toxic effects of scleractinian coral <i>Galaxea fascicularis</i> to ZnO	5
Jian Chen, Kefu Yu, Xiaopeng Yu, Yonggang Wang	5
Regulation of the Symbiotic Bacteria and Transcriptome in <i>Porites lutea</i> Under feeding by Crown-of-Thorns Starfish	7
Jiaoyang Yu, Kefu Yu.....	7
Content and source analysis of organic carbon in outer slope sediments of Yongle Atoll, Xisha Islands	9
Jie Gao, Kefu Yu, Shendong Xu, Xueyong Huang	9
The rapid ecological degradation and its impact on fish of the Yinyu Island in the the Xisha Archipelago	11
Mingfeng Lei, Kefu Yu, Zhiheng Liao, Biao Chen, Xueyong Huang, Xiaoyan Chen.....	11
Development Process and Ecological Significance of Holocene Coral Reef in the Weizhou Island	13
Leilei Jiang, Kefu Yu, Yating Long.....	13
Sexual reproduction of scleractinian corals in the Weizhou Island, Guangxi	15
Mengyao Cui, Fen Wei, Kefu Yu, Wen Huang.....	15
Acute and chronic low-temperature stress responses in <i>Porites lutea</i> from a high-latitude coral reef of the South China Sea	17
Xuelu Wei, Kefu Yu, Zhenjun Qin.....	17
Organophosphate esters (OPEs) in a coral reef food web of the Xisha Islands, South China Sea: occurrence, trophodynamic, and exposure risk.	19

Yaru Kang, Ruijie Zhang, Kefu Yu, Minwei Han, Haolan Li, Annan Yan, Fang Liu, Jingwen Shi, Yinghui Wang	19
Molecular response of coral <i>Porites lutea</i> holobionts from Weizhou Island under heat stress	21
Yonggang Wang, Kefu Yu, Wen Huang	21
Growth Characteristics and Climatic Significance of <i>Porites</i> Coral in Tanmen, Hainan Island during the Mid-Holocene.....	23
Yueer Li, Kefu Yu, Tingli Yan, Leilei Jiang	23
Content and source analysis of organic carbon in outer slope sediments of Yongle Atoll, Xisha Islands	25
Jie Gao, Kefu Yu, Shendong Xu, Xueyong Huang	25
Petrologic and geochemical features of weathering paleo-crust in coral reef carbonate strata in Xisha Island since Miocene.....	27
Yang Yang, Kefu Yu	27

Late Pleistocene sedimentary record during the past 60 kyr from the slope of one isolated coral atoll in southern South China Sea

Gang Li ^{a*}, Wanqiu Zhou ^{a,b}, Xiaowei Zhu, Wen Yan ^{a,b}

^a Key Laboratory of Ocean and Marginal Sea Geology, South China Sea Institute of Oceanology, Innovation Academy of South China Sea Ecology and Environmental Engineering, Chinese Academy of Sciences, Guangzhou 510301, China

^b University of Chinese Academy of Sciences, Beijing 100049, China

* Corresponding author at South China Sea Institute of Oceanology, No. 164 West Xingang Road, Guangzhou, China

E-mail address: gangli@scsio.ac.cn; (G. Li)

Abstract

Coral reefs are widely distributed across the South China Sea (SCS). Although previous studies on coral reefs of the SCS contributed many important information of high-resolution environmental variation in the tropic of west Pacific, most drilling cores on modern reefs span only the past 8000 years and long-term records of the coral-reef growth are rare. Here we studied one gravity core on the lower slope of Yongshu Atoll and analyzed multiple proxies (organic C-N isotope, XRD mineralogy and chemical composition) to explore the carbonate shedding history of this isolated coral atoll over the past 60 kyr. Aragonite in slope sediments is mainly derived from muddy carbonate plume escaping out of coral atoll. The aragonite flux from the reef to deep water is firstly determined by sea-level changes. The enhanced aragonite shedding after the low sea-level period occurred at around 14.6 ka BP which responses to the meltwater pulse 1a. Coral reefs flourished over broader areas when this coral island was submerged after 8.6 ka BP and the production of carbonates and organic materials seems to significantly increase. However, the highest aragonite flux to the slope occurred in recent 3000 years

which lags behind the sea level change. The aragonite shedding events in slope sediments can be chronologically correlated with coarse-grained layers in the lagoon of Yongshu Atoll, indicating a common cause of the two types of sedimentation. This study provides a new and long record of sediment shedding from the coral atoll system, including carbonates and organic matter. It also demonstrates that both sea level changes and shallow-water storms played important roles for carbonate shedding on coral atolls which can be well preserved in deep-sea stratigraphic records.

Orbital-insolation controlled *Porites* coral $\delta^{13}\text{C}$ seasonality variations since the mid-Holocene in the northern South China Sea

Hao Wang ^a, Kefu Yu ^{a,b*}, Tao Han ^c, Shendong Xu ^{a,b}, Shichen Tao ^d, Shaohua Dang ^e, Xiaopeng Yu ^a

^a Guangxi Laboratory on the Study of Coral Reefs in the South China Sea, Coral Reef Research Centre of China, School of Marine Sciences, Guangxi University, Nanning 530004, China,

^b Southern Marine Sciences and Engineering Guangdong Laboratory (Zhuhai), Zhuhai 519082, China,

^c State Key Laboratory of Loess and Quaternary Geology, Institute of Earth Environment, Chinese Academy of Sciences, Xi'an 710075, China,

^d South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou 510301, China,

^e State Key Laboratory of Marine Geology, Tongji University, Shanghai 200092, China

* Corresponding author at Guangxi University, No. 100 Daxue East Road, Nanning 530004, China.

E-mail address: kefuyu@scsio.ac.cn; (K.F. Yu)

Abstract

Coral skeleton $\delta^{13}\text{C}$ is a routinely measured indicator in modern insolation change research, but the knowledge of environmental and climatic signals recorded in its seasonality during geological time is sparse. In this study, we present eight *Porites* coral $\delta^{13}\text{C}$ records from the mid-late Holocene to the present from the northern South China Sea (NSCS). Compared with the main control factors for modern $\delta^{13}\text{C}$ changes, coral $\delta^{13}\text{C}$ seasonality in the NSCS since the mid-Holocene shows a long-term decreasing trend, which is consistent with the change trend as orbital-induced (precession)

insolation seasonal amplitude. By excluding other influencing factors, we speculate that the stronger coral $\delta^{13}\text{C}$ seasonality (18.8%) over the mid-Holocene than modern period is attributable to the metabolic effect, which predicts the stronger coral $\delta^{13}\text{C}$ seasonality under stronger insolation seasonality. Our study has implications for coral $\delta^{13}\text{C}$ seasonality as a potential indicator to record past insolation information under different climatic backgrounds.

Keywords: Coral skeleton $\delta^{13}\text{C}$; insolation; Porites; mid-late Holocene; South China Sea (SCS)

Integrating transcriptome and physiological analyses to reveal the toxic effects of scleractinian coral *Galaxea fascicularis* to ZnO

Jian Chen ^a, Kefu Yu ^{a,b,*}, Xiaopeng Yu ^a, Yonggang Wang ^a

^a Guangxi Laboratory on the Study of Coral Reefs in the South China Sea; Coral Reef Research Center of China; School of Marine Sciences, Guangxi University, Nanning 530004, China

^b Southern Marine Science and Engineering Guangdong Laboratory, Zhuhai 519000, China

* Corresponding author at Guangxi University, No. 100 Daxue East Road, Nanning 530004, China.

E-mail address: kefuyu@scsio.ac.cn; (K.F. Yu)

Abstract

Coral reefs are one of the most diverse and biologically significant ecosystems on the planet. However, anthropogenic impacts have led to a global decline in overall reef health in recent years. In order to understand the toxic effects on corals of the main active ingredient in sunscreen (nano-zinc oxide or nZnO), this study evaluated the changes in phenotype, physiology and gene expression of the scleractinian coral *Galaxea fascicularis* due to exposure to nZnO. Our study found that the zooxanthellae density (ZD), Fv/Fm, and chlorophyll (Chl) a concentration of coral significantly decreased, while the reactive oxygen species (ROS) concentration increased and antioxidant enzyme activity was abnormal. The transcriptome analysis further demonstrated that the upregulated differentially expressed genes (DEGs) were mainly involved in oxidative stress, endocytosis, and apoptosis, they were mainly enriched in

signaling pathways such as MAPK, IL-17, Ras, and endocytosis. The downregulated DEGs were mainly involved in carbon metabolism, amino acid metabolism, and DNA replication pathway. The results revealed that nZnO can cause the collapse of the coral-zooxanthellae symbiotic relationship, while causing oxidative stress in the coral, damaging the coral's anti-stress ability and immune system, reducing the metabolic level of the coral, and thus causing coral bleaching or death.

Keywords: nZnO, sunscreens; coral, stress; transcriptional responses

Regulation of the Symbiotic Bacteria and Transcriptome in *Porites lutea* Under feeding by Crown-of-Thorns Starfish

Jiaoyang Yu ^a, Kefu Yu ^{a,b*}

^a Guangxi Laboratory on the Study of Coral Reefs in the South China Sea; Coral Reef Research Center of China; School of Marine Sciences, Guangxi University, Nanning 530004, China

^b Southern Marine Science and Engineering Guangdong Laboratory, Zhuhai 519000, China

* Corresponding author at Guangxi University, No. 100 Daxue East Road, Nanning 530004, China.

E-mail address: kefuyu@scsio.ac.cn; (K.F. Yu)

Abstract

The outbreak of the crown-of-thorns starfish (*Acanthaster* spp, COTS) is an important reason of coral reef degradation, while the coral *Porites lutea* is relatively rare to be feeding. In this study, we examined the changes of host transcriptional response and symbiotic bacteria during feeding process in coral *Porites lutea* from Paracel Islands in South China Sea, to explore the response to the feeding of COTS. The microbiome results showed that the feeding process caused the transfer of 12 bacteria OTU from the stomach to the coral surface, and decreased the diversity of coral symbiotic bacteria and the relative abundance of probiotics such as *Brevundimonas*. In addition, microbiome function prediction revealed higher biosynthesis levels of fatty acid, aminoacyl tRNA and antibiotic in coral-fed symbiotic bacteria. The transcriptome analysis showed that 5310 genes were up-regulated and 1233 genes were down-regulated during feeding process, compared to healthy coral host. Function analysis of enrichment of gene significantly up-regulated obtain 44 KEGG pathways, which the most significant pathway is regulation of actin cytoskeleton. The significantly enriched

pathways included signaling pathways related to coral innate immunity such as TNF, MAPK, NF- κ B signaling pathway, also contained the platelet activation pathways which related to coral defense. To sum up, we argue that the feeding process of COTS not only digest the coral through the secretion of digestive enzymes, but also by passing the bacteria, reduce the symbiotic bacteria diversity and probiotics abundance further damage symbiotic relationship. Coral hosts might repair the damage caused by the feeding process by activating the innate immune system and reorganizing the actin cytoskeleton, and might defend against the COTS by stinging cells and coral venom. The symbiotic bacteria may promote host recovery by secreting antibiotics and synthesizing nutrients. This study reveals the response of coral holobiont *Porites lutea* to the COTS feeding, which provides molecular insight into the ecological phenomena that coral *Porites lutea* are less susceptible to COTS outbreaks.

Keywords: bacterial community; crown-of-thorns starfish; coral holobionts; immunity; porites

Content and source analysis of organic carbon in outer slope sediments of Yongle Atoll, Xisha Islands

Jie Gao ^a, Kefu Yu ^{a,b*}, Shendong Xu ^{a,c}, Xueyong Huang ^a

^a Guangxi Laboratory on the Study of Coral Reefs in the South China Sea, Coral Reef Research Center of China, School of Marine Sciences, Guangxi University, Nanning 530004, China

^b Southern Marine Sciences and Engineering Guangdong Laboratory (Zhuhai), Zhuhai 519082, China,

^c Key Laboratory of Coastal Zone Environmental Processes and Ecological Remediation, Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences, Yantai 264003, China

* Corresponding author at Guangxi University, No. 100 Daxue East Road, Nanning 530004, China.

E-mail address: kefuyu@scsio.ac.cn; (K.F. Yu)

Abstract

Organic carbon burial is an important part of the carbon cycle, but there are few studies on organic carbon in coral reef sediments, which affects the accurate assessment of coral reef carbon cycle. In this paper, the modern surface sediments from the outer slope of Yongle Atoll, Xisha Islands, South China Sea, were analyzed for their total organic carbon (TOC) content, total nitrogen (TN) content, organic carbon isotope ($\delta^{13}\text{C}$) value, as well as sediment grain size, chlorophyll content and other indicators. The ecological condition of the outer slope of Yongle Atoll reef is relatively good, and has the potential to represent the organic carbon characteristics in sediments of healthy coral reef ecosystems. The results showed that: 1) the TOC content in the sediments from the outer slope of Yongle Atoll reef ranged from 0.71 to 1.66 $\text{mg}\cdot\text{g}^{-1}$, with an average of 1.23 ± 0.31 $\text{mg}\cdot\text{g}^{-1}$; the TN content ranged from 0.12 to 0.28 $\text{mg}\cdot\text{g}^{-1}$, with an average of 0.20 ± 0.05 $\text{mg}\cdot\text{g}^{-1}$. 2) the C/N ratio ranged from 6.16 to 7.59, with an average of 6.75 ± 0.34 ; $\delta^{13}\text{C}$ values ranged from -17.49 to -15.85‰, with an average of -16.61 ± 0.49 ‰, indicating that the organic carbon in the sediments was predominantly of marine autochthonous origin and mainly from benthic plants. 3) Organic carbon content was negatively correlated with water depth and positively correlated with chlorophyll a content and pheophytin content, indicating that primary productivity controlled by

benthic plants was the main source of organic carbon content on the outer slope of the reef. Combined with the vertical accumulation rate of the outer reef slope sediments of the Pacific Ocean since the Holocene (the average is between 2~5mm·a⁻¹), it is inferred that the organic carbon burial flux of the outer slope of Yongle Atoll is between 3~8g · m⁻²·a⁻¹. The present study provides new information for evaluating the contribution of coral reefs in the South China Sea to the carbon cycle.

Key words: coral reef; sediment; organic carbon; carbon isotope; Yongle Atoll; Xisha Islands

The rapid ecological degradation and its impact on fish of the Yinyu Island in the the Xisha Archipelago

Mingfeng Lei ^a, Kefu Yu ^{a,b*}, Zhiheng Liao ^a, Biao Chen ^a, Xueyong Huang ^a, Xiaoyan Chen ^a

^a Guangxi Laboratory on the Study of Coral Reefs in the South China sea, Coral Reef Research Center of China, School of Marine Science, Guangxi University, Nanning 530004, China;

^b Key laboratory of Beibu Gulf Environment Change and Resources Utilization of Ministry of Education, Nanning Normal University, Nanning 530001, China

* Corresponding author at Guangxi University, No. 100 Daxue East Road, Nanning 530004, China.

E-mail address: kefuyu@scsio.ac.cn; (K.F. Yu)

Abstract

The degradation of coral reef ecosystem can alter the topographic complexity and biotic composition, thereby affecting the coral reef fish community significantly. Coral reefs in the South China Sea have undergone rapid degradation in recent decades, but the ecological consequences for coral reef fish community remain unclear. The coral reefs of the Xisha Archipelago have experienced ecological degradation in recent years due to the impacts of high temperature and crown-of-thorns starfish (CoTs). We conducted an ecological investigation on Yinyu Island of the Xisha Archipelago to assess the ecological degradation of the coral reef and its effect on the coral reef fish community. The results show that: from 2020 to 2021, the live coral cover on Yinyu Island declined from 33.27 % to 9.07 %, while the turf algae cover increased from 8.38 % to 36.50 %. The coral recruitment, species richness and Shannon-Weaner index also decreased from 21.42 ind.m⁻² to 3.64 ind.m⁻², 40.00 to 16.83 and 3.26 to 2.14, respectively. The fish density, species richness, Shannon- Weaner index, declined from 1.77 ind.m⁻² to 1.05 ind.m⁻², 30.56 to 17.17 and 2.24 to 1.63, respectively. The biomass

of corallivore, carnivore, omnivore and total biomass also declined from 2.45 g. m⁻² to 0.43 g. m⁻², 7.35 g. m⁻² to 1.70 g. m⁻², 7.04 g. m⁻² to 0.95 g. m⁻² and 32.99 g. m⁻² to 11.66g. m⁻², respectively. Within two years, turf algae and macroalgae have dominated Yinyu Island, but the fish community has not demonstrated top-down control of algae. Among the four functional groups in the whole fish community, the herbivore functional group is the least affected by ecological degradation. The coral species richness constrains the fish species richness and diversity. Our data indicate that the rapid deterioration of the coral reef resulted in the reduction of species diversity and density of coral reef fish community, and consequently altered the fish community structure.

Key words: coral reef; ecological degradation; fish community; Yinyu; Xisha Archipelago

Development Process and Ecological Significance of Holocene Coral Reef in the Weizhou Island

Leilei Jiang ^a, Kefu Yu ^{a,b*}, Yating Long ^a

^a Guangxi Laboratory on the Study of Coral Reefs in the South China Sea; Coral Reef Research Center of China; School of Marine Sciences, Guangxi University, Nanning 530004, China

^b Southern Marine Science and Engineering Guangdong Laboratory, Zhuhai 519000, China

* Corresponding author at Guangxi University, No. 100 Daxue East Road, Nanning 530004, China.

E-mail address: kefuyu@scsio.ac.cn; (K.F. Yu)

Abstract

Under the background of widespread coral bleaching and rapid degradation of global coral reef ecosystems caused by climate warming, relatively high latitude sea area is considered as a potential refuge for corals. In this context, reconstructing the development process of coral reefs in relatively high latitude sea areas is of great scientific significance for understanding the response of corals to the past climate and evaluating the development trend of coral reefs in this sea area. But so far, there is little research on the development process of coral reefs in relatively high latitude. Weizhou Island in Beibu Gulf, located in the northern edge of the tropics, belongs to relatively high latitude coral reefs. In this study, the ages of 32 corals were measured by high-precision uranium dating technology with 6 fully cores in the coral reef area of Weizhou Island. The results showed that the initial development age of the coral reef and the thickness of the coral reef layer in Weizhou Island vary in different parts. It is measured that the oldest age is 8252 ± 15 a BP, and the maximum thickness of the coral reef is 7.7 m. The basement of the coral reef is quartz sandy deposit. The particle size of the coral reef sediments in Weizhou Island is medium to fine sand. The biological components are mainly composed of corals, mollusks, and coral algae. The mineral components are mainly aragonite, quartz, and calcite. Generally, the coral reef

carbonate component is the main component. The average accretion rate of coral reefs in Weizhou Island is 1.11 m/ka, but there are obvious temporal and spatial differences. According to the spatial distribution of the initial development time, reef thickness, and accretion rate of coral reefs, the development process of coral reefs in Weizhou Island can be divided into four stages: (I) reef germination and slow development stage (8252-4193 a BP). It began to germinate at 2000 m from the current coastline. The average accretion rate was 0.19 m/ka. (II) rapid development towards the shore stage (4193-1645 a BP). The average accretion rate of reef is 1.73 m/ka. Reef developed rapidly and extends developed 1500 m towards the shore. (III) slow development stage (1645-571 a BP). The average accretion rate of reef is 0.73 m/ka. It developed slowly and mainly developed bioclastic deposits. (IV) lateral high-speed development stage (571 a BP - now). The average accretion rate of reef is 3.37 m/ka. Reef developed is dominated by coral growth. Reef developed rapidly laterally to the modern coastline. Comparing the accretion rate of coral reefs in Weizhou Island with the corresponding climate background, it can be concluded that the overall accretion rate of coral reefs in Weizhou Island is generally regulated by cold and warm climate. Coral reefs developed fast during the warm period, while slowly during the cold period. This indicates that the warm climate is conducive to the development of coral reefs in Weizhou Island. In addition, under the background of global warming, the seawater warming in winter is conducive to alleviating the threat of low temperature of seawater in winter to the growth of coral in Weizhou Island. Therefore, the coral reefs of Weizhou Island have the potential to serve as a refuge for coral reefs in the South China Sea under the background of climate warming.

Keywords: coral reefs; accretion rate; Holocene; Weizhou Island

Sexual reproduction of scleractinian corals in the Weizhou Island, Guangxi

Mengyao Cui^a, Fen Wei^a, Kefu Yu^{a,b,*}, Wen Huang^a

^a Guangxi Laboratory on the Study of Coral Reefs in the South China Sea; Coral Reef Research Center of China; School of Marine Sciences, Guangxi University, Nanning 530004, China

^b Southern Marine Science and Engineering Guangdong Laboratory, Zhuhai 519000, China

* Corresponding author at Guangxi University, No. 100 Daxue East Road, Nanning 530004, China.

E-mail address: kefuyu@scsio.ac.cn; (K.F. Yu)

Abstract

Sexual reproduction plays an important role in population and community structure maintenance in scleractinian corals. Despite this, only a few studies have been conducted on the sexual reproduction of corals in the Weizhou Island. From 2018 to 2023, our study focused on the corals in the Weizhou Island and comprehensively investigated their sexual reproductive biology using methods such as histology and ex situ aquaculture. The results demonstrated that the oocytes of *Galaxea fascicularis*, *Dipsastraea favus*, *Acropora formosa*, and *Favites abdita* in the wild began to develop in autumn (September), while the testes started developing 2-5 months before ovulation. Four corals' gametes matured in May, and spawning events primarily occurred around April 15th, Chinese lunar calendar. *G. fascicularis* is thought to be gonochoric, the other three species are hermaphrodites, in vitro fertilization. The early development of embryos and larvae experienced the cleavage stage, blastula stage, gastrula stage, and planula stage; the oocytes of these corals did not have zooxanthella as they were ejected. Larvae of *G. fascicularis* showed association with zooxanthellae 9 d after spawning (4 d after settlement) and completed metamorphosis after 1 month. The mean diameter of *G. fascicularis* recruits was 4.74 ± 1.12 mm in the first year, By the end of the first year, the final survival rate was 5.46%, which may be attributed to their competition with

algae. This study provides valuable information on the reproductive biology of corals in Weizhou Island, and provides a theory when using sexual reproduction for coral ecological restoration in the future.

Key words: Sexual reproduction; spawning time; gonad; early life history; Weizhou Island

Acute and chronic low-temperature stress responses in *Porites lutea* from a high-latitude coral reef of the South China Sea

Xuelu Wei ^a, Kefu Yu ^{a,b*}, Zhenjun Qin ^a

^a Guangxi Laboratory on the Study of Coral Reefs in the South China Sea; Coral Reef Research Center of China; School of Marine Sciences, Guangxi University, Nanning 530004, China

^b Southern Marine Science and Engineering Guangdong Laboratory, Zhuhai 519000, China

* Corresponding author at Guangxi University, No. 100 Daxue East Road, Nanning 530004, China.

E-mail address: kefuyu@scsio.ac.cn; (K.F. Yu)

Abstract

Relatively high-latitude coral reefs serve as potential "refuges" for corals amid climate change and global warming. Low-temperature stress is an important factor that limits their ability to act as coral refuges. However, the mechanisms underlying the tolerance of coral holobionts to low-temperature stress remain unclear. To explore the underlying mechanisms, *Porites lutea* from a high-latitude reef in the South China Sea were subjected to both acute (1–2 weeks) and chronic (6–12 weeks) low-temperature stress across three temperature gradients (26 °C, 20 °C, and 14 °C, with an initial temperature of 26 °C). We analyzed alterations in the maximum photochemical efficiency of photosystem II (Fv/Fm) and transcriptome responses within *P. lutea*. Under low-temperature stress, the Fv/Fm of Symbiodiniaceae dropped to 36% with acute stress, which was significantly lower than the 51% observed under chronic stress. Photosynthesis in Symbiodiniaceae is inhibited by low-temperature stress, with greater inhibition under acute stress. Under low-temperature stress, downregulation of calcification-related gene expression in coral hosts was observed, which may have been caused by energy deficiency due to inhibited photosynthesis, Symbiodiniaceae excretion, and oxidative phosphorylation uncoupling. Acute low-temperature stress

also induced upregulation of gene expression for the TNF signaling pathway and endoplasmic reticulum stress, which promoted the upregulation of apoptotic genes expression and coral bleaching. However, these phenomena were not observed under chronic stress conditions. This indicates that coral holobionts are more threatened by acute low-temperature stress. In conclusion, low-temperature stress inhibits photosynthesis of Symbiodiniaceae, resulting in decreased energy production in coral holobionts and affecting the calcification process. Acute low-temperature stress is more threatening to coral holobionts than chronic low-temperature stress.

Key words: coral holobionts; low-temperature stress; Relatively high-latitude coral reef

Organophosphate esters (OPEs) in a coral reef food web of the Xisha Islands, South China Sea: occurrence, trophodynamic, and exposure risk

Yaru Kang^a, Ruijie Zhang^{ab*}, Kefu Yu^{ab*}, Minwei Han^a, Haolan Li^a, Annan Yan^a,
Fang Liu^a, Jingwen Shi^a, Yinghui Wang^a

^a Guangxi Laboratory on the Study of Coral Reefs in the South China Sea; Coral Reef Research Center of China; School of Marine Sciences, Guangxi University, Nanning 530004, China

^b Southern Marine Science and Engineering Guangdong Laboratory (Zhuhai), Zhuhai 519080, China

* Corresponding author at Guangxi University, No. 100 Daxue East Road, Nanning 530004, China.

E-mail address: rjzhang@gxu.edu.cn; (R.J.Zhang); kefuyu@scsio.ac.cn; (K.F. Yu)

Abstract

Despite organophosphate esters (OPEs) are widely prevalent in the environment, however, limited information is available regarding their occurrence, trophodynamics, and exposure risks in coral reef ecosystems. In this study, 11 OPEs were investigated in a tropical marine food web (7 fish species and 9 benthos species) from the Xisha (XS) Islands, South China Sea (SCS). The \sum_{11} OPEs were 1.52 ± 0.33 ng/L, 2227 ± 2062 ng/g lipid weight (lw), 1024 ± 606 ng/g lw, and 1800 ± 1344 ng/g lw in seawater, fish, molluscs, and corals, respectively. Tris (2-chloroisopropyl) phosphate (TCIPPs) were the dominant OPEs in seawater, fish, and molluscs, while tris (2-butoxyethyl) phosphate (TBOEP) predominated in coral tissues. Abiotic and biotic factors jointly affect the OPEs enrichment in marine organisms. Trophic magnification factors (TMFs) (range: 1.31 – 39.2) indicated the biomagnification potency of OPEs. A dietary exposure risk assessment indicated that OPEs at current levels in coral reef fish posed a low risk to human health but were not negligible. Overall, this study contributes to a further understanding of the environmental behaviors of OPEs in coral reef ecosystems.

Key words: Organophosphate esters, coral reefs, trophic magnification, potential risk, South China

Sea

Molecular response of coral *Porites lutea* holobionts from Weizhou Island under heat stress

Yonggang Wang ^a, Kefu Yu ^{a,b*}, Wen Huang ^a

^a Guangxi Laboratory on the Study of Coral Reefs in the South China Sea; Coral Reef Research Center of China; School of Marine Sciences, Guangxi University, Nanning 530004, China

^b Southern Marine Science and Engineering Guangdong Laboratory, Zhuhai 519000, China

* Corresponding author at Guangxi University, No. 100 Daxue East Road, Nanning 530004, China.

E-mail address: kefuyu@scsio.ac.cn; (K.F. Yu)

Abstract

Global warming poses a significant threat to the well-being and persistence of coral reefs. An extensive occurrence of coral bleaching has been documented in the northern waters of Weizhou Island in the South China Sea, attributed to abnormal ocean heat waves. This event has had a notable detrimental effect on the ecological vitality of coral reefs in the area. To gain a deeper comprehension of the alterations in the interplay among diverse biological constituents of coral holobionts under heat stress, as well as to elucidate the molecular regulatory mechanism of coral thermal adaptation, further investigation is warranted. In this study, a comprehensive examination of proteomics and microbiota was conducted on bleaching and unbleaching *Porites lutea* corals from Weizhou Island during a coral thermal bleaching event. The findings revealed a significant reduction in Symbiodiniaceae density and Fv/Fm in the bleaching coral tissue. However, despite this decline, a stable symbiotic association with Symbiodiniaceae subclade C15 was still observed. Additionally, significant differences were recorded in the 16S profiling, the symbiotic bacteria α diversity in the bleaching coral was significantly higher than that in the unbleaching coral. The abundance of *Proteobacteria* decreases, while the abundance of opportunistic *Bacteroidetes*

increases. Microbiota changes in the structure and function of symbiotic bacterial communities may affect the *P. lutea* holobiont health and fitness. TMT proteomics analysis identified 2067 unique proteins from coral samples (1906 from hosts and 161 from symbiotic algae C15). Compared to bleaching coral tissue, there were 97 increases and 170 decreases in host protein expression in unbleaching tissue, 59 increases and 54 decreases in symbiotic algal protein expression. Differential protein functional enrichment shows that heat stress affects the core physiological metabolic pathways of coral holobiont, including coral host cell structure, protein turnover, energy metabolism, nutrient cycling, photosynthetic efficiency and material transport of symbiotic algae. Nutritional cycling changes represented by carbon and nitrogen metabolism in coral symbiotic algae may be an important molecular mechanism for symbiotic functional organisms to respond to heat stress. In addition, PSII light harvesting protein and host fluorescent protein (GFP) from host can become significant molecular markers of heat stress in symbiotic algae and hosts, respectively. Our results may help to elucidate the thermal adaptation molecular mechanism of *P. lutea* holobiont and have great significance for the protection of coral reefs in the context of global warming.

Keywords: Heat stress, Coral holobionts, *Porites lutea*, Symbiodiniaceae, Proteomics

Growth Characteristics and Climatic Significance of Porites Coral in Tanmen, Hainan Island during the Mid-Holocene

Yueer Li ^a, Kefu Yu ^{a,b*}, Tingli Yan ^a, Leilei Jiang ^a

^a Guangxi Laboratory on the Study of Coral Reefs in the South China Sea; Coral Reef Research Center of China; School of Marine Sciences, Guangxi University, Nanning 530004, China

^b Southern Marine Science and Engineering Guangdong Laboratory, Zhuhai 519000, China

* Corresponding author at Guangxi University, No. 100 Daxue East Road, Nanning 530004, China.

E-mail address: kefuyu@scsio.ac.cn; (K.F. Yu)

Abstract

Coral growth rate is a physical index closely associated with climatic factors such as sea surface temperature (SST), which provides high-resolution climate and environmental change information. As coral growth rate is minimally affected by environmental changes, it has become an informative index for coral paleoclimate research. However, limited research has been conducted on the mid-Holocene period, which shares similar climatic characteristics with the current warm period. Therefore, this study aimed to investigate the climate and environmental conditions during the mid-Holocene by analyzing the coral growth rates of modern and sub-fossil Porites coral cores collected from Tanmen, located on the eastern coast of Hainan Island. Firstly, by using X-ray radiography and image processing methods, the coral growth rates of all these cores were measured and analyzed, resulting in the identification of the growth rate patterns during the mid-Holocene. Additionally, a linear relationship was established between coral growth rate (L) and SST in Tanmen, expressed as $SST = (2.945 \pm 0.237) \times L + 22.481 \pm 0.301(1 \text{ s. e.})$, based on analyzing the environmental factors that impact modern coral (2005—2021 AD). Then the reconstructed annual average SST sequence of 406 years during the mid-Holocene (6143—4356aBP) revealed an average coral growth rate of 1.079cm/a, ranging from 0.607 to 1.670cm/a, with noticeable fluctuations. The coral growth rate sequence also shows three consecutive periods of low growth rate characteristics, accompanied by a significant increase in interannual variability after 4515 a BP, resulting in more

complex fluctuations. Moreover, the reconstructed SST sequence based on coral growth rate data reveals that the mean SST of the mid-Holocene is $25.7\pm 0.54^{\circ}\text{C}$, which is comparable to the modern SST under the context of aggravating global warming. The average annual SST varies from 24.7°C to 26.8°C in the mid-Holocene, exhibiting considerable fluctuations between warm and cold periods, and with three distinct periods of low SST at 5860 a BP, 5660 a BP, and 5160 a BP. Moreover, spectral analysis conducted on both modern coral growth rate sequences and instrumental SST reveals the presence of a significant 3—7-year ENSO cycle. However, during the mid-Holocene, the primary cycle of ENSO experienced a change, and its frequency markedly decreased, suggesting that ENSO activity was weaker compared to the modern period. Nevertheless, further statistical analysis employing the probability density function indicates a gradual increase in ENSO variability during this period. In conclusion, this study provides detailed insights into the temperature variations and tropical climate characteristics during the mid-Holocene, highlighting the significance of coral growth rate as an informative index for paleoclimate research.

Keywords: Sea Surface Temperature; ENSO; Mid-Holocene; Coral Growth Rate; Northern South China Sea

Content and source analysis of organic carbon in outer slope sediments of Yongle Atoll, Xisha Islands

Jie Gao^a, Kefu Yu^{a,*}, Shendong Xu^{a,b}, Xueyong Huang^a

^a Guangxi Laboratory on the Study of Coral Reefs in the South China Sea, Coral Reef Research Center of China, School of Marine Sciences, Guangxi University, Nanning 530004, China;

^b Key Laboratory of Coastal Zone Environmental Processes and Ecological Remediation, Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences, Yantai 264003, China;

* Corresponding author, E-mail address: kefuyu@scsio.ac.cn (Kefu Yu).

Abstract

Organic carbon burial is an important part of the carbon cycle, but there are few studies on organic carbon in coral reef sediments, which affects the accurate assessment of coral reef carbon cycle. In this paper, the modern surface sediments from the outer slope of Yongle Atoll, Xisha Islands, South China Sea, were analyzed for their total organic carbon (TOC) content, total nitrogen (TN) content, organic carbon isotope ($\delta^{13}\text{C}$) value, as well as sediment grain size, chlorophyll content and other indicators. The ecological condition of the outer slope of Yongle Atoll reef is relatively good, and has the potential to represent the organic carbon characteristics in sediments of healthy coral reef ecosystems. The results showed that: 1) the TOC content in the sediments from the outer slope of Yongle Atoll reef ranged from 0.71 to 1.66 $\text{mg}\cdot\text{g}^{-1}$, with an average of $1.23\pm 0.31 \text{ mg}\cdot\text{g}^{-1}$; the TN content ranged from 0.12 to 0.28 $\text{mg}\cdot\text{g}^{-1}$, with an average of $0.20\pm 0.05 \text{ mg}\cdot\text{g}^{-1}$. 2) the C/N ratio ranged from 6.16 to 7.59, with an average of 6.75 ± 0.34 ; $\delta^{13}\text{C}$ values ranged from -17.49 to -15.85‰, with an average of $-16.61\pm 0.49\%$, indicating that the organic carbon in the sediments was predominantly of marine autochthonous origin and mainly from benthic plants. 3) Organic carbon content was negatively correlated with water depth and positively correlated with chlorophyll a content and pheophytin content, indicating that primary productivity controlled by benthic plants was the main source of organic carbon content on the outer slope of the reef. Combined with the vertical accumulation rate of the outer reef slope sediments of the Pacific Ocean since the Holocene (the average is between 2~5 $\text{mm}\cdot\text{a}^{-1}$), it is inferred that the organic carbon burial flux of the outer slope of Yongle Atoll is between 3~8 $\text{g}\cdot\text{m}^{-2}\cdot\text{a}^{-1}$. The present study provides new

information for evaluating the contribution of coral reefs in the South China Sea to the carbon cycle.

Key words: Coral reef; Sediment; Organic carbon; Carbon isotope; Yongle Atoll; Xisha Islands

Petrologic and geochemical features of weathering paleo-crust in coral reef carbonate strata in Xisha Island since Miocene

Yang Yang ^a, Kefu Yu ^{b*}

^a Guangxi Key Laboratory of Hidden Metallic Ore Deposits Exploration, College of Earth Sciences, Guilin University of Technology, Guilin, 541004, China.

^b Guangxi Laboratory on the Study of Coral Reefs in the South China Sea; Coral Reef Research Center of China; School of Marine Sciences, Guangxi University, Nanning 530004, China.

mail: kefuyu@scsio.ac.cn; yangyang007@glut.edu.cn

Abstract

Coral reef response to sea level fluctuation sensitively and rapidly. The weathering paleo-crust in coral reef carbonate strata are formed by coral reef carbonate weathering and leaching during lowland, which is an important indicator of sea level fluctuation. However, most studies focus on shorter timescales, which are limited by the absence of effective indicators and high-resolution dating tools. To overcome this limitation, we investigated the Petrologic and geochemical features of a 928.75-m-long coral reef core (CK2) from Xisha Islands, northern South China Sea and their relationship to sea level fluctuations. Compared with the white coral reef carbonate formed under normal environment, the weathering paleo-crust are usually yellow, brownish yellow and maroon red. A large number of voids and dissolution pores can be seen in the core. The surface of the pores is mostly covered with calcareous crusts and clayey mud materials, and some of the pores develop stalactite-shaped crystals. And along with the geochemical anomalies, which were characterized by higher $^{87}\text{Sr}/^{86}\text{Sr}$ than the upper and lower level or a sudden jump increase, negative shift of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$, higher Mn, Ti, Zr, Al, Si, K and Fe and lower Sr content. Beside, The $^{87}\text{Sr}/^{86}\text{Sr}$ of coral reef carbonate in CK2 showed a continuously increasing trend with shallower depth, from

0.708509±10 at the bottom to 0.709164±8 at the top. The overall variation range and trend were consistent with the variation range and trend of $^{87}\text{Sr}/^{86}\text{Sr}$ of seawater since 19.6 Ma, showing that the $^{87}\text{Sr}/^{86}\text{Sr}$ of the South China Sea and the open ocean are homogeneous in the last 20 Ma, and can be used to reconstruct the chronological framework based on Strontium Isotopic Stratigraphy (SIS). We reconstructed the relative sea level fluctuation in the northern South China Sea, the tectonic activity of Xisha block, and global sea level fall based on the weathering paleo-crust and SIS of CK2, the results are mostly consistent with other records, suggesting that the petrologic and geochemical indicators proposed by this study are reliable, and SIS can provide relatively high resolution age limits.