

## Report on the 2015 workshop of the International Research Coordination Network for Biodiversity of Ciliates (IRCN-BC) held at Ocean University of China (OUC), Qingdao, China, 19–21 October 2015

Alan WARREN<sup>1</sup>, Nettie McMILLER<sup>2</sup>, Lúcia SAFI<sup>3</sup>, Xiaozhong HU<sup>4</sup>, Jason TARKINGTON<sup>5</sup>

<sup>1</sup> Department of Life Sciences, Natural History Museum, London SW7 5BD, UK; <sup>2</sup> North Carolina Central University, Durham, NC27707, USA; <sup>3</sup> Virginia Institute of Marine Science, Gloucester Point, VA23062, USA; <sup>4</sup> Institute of Evolution and Marine Biodiversity, Ocean University of China, Qingdao 266003, China; <sup>5</sup> Department of Biology and Biochemistry, University of Houston, Houston, TX77023, USA

The 4<sup>th</sup> workshop of the IRCN-BC, entitled ‘Current Trends, Collaborations and Future Directions in Biodiversity Studies of Ciliates’ and convened by Weibo Song and colleagues at OUC, was attended by 53 participants from 12 countries. The workshop comprised oral presentations and posters grouped into three themes reflecting the three dimensions of biodiversity, namely: taxonomic diversity, ecological diversity and genetic diversity. The main aims of the workshop were to provide a platform for the presentation of recent findings and to facilitate future collaborations for enhancing research and training.

Thirteen talks focused mainly on ciliate taxonomy and systematics including both of free-swimming and epibiotic forms. There have been intensive studies in a number of institutions in China in recent years of free-living ciliate diversity, mainly in coastal and oceanic waters. Weiwei Liu (South China Sea Institute of Oceanology) reported on the diversity of marine and brackish water oligotrich ciliates from coastal and oceanic waters off southern China. Thirty morphospecies

were recorded for the first time in the South China Sea including two new strombidiid genera. The coastal waters of the South China Sea are also the location of the last remaining mangrove wetlands in China. Xiaofeng Lin (South China Normal University) reported the discovery of > 200 ciliate species, including 60 new species and one new family, from three such wetlands over the past decade, whereas previously < 20 spp. had been recorded from all of China’s mangroves. The most frequently encountered groups were hypotrichs (55 spp.), pleurostomatids (36 spp.) and colpodids (27 spp.). Hongbo Pan (Shanghai Ocean University) reported on community diversity in Hangzhou Bay, the most highly polluted marine habitat in China. Despite high organic pollution and eutrophication, 52 spp., including 8 new species, were recorded, mainly hypotrichs and scuticociliates. Using High Throughput Sequencing (HTS) techniques, Dapeng Xu (Xiamen University) reported on ciliate diversity at over thirty near-shore and oceanic sites in both the east and west Pacific Ocean. Generally, the ciliate community showed high diversity with

spirotricheans usually dominant in terms of both species diversity and relative sequence abundance. Following analyses of morphological, morphogenetic and molecular data, Yuan Xu (East China Normal University) reviewed the systematics of the class Karyorelictea and proposed an evolutionary process for explaining the patterns of development of oral structures. It was also concluded that the only freshwater karyorelictean genus (*Loxodes*) probably evolved from a *Remanella*-like ancestor. In his talk on the large colonial peritrich genus *Zoothamnium*, Daode Ji (Yantai University) critically reviewed the value of various morphological features for asserting taxonomic affinities. He concluded that features of the stalk (shape, branching pattern, etc.) and zooid *in vivo* (size, shape, etc.) are useful for species circumscription and identification whereas other features that have been traditionally used, such as the contractile vacuole, macronucleus and silverline system, are of only limited value. Xinpeng Fan (East China Normal University) gave an overview of extrusomes in hypotrichs and their potential importance in studies of systematics, ecology, and regulated exocytosis. Using electron microscopy, five different kinds of extrusomes were identified in hypotrichs including various enigmatic cortical granules the functions of which were previously unknown.

Elsewhere, based on analyses of phylogenomic data, Denis Lynn (University of British Columbia) concluded that: (1) the SAL group is monophyletic; (2) nassulids and microthoracids are a clade; (3) the position of *Protoctozia* is unresolved, but it is not a spirotrichean as has been previously suggested, and; (4) *Halteria* is an 'oligotrichous' hypotrich. Sripoorna Somasundaram and Jeeva Susan Abraham (Acharya Narendra Dev College, University of Delhi) investigated the systematics of spirotricheans isolated from different freshwater habitats in India, using combinations of multi-gene and protein (SSU rDNA, hsp70 and metallothionein) structure data, and morphological and morphogenetic data, respectively.

Epibiontic or ectoparasitic ciliates were the subject of three presentations. Rosaura Mayén-Estrada (Universidad Nacional Autónoma de México) and John C. Clamp (North Carolina Central University) reviewed the global species diversity of the loricate peritrich *Lagenophrys* from crustacean hosts. A total of 62 *Lagenophrys* spp. have been recorded from > 200 crustacean host species in 49 countries worldwide. Investigations by Yuanjun Zhao (Chongqing Normal University) on trichodinids from marine and freshwater fishes of Chi-

na have resulted in the recovery of > 50 species, 12 of which are new. Morphological and molecular data revealed that: (1) both blade morphology and GC content are phylogenetically informative, and (2) *Trichodina*, the most speciose mobiline genus, is not monophyletic. Igor Dovgal (Schmalhausen Institute of Zoology, Kiev) reported the presence of epibiontic ciliates, mostly suctorians and peritrichs, on invertebrates in extreme environments including: hypersaline waters up to 100‰, hydrothermal vents at depths of more than 4000 m and in subterranean habitats.

Ciliate ecology was the main focus eight talks. Jun Gong (Yantai Institute of Coastal Zone Research) gave an overview of adaptations by bacteria for avoiding ingestion and digestion by predators such as ciliates. He noted that digestion resistant bacteria (DRB) are rare in the marine plankton but abundant within ciliate cells. He also demonstrated that the composition of the DRB community is influenced by certain environmental factors. Yoshinari Endo (Tohoku University) presented findings on the development of the suctorian *Ephelota* living epibiotically on the crustacean *Euphausia pacifica*, the dominant krill in the North Pacific Ocean. He reported adaptations adopted by *Ephelota* in response to the frequent moulting of *Euphausia pacifica* including attachment to the krill at early moult stage and initiation of budding prior to moulting, thus ensuring colonization of the new individual. Lucia Safi (Virginia Institute of Marine Science) also investigated the relationship between a ciliate epibiont and a marine crustacean host, in this case *Zoothamnium intermedium* on the copepods *Acartia tonsa* and *Eurytemora affinis*. The distribution of *Z. intermedium* was found to vary seasonally, abundances being highest in the summer and lowest during the winter, thus correlating with high concentrations in the water of its bacterial food. Yingchun Gong (Institute of Hydrology, Wuhan) presented findings of an investigation of commercial algal systems used for biofuel production, and their contamination by algivorous protozoa. Over 20 spp. of algivorous ciliates were found in three of the main algal culture systems, however only one protozoan predator at a time, usually either an amoeba or a flagellate, causes cultures to crash. The effects of climate change on marine pelagic ciliate communities in polar regions was the subject of a talk by Yong Jiang (OUC). Analyses of over 1,000 samples revealed significant spatial variations in ciliate community structure and that these appear to be influenced by ice-melt. Anton Esaulov (Penza State University) also reported on polar ciliate diversity, focusing

on interstitial karyorelictean communities in intertidal sediments of the White Sea. It was found that horizontal distributions varied both seasonally and according to food availability, whereas vertical distributions were relatively stable and restricted by the rapid decrease in redox potential below about 3 cm depth. Chris Lobban (University of Guam) reported on the mostly sedentary marine heterotrich *Maristentor dinoferus* inhabiting the somewhat warmer coastal waters of Guam. *Maristentor* exhibits a diurnal behavioural pattern, dispersing during daylight hours but forming clusters at night, probably as a defensive mechanism against potential fish predators. Data were also presented on the cell contents of *Maristentor*, including endosymbiotic zooxanthellae and the pigment maristentorin. Zhuo Shen (Hong Kong University of Science and Technology) investigated microbial food web interactions between euplotid ciliates *Diophrys* and *Euplotes* and their algal prey *Dunalliella salina* in laboratory-controlled conditions. Using video recordings, *D. salina* was shown to exhibit a chemotactic response by swimming towards the ciliates, possibly in search of nutrients. In some cases, individual ciliates become stationary, reduce in size, and eventually die in the presence of sufficient numbers of their pursuers.

The genetic diversity of ciliates was the focus of six talks. Jie Xiong (Institute of Hydrobiology, Chinese Academy of Sciences) discussed the distinct nucleosome distribution patterns in the structurally and functionally differentiated micro and macro nuclei of *Tetrahyemna thermophila*. Jie Xiong also spoke on behalf of Wei Miao (Institute of Hydrobiology, Chinese Academy of Sciences) about the many genomic studies of ciliates that are being undertaken in China. Jason Tarkington (University of Houston) presented the results of a long-term evolution experiment in *Tetrahyemna thermophila* that showed an increase in evolvability following sex. The distinct genetic architecture of *Tetrahyemna*, which is thought to be responsible for this observation, was also discussed. Rebecca Zufall

(University of Houston) also spoke about the distinct genetic architecture of *Tetrahyemna thermophila* and its role in the evolution of asexuality in this species. The results of computational modelling show how the genetic architecture of *Tetrahyemna* could alleviate some of the negative consequences of asexuality and thus explain the higher than usual prevalence of asexuals in this species. Wei Wang (Institute of Biotechnology, Shanxi University) presented research on the roles of Tcd1 and Tcd2 in regulating genome rearrangements and chromatin modifications in *Tetrahyemna*. These genes play an important role in genome regulation, and a mechanism for epigenetic inheritance during macronuclear development was discussed. Maria Rautian (St. Petersburg State University) presented research using *Paramecium* morphospecies and syngens as a model system for species structure investigations. She suggested that the epigenetic mechanism allowing for extensive genome rearrangement in ciliates could cause reproductive isolation.

In the spirit of the collaborative theme of the workshop, Alan Warren (Natural History Museum, UK) mentioned the many benefits of joint research, and gave an overview of the main funding sources for supporting international collaboration for research, and opportunities for training, in ciliate biodiversity.

Five posters were presented as follows: Igor V. Dovgal (Schmalhausen Institute of Zoology) on suctorians in Taiwanese waters; Ilham Kh. Alakbarov (Institute of Zoology National Academy of Sciences of Azerbaijan) on biodiversity of the free-living ciliates of Azerbaijan; Pu Wang (OUC) on the molecular phylogeny of Phyllopharyngea; Hongbo Pan (Shanghai Ocean University) on diversity of *Pleuronema* in the Hangzhou Bay estuary; Yuan Xu (East China Normal University) on the systematics of two new trachelocercid spp.

The 2016 workshop will be held in Guam, 26–29 July 2016. For further details, see the IRCN-BC website at [ircn-bc.org](http://ircn-bc.org).