Chapter 15

Synthesis: Coral reef conservation and restoration in the omics age

Manuel Aranda, Madeleine J.H. van Oppen

The dire outlook for coral reefs in the Anthropocene has intensified efforts in many research areas to improve and scale coral reef conservation and restoration. The multitude of threats faced by corals and the scale at which restoration needs to be applied to mitigate or, if possible, reverse current projections require approaches to become more holistic and to integrate a diverse range of research fields and methodologies (Voolstra et al. 2021; National Academies of Sciences and Medicine 2019; Duarte et al. 2020; van Oppen et al. 2015). These include marine spatial planning (Chapter 2) to identify and protect high value areas, biodiversity studies (Chapter 13) to understand the role of biodiversity in resilience and to track changes over time, but also molecular studies aimed at dissecting specific biological processes through transcriptomics (Chapter 10), reverse genetics (Chapter 11) or metabolomics (Chapter 12). Many of these fields already rely on or can greatly benefit from the technological advances made in the characterization and quantification of biological molecules such as nucleic acids, proteins, and metabolites, collectively known as omics (Chapter 1).

In this volume, we highlight how omics can support coral reef conservation and restoration by enabling certain research areas but also through the generation of important synergies between the different fields and approaches that can further leverage coral reef restoration efforts. For instance, while marine spatial planning (Chapter 2) can greatly benefit from genetic connectivity studies to identify sink and source reefs, this can be further supported through the integration of studies on genetic diversity (Chapters 3 and 13) and adaptive genetic variation in the host (Chapters 4 and 5) as well as the microbial symbionts (Chapters 6 and 7). Further, such an integrative approach for MPA design has the potential to significantly increase the scale and success of interventions such as selective breeding (Chapter 5), probiotics (Chapter 8) and acquired tolerance through environmental hardening (Chapter 9), by identifying suitable reefs with high dispersal potential for the deployment of enhanced coral stock. Selective breeding can benefit greatly from studies on adaptive genetic variation (Chapter 4), gene expression (Chapter 10), reverse genetics (Chapter 11) and metabolomics (Chapter 12), as these can provide functional context to genetic traits underlying coral resilience. Omics research is equally important for deciphering gene function in microalgal symbionts (Chapter 6) and other coral-associated microbes (Chapters 7 and 8); the continuous advances in sequencing technologies allow increasingly more in-depth studies of the microbial component of the coral holobiont. In essence, such studies provide a means to bridge the gap between correlations observed in metabarcoding studies and evidence of their functional contribution to holobiont biology. Such detailed knowledge of the microbial partners, their functions and the mechanisms underlying the structuring of their assemblages is paramount for our understanding the roles microbes play in holobiont acclimation and adaptation and, thus, coral resilience. It is also a prerequisite for the development of microbiome manipulation approaches that aim to increase coral resilience (Chapter 8).

While omics technologies can provide invaluable support for informing, guiding, and implementing conservation and restoration efforts, they also provide means for biodiversity
monitoring, and to identify potential risks and to track success of interventions over time. eDNA metabarcoding studies (Chapter 13) can aid in the monitoring of diversity losses and gains to aid in the assessment of the ecological state of an area and in this way help measuring the success of restoration efforts. Similarly, metabarcoding studies of coral-associated microbial communities (Chapter 7) may be used to identify potential disease outbreaks at early stages while biomarkers identified through transcriptomics (Chapter 10) or metabolomics (12) can help in assessing the health status of corals and identifying early signs of stress. It should be noted, however, that the technological advances that can contribute to improving restoration efforts are not restricted to omics technologies. For instance, issues arising from low survivability of transplanted corals in managed translocation approaches or offset spawning of donor and acceptor populations used for selective breeding (Chapter 5) can potentially be addressed through cryopreservation (Chapter 14) that allows the long-term storage of donor sperm, larvae, symbionts, or potentially even coral tissue. Cryopreservation, however, can also be used as means to protect biodiversity and to retain genetic diversity for restoration purposes if it is informed by studies on adaptive genetic variation (Chapter 4).

In summary, coral reef conservation and restoration efforts are facing a myriad of challenges due to rapidly increasing sea surface temperatures and other anthropogenic perturbations that drive the decline of coral reef ecosystems. The mitigation and, if possible, reversal, of coral reef decline will require a broad multidisciplinary approach to achieve the scale and speed at which restoration needs to happen. The technological advances, such as those in omics technologies, provide unique opportunities to not only further our knowledge of coral holobiont biology and its complex multispecies interactions, but to also improve restoration approaches at large as discussed in this volume. To date, the use of omics in coral research is limited to a few specific subfields but its broad multidisciplinary integration (multimomics or panomics) will allow unlocking critical synergies and, thus, its full potential. Doing so, however, will require the development of tools to translate genomic, environmental, and modelled data into accessible and useable formats and the fostering of partnerships between the different scientific fields, managers, and other stakeholders. Looking forward, it will be critical to integrate the technological advances in the fields of omics in the conservation and restoration of coral reefs to secure a future for these iconic ecosystems.

References

