Received: 30 October 2019 | Revised: 25 March 2020 | Accepted: 31 March 2020

DOI: 10.1111/1440-1703.12128

ECOLOGICAL RESEARCH WILEY

SPECIAL FEATURE

Promoting idea sharing via Idea Paper

Idea Paper: Tracking the distribution of accretive reef communities across the Kuroshio region

Vianney Denis[1] | **Tung-Yung Fan**[2,3] | **Wanchien Victoria Hsiao**[1] | **Sung-Jin Hwang**[4] | **Yuting Vicky Lin**[1] | **Yoko Nozawa**[5]

[1]Institute of Oceanography, National Taiwan University, Taipei, Taiwan

[2]Graduate Institute of Marine Biology, National Dong Hwa University, Pingtung, Taiwan

[3]National Museum of Marine Biology and Aquarium, Pingtung, Taiwan

[4]Department of Life Science, Woosuk University, Jincheon, Republic of Korea

[5]Biodiversity Research Center, Academia Sinica, Taipei, Taiwan

Correspondence
Vianney Denis, Institute of Oceanography, National Taiwan University, Taipei 10617, Taiwan.
Email: vianney.denis@gmail.com

Funding information
Ministry of Science and Technology, Taiwan, Grant/Award Numbers: 107-2611-M-002-011, 108-2611-M-002-013; MOST Add-on Grant for International Cooperation (MAGIC)

Abstract

In line with contemporary changes in oceanic conditions, reef communities could be declining at the equator and expanding polewards, having previously happened in the past. Yet, some tropical organisms are now decimated at their distributional cores and observed beyond their inferred range limits. However, it remains unclear if this is happening at the community scale, especially due to the challenges of collecting quantitative and comparable data across latitudes. Here, we propose that monitoring sentinel plots via photogrammetry could help to assess abiding changes in benthic communities and trajectories of reef-building populations across the Kuroshio region. We think that as oceans are becoming warmer, accretive reef communities may shift their distribution northwards which may be primarily due to a change in the relative biomass-abundance of resident taxa. Consistent trends among latitudes will resolve the possibility of contraction or expansion of accretive reef communities, providing further insight into the variety of responses and dynamics observed across latitudes in the context of the Anthropocene.

KEYWORDS

coral reef, distributional shift, ecosystem, experiment, photogrammetry

1 | RESEARCH QUESTION

Are accretive reef communities shifting northwards across the Kuroshio region?

2 | VALUE

Climate change fundamentally alters ocean ecosystems by reconfiguring marine communities (Hoegh-Guldberg & Bruno, 2010). In the tropics, this is typically illustrated by its role in the transformation of benthic assemblages (Hughes et al., 2018), which are shifting away from the dominance and/or diversity of habitat-forming species (Alvarez-Filip, Dulvy, Gill, Côté, & Watkinson, 2009). Based on recent estimates, the contemporary tropical accretive reefs could be gone by 2070 if global heating continues on its current path (IPCC, 2018), leaving only small opportunities for strategic conservation and management of the world's last functioning coral reefs (Darling et al., 2019). In the meantime, the habitability for taxa with warm water affinities will increase in temperate locations (Couce, Ridgwell, & Hendy, 2013; Jones et al., 2019). Recent new records at high latitudes (Baird, Sommer, & Madin, 2012; Yamano, Sugihara, & Nomura, 2011) endorse an on-going tropicalization of temperate communities (Vergés et al., 2014), with potential ramifications on overall ecosystem properties and productivity (Vergés

et al., 2019). Paleontological records seem to empirically support the possibility of equatorial decline (Kiessling, Simpson, Beck, Mewis, & Pandolfi, 2012) and poleward expansion (Veron, 1992) of reef corals. Furthermore, and despite a global decline in coral recruitment since 1974 (Price et al., 2019), the persistent reduction in the densities of recruits in equatorial latitudes coupled with increased densities in sub-tropical latitudes suggest that coral recruitment may also be shifting poleward (Price et al., 2019). In this context, high latitude areas are hypothesized to constitute refuge habitats for endangered tropical taxa as climate changes (Beger, Sommer, Harrison, Smith, & Pandolfi, 2014), especially in areas with strong poleward currents that encourage dispersion like the Kuroshio region (Kumagai et al., 2018).

3 | RELEVANT HYPOTHESIS

Concurrently, accretive reef communities (i.e., communities forming their own substrata) could be shifting poleward as waters are warming. Tracking this distributional change in accretive reef communities across the Kuroshio region relies on testing two independent hypotheses related to the habitability at various latitudes:

1 Are accretive reef communities showing an *equatorial decline* in response to increasingly unfavorable environmental conditions at low latitude?
2 Are accretive reef communities showing a *northward expansion* in response to increasingly favorable environmental conditions at higher latitudes?

To date, conclusions on the possibility of a poleward shift in the distribution of coral reefs are often biased by being drawn on the interpretation of species occurrence (presence/absence) data (see discussion in MacKenzie, Nichols, Hines, Knutson, & Franklin, 2003). Actually, the shift in the distribution of accretive reef communities may only be restricted to modifications in the relative biomass-abundance of resident taxa, an aspect of their demography that has been largely overlooked. We argue that this shift does not necessarily involve the disappearance/appearance of reef organisms and cannot be restricted to the interpretation of taxa hypothetically migrating polewards. In fact, this shift can be restricted with changes in local population biomass or abundance, which will be depicted by both an "extirpation" and an "expansion" of the overall reef-building organisms' biomass-abundance at their trailing and leading edges, respectively (Pinsky, Selden, & Kitchel, 2020). Tracking those modern changes (decadal time scale) is critical to comprehend the overall persistence of coral reef ecosystem services in the Anthropocene (Woodhead, Hicks, Norström, Williams, & Graham, 2019), but must challenge our current way of addressing this problem to get empirical evidence in support of a distributional shift of the accretive reef communities.

4 | NEW RESEARCH IDEA

The recent advances in photogrammetry allow rapid, simple and wide-scale acquisition of benthic community composition (relative biomass-abundance distribution). Repeated photogrammetric surveys allow to obtain quantitative data that warrant accurate measurement of the gain and loss of habitat-forming taxa over time. Therefore, we propose to monitor sentinel plots via photogrammetry and assess abiding changes in benthic communities that will allow us to conclude on the possible shift in the distribution of accretive reef communities across the Kuroshio region.

5 | HOW TO SOLVE THE QUESTION THROUGH THE NEW IDEA

This research idea aims at using photogrammetric surveys to provide quantitative data that will allow us to empirically test both hypotheses and appreciate the possibility for the accretive reef communities to move northwards across the Kuroshio region. A conceptual view of the changes possibly affecting the contribution of reef builders to the communities through time (recent past, present-day and near future) is depicted in Figure 1, which expands the considerations on species richness to the communities.

The photogrammetric surveys will allow detecting fine-scale changes in large community areas by comparing, yearly, the contribution of reef builders in 10×10 m "plots" set up on hard substrates at −10 m depth across the Kuroshio region. Ideally, the experimental design will benefit from uniform contributions from tropical, subtropical and temperate locations with a minimum of five replicates surveyed within one degree of latitude to reduce confounding effects from local factors contributing to the regional variation. At each plot, three-dimensional (3D) models of the community will be acquired following the methodology described in Edwards et al. (2017). Orthomap produced will allow to quantitatively assess reef builder organisms for their density, size and morphology which will further provide insight into the structural complexity offered by the

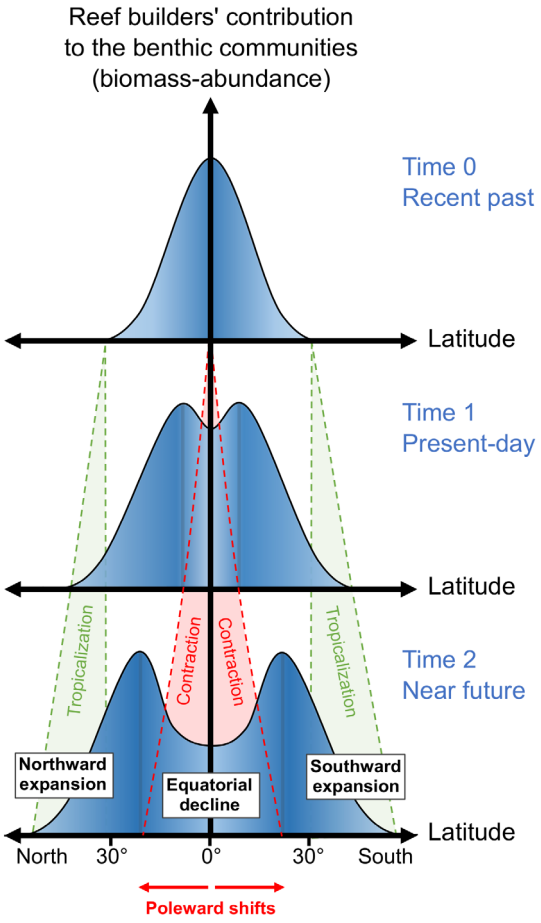

FIGURE 1 Hypothetical scenario in the changes affecting the contribution of reef builders to the communities through time (recent past, present-day and near future). This research aims to use the present-day situation (Time 1) to experimentally test equatorial decline and poleward expansion. If both are positive, this will provide evidence for the support of the poleward shifting of accretive reef communities. See Jones et al. (2019) for an example that uses coral fossils to predict reef habitability [Color figure can be viewed at wileyonlinelibrary.com]

habitat (e.g., Denis, Ribas-Deulofeu, Sturaro, Kuo, & Chen, 2017). Over the years (within 5–10 years), this procedure will be repeated at the same plots and models aligned for an accurate estimation of the demographic changing rate of reef builders. Overall, their trajectory will be defined as decreasing or increasing. Consistent trends among latitudes will resolve the possibility of expansion or contraction of reef communities in the context of the Anthropocene.

Ideally, this research should span between tropical and temperate areas by putting together collaborators such as in the Philippines, Taiwan, Japan and Korea as it questions the response of marine benthic organisms along latitudinal gradients in the Kuroshio region. Overall, and despite the challenges presented by an international partnership, this idea is relatively simple to set up yet it will fill a major gap in current knowledge. It tackles the difficulties of acquiring long-term quantitative data at permanent plots by using recent advances in photogrammetric techniques and inspirational monitoring examples from The 100 Island Challenge effort (http://100islandchallenge.org).

ACKNOWLEDGMENTS

Vianney Denis is supported by grants from the Ministry of Science and Technology (MOST, nos. 107-2611-M-002-011 and 108-2611-M-002-013) of Taiwan. The MOST Add-on Grant for International Cooperation (MAGIC) initiates discussion on this topic. Authors thank Stéphane De Palmas, Aziz Mulla and two anonymous reviewers for their critical comments on this manuscript.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

ORCID

Vianney Denis https://orcid.org/0000-0002-0914-5586
Wanchien Victoria Hsiao https://orcid.org/0000-0002-6747-1216
Sung-Jin Hwang https://orcid.org/0000-0002-1259-6775
Yuting Vicky Lin https://orcid.org/0000-0003-0438-3507
Yoko Nozawa https://orcid.org/0000-0001-6124-6045

REFERENCES

Alvarez-Filip, L., Dulvy, N. K., Gill, J. A., Côté, I. M., & Watkinson, A. R. (2009). Flattening of Caribbean coral reefs: region-wide declines in architectural complexity. *Proceedings of the Royal Society B: Biological Sciences*, *276*, 3019–3025. https://doi.org/10.1098/rspb.2009.0339

Baird, A. H., Sommer, B., & Madin, J. S. (2012). Pole-ward range expansion of *Acropora* spp. along the east coast of Australia. *Coral Reefs*, *31*, 1063. https://doi.org/10.1007/s00338-012-0928-6

Beger, M., Sommer, B., Harrison, P. L., Smith, S. D. A., & Pandolfi, J. M. (2014). Conserving potential coral reef refuges at high latitudes. *Diversity and Distributions*, *20*, 245–257. https://doi.org/10.1111/ddi.12140

Couce, E., Ridgwell, A., & Hendy, E. J. (2013). Future habitat suitability for coral reef ecosystems under global warming and ocean acidification. *Global Change Biology*, *19*, 3592–3606. https://doi.org/10.1111/gcb.12335

Darling, E. S., McClanahan, T. R., Maina, J., Gurney, G. G., Graham, N. A. J., Januchowski-Hartley, F., … Mouillot, D. (2019). Social–environmental drivers inform strategic management of coral reefs in the Anthropocene. *Nature Ecology & Evolution*, *3*, 1341–1350. https://doi.org/10.1038/s41559-019-0953-8

Denis, V., Ribas-Deulofeu, L., Sturaro, N., Kuo, C.-Y., & Chen, C. A. (2017). A functional approach to the structural complexity of coral assemblages based on colony morphological features. *Scientific Reports*, *7*, 9849. https://doi.org/10.1038/s41598-017-10334-w

Edwards, C. B., Eynaud, Y., Williams, G. J., Pedersen, N. E., Zgliczynski, B. J., Gleason, A. C. R., … Sandin, S. A. (2017).

Large-area imaging reveals biologically driven non-random spatial patterns of corals at a remote reef. *Coral Reefs*, *36*, 1291–1305. https://doi.org/10.1007/s00338-017-1624-3

Hoegh-Guldberg, O., & Bruno, J. F. (2010). The impact of climate change on the world's marine ecosystems. *Science*, *328*, 1523–1528. https://doi.org/10.1126/science.1189930

Hughes, T. P., Kerry, J. T., Baird, A. H., Connolly, S. R., Dietzel, A., Eakin, C. M., ... Torda, G. (2018). Global warming transforms coral reef assemblages. *Nature*, *556*, 492–496. https://doi.org/10.1038/s41586-018-0041-2

IPCC (2018). In V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, et al. (Eds.), *Global warming of 1.5°C—an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change* (p. 616). Geneva, Switzerland: IPCC. https://www.ipcc.ch/report/sr15/

Jones, L. A., Mannion, P. D., Farnsworth, A., Valdes, P. J., Kelland, S.-J., & Allison, P. A. (2019). Coupling of palaeontological and neontological reef coral data improves forecasts of biodiversity responses under global climatic change. *Royal Society Open Science*, *6*, 182111. https://doi.org/10.1098/rsos.182111

Kiessling, W., Simpson, C., Beck, B., Mewis, H., & Pandolfi, J. M. (2012). Equatorial decline of reef corals during the last Pleistocene interglacial. *Proceedings of the National Academy of Sciences of the United States of America*, *109*, 21378–21383. https://doi.org/10.1073/pnas.1214037110

Kumagai, N. H., García Molinos, J., Yamano, H., Takao, S., Fujii, M., & Yamanaka, Y. (2018). Ocean currents and herbivory drive macroalgae-to-coral community shift under climate warming. *Proceedings of the National Academy of Sciences of the United States of America*, *115*, 8990–8995. https://doi.org/10.1073/pnas.1716826115

MacKenzie, D. I., Nichols, J. D., Hines, J. E., Knutson, M. G., & Franklin, A. B. (2003). Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. *Ecology*, *84*, 2200–2207. https://doi.org/10.1890/02-3090

Pinsky, M. L., Selden, R. L., & Kitchel, Z. J. (2020). Climate-driven shifts in marine species ranges: scaling from organisms to communities. *Annual Review of Marine Science*, *12*, 1–27. https://doi.org/10.1146/annurev-marine-010419-010916

Price, N. N., Muko, S., Legendre, L., Steneck, R., Van Oppen, M. J. H., Albright, R., ... Edmunds, P. J. (2019). Global biogeography of coral recruitment: tropical decline and subtropical increase. *Marine Ecology Progress Series*, *621*, 1–17. https://doi.org/10.3354/meps12980

Vergés, A., Steinberg, P. D., Hay, M. E., Poore, A. G. B., Campbell, A. H., Ballesteros, E., ... Wilson, S. K. (2014). The tropicalization of temperate marine ecosystems: climate-mediated changes in herbivory and community phase shifts. *Proceedings of the Royal Society B: Biological Sciences*, *281*, 20140846. https://doi.org/10.1098/rspb.2014.0846

Vergés, A., McCosker, E., Mayer-Pinto, M., Coleman, M. A., Wernberg, T., Ainsworth, T., & Steinberg, P. D. (2019). Tropicalisation of temperate reefs: implications for ecosystem functions and management actions. *Functional Ecology*, *33*, 1000–1013. https://doi.org/10.1111/1365-2435.13310

Veron, J. E. N. (1992). Environmental control of Holocene changes to the world's most northern hermatypic coral outcrop. *Pacific Science*, *46*, 405–425.

Woodhead, A. J., Hicks, C. C., Norström, A. V., Williams, G. J., & Graham, N. A. J. (2019). Coral reef ecosystem services in the Anthropocene. *Functional Ecology*, *33*, 1023–1034. https://doi.org/10.1111/1365-2435.13331

Yamano, H., Sugihara, K., & Nomura, K. (2011). Rapid poleward range expansion of tropical reef corals in response to rising sea surface temperatures. *Geophysical Research Letters*, *38*, L04601. https://doi.org/10.1029/2010GL046474

How to cite this article: Denis V, Fan T-Y, Hsiao WV, Hwang S-J, Lin YV, Nozawa Y. Idea Paper: Tracking the distribution of accretive reef communities across the Kuroshio region. *Ecological Research*. 2020;35:595–598. https://doi.org/10.1111/1440-1703.12128