A crash course in coral taxonomy: coral collection and curation

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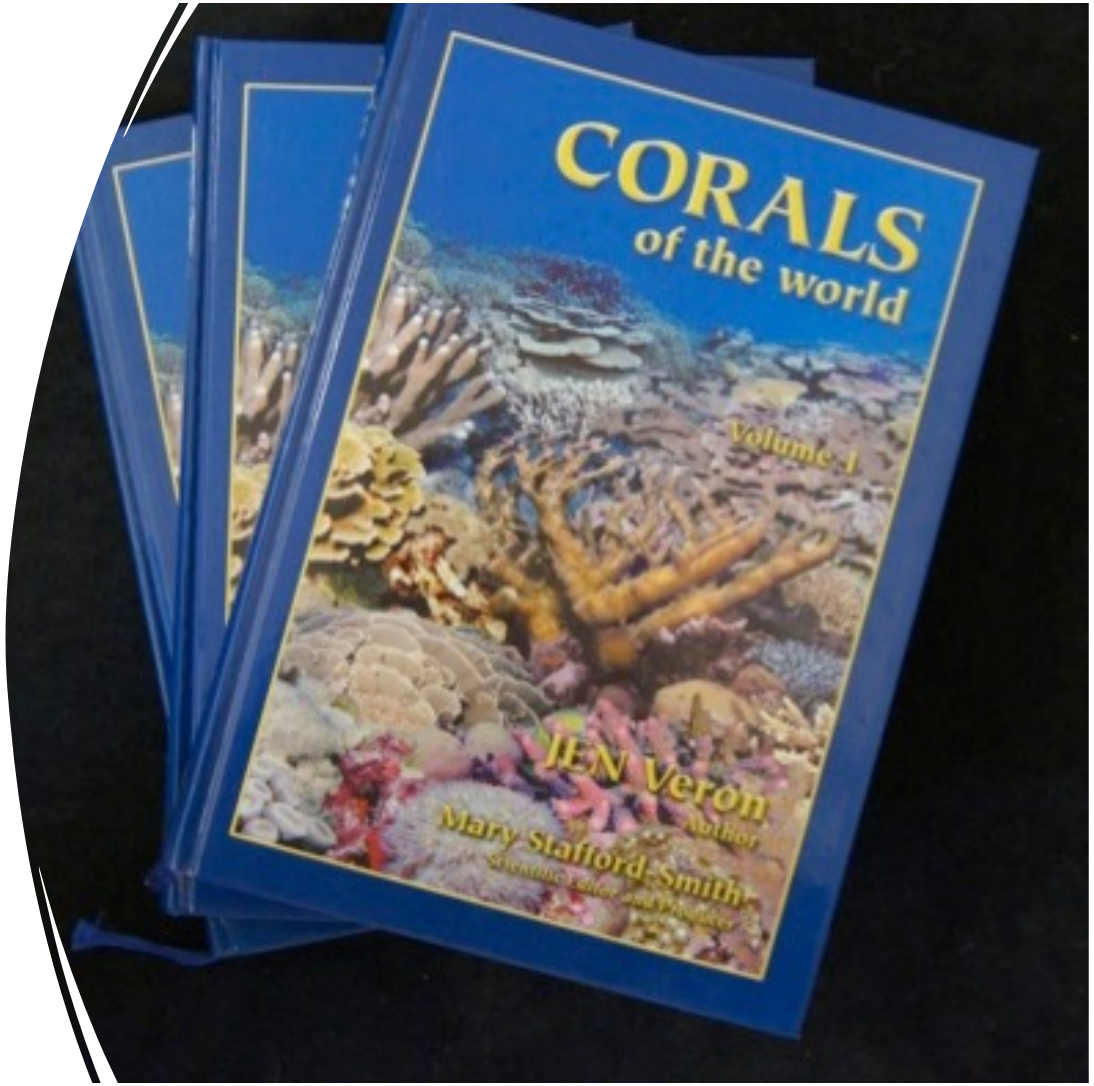
JCU

QUEENSLAND MUSEUM

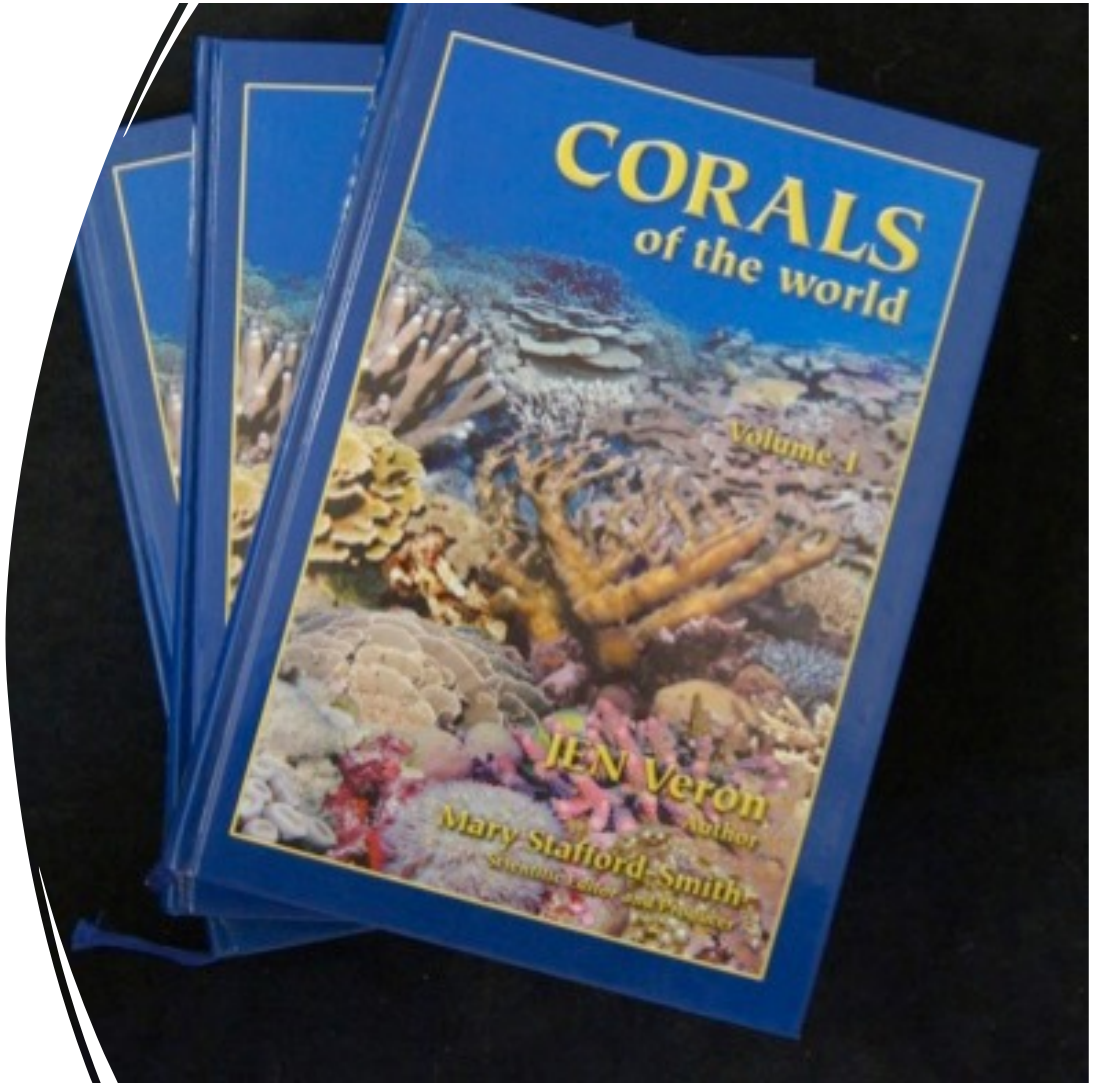
Veron (2000)

- 18 families
- 112 genera
- 799 species

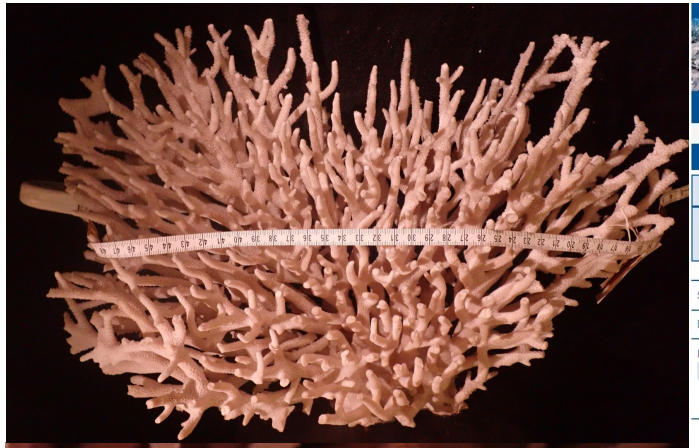


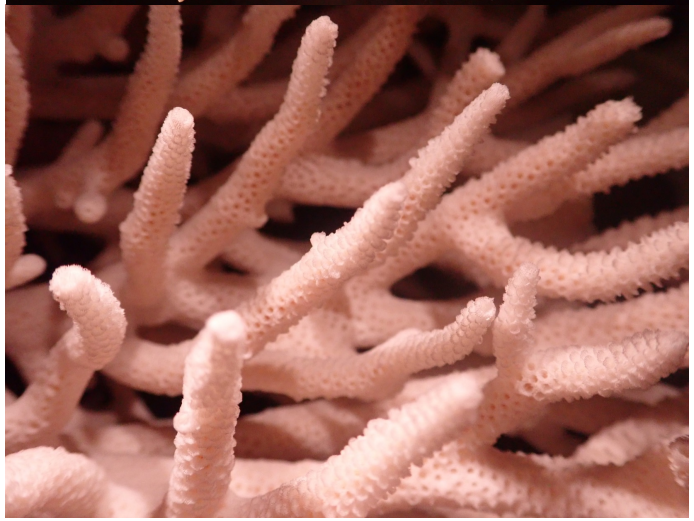
Veron (2000)

- No molecular data
- No quantitative morphology
- No reproductive biology
- No experimental tests of key concepts, such as morphological plasticity
- Surprising indifference to much of the type material



Acropora subulata sensu Veron 2000





Lectotype USNM_256

Nine images, 8 species, none of which match the type of *A. subulata (*Dana 1846)

The genus *Montastrea sensu Veron*

Veron species	Molecular species	Molecular family
Montastrea annuligera	Astrea annuligera	Merulinidae
Montastrea curta	Astrea curta	Merulinidae
Montastrea colemani	Favites colemani	Merulinidae
Montastrea magnistellata	Favites magnistellata	Merulinidae
Montastrea valenciennesi	Favites valenciennesi	Merulinidae
Montastrea multipunctata	Micromussa multipunctata	Lobophyllidae
Montastrea cavernosa	Montastraea cavernosa	Montastreidae
Montastrea annularis	Orbicella annularis	Merulinidae
Montastrea faveolata	Orbicella faveolata	Merulinidae
Montastrea franksi	Orbicella franksi	Merulinidae
Montastrea salebrosa	Paramontastraea salebrosa	Merulinidae
Montastrea serageldini	Paramontastraea serageldini	Merulinidae

The 12 species accepted by Veron 2000 are now in 6 genera in 3 Families

Testing the genus *Acropora*

- 166 spp recognised by Veron 2000
- 400 nominal species (Crosbie et al 2026)
- Therefore, there are 234 nominal species that are not mentioned in *Corals of the World* because they were either synonymised or unresolved

Crosbie et al 2026

The Genus *Acropora*

Cowman et al in review

890 specimens, 272 Primary Species hypotheses (PSH)

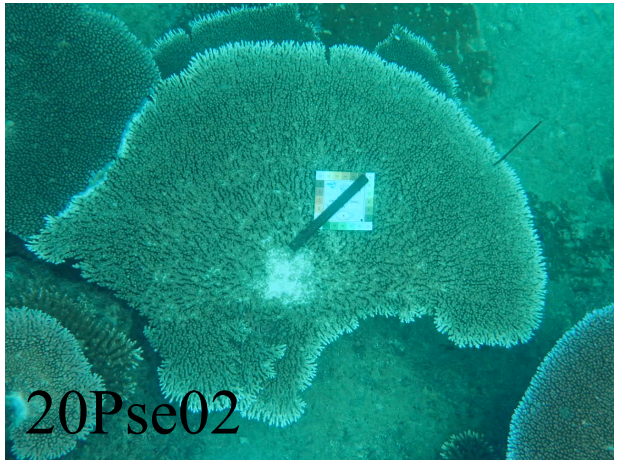
- 50 PSH - accepted species
- 28 PSH – previously synonymised
- 122 PSH – unresolved, many likely to be new
- 72 PSH – undescribed

- Only 50 of 272 species are in the identification guides

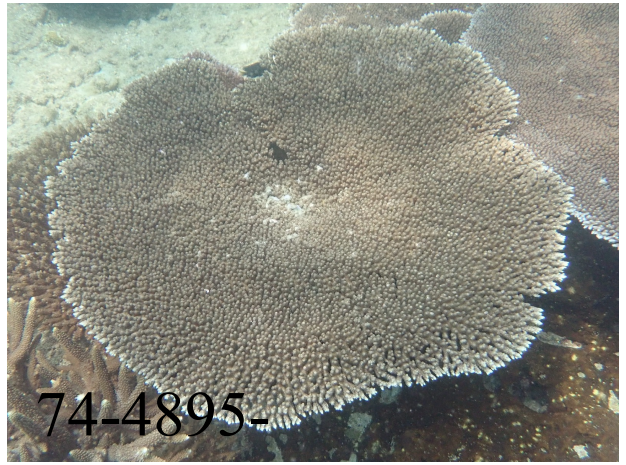
Testing Veron's hypotheses: range size of *Acropora hyacinthus* (Dana 1846)

The *Acropora hyacinthus* species complex is composed of at least 20 different species all with restricted geographical distributions (e.g. Rassumussen et al 2025)

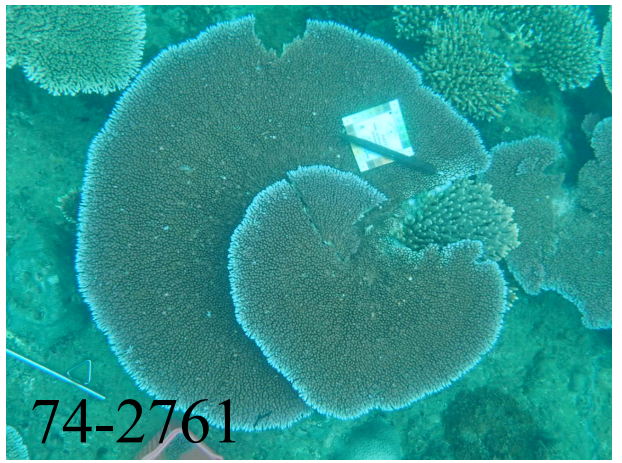
Acropora hyacinthus sensu Veron & Wallace 1984 at south-east Pelorus on the Great Barrier Reef



A. aff pectinata

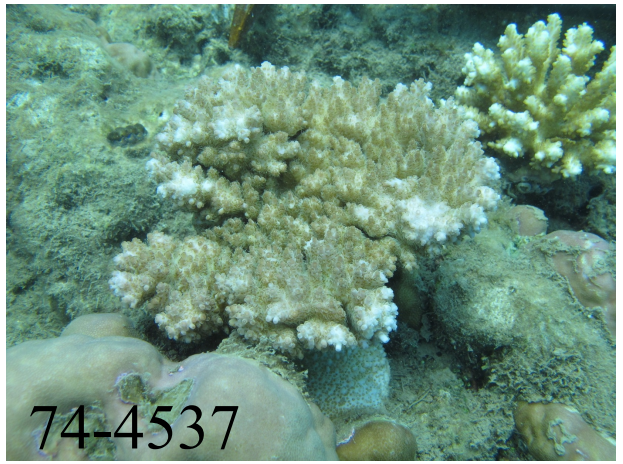


A. pectinata



A. hyacinthus

A. tersa



A. hya-bifurcata

Provincialism in the *Acropora*

Cowman et al in review

		WWAC	PP
WIO	Red Sea	65	14
WIO	Andaman Sea	82	15
WIO	SW Pacific	62	15

Summary of Acropora results

- Far more species 170 v 500+
- Many of these species undescribed
- Many have narrow geographical range size

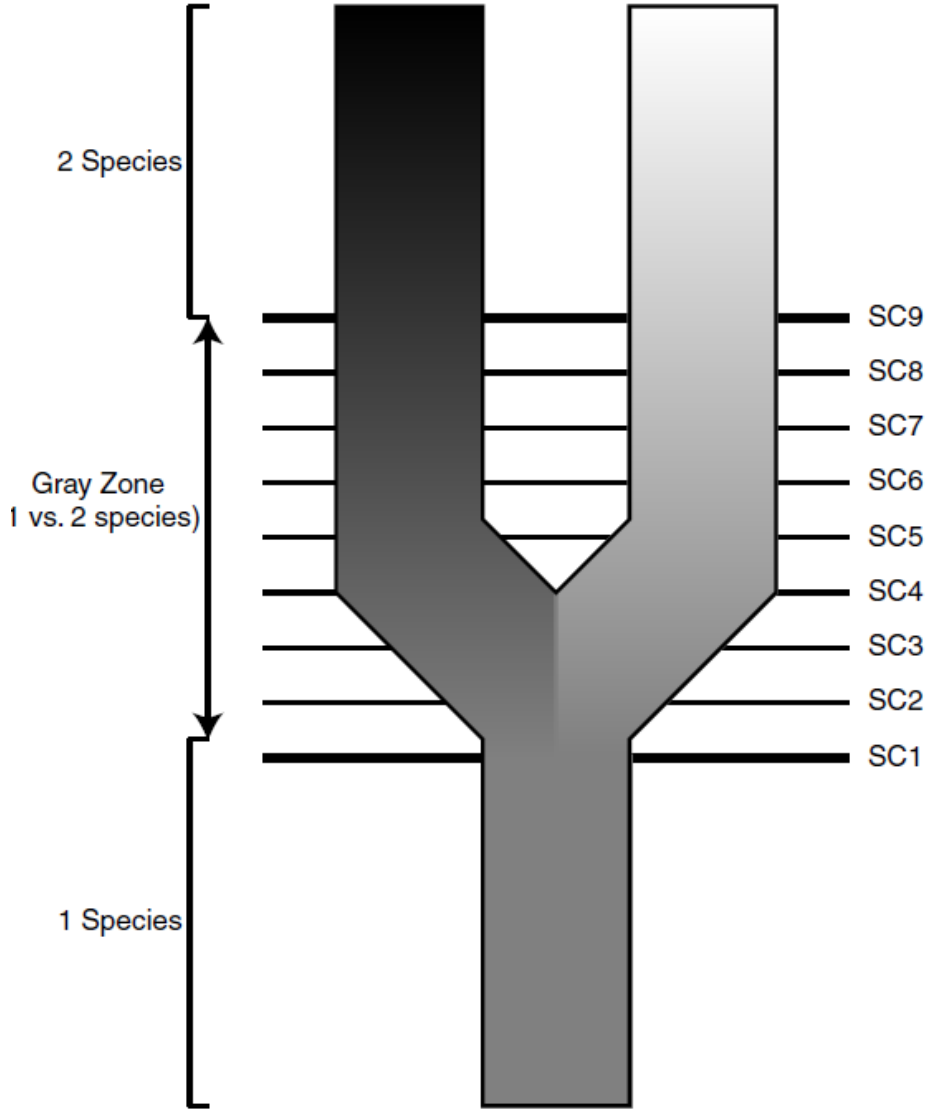
The good news is that there is a way forward

- A robust species concept and approach to species delimitation
- Next generation molecular markers
- Access to all the type material and original description

Unified species concept

Species defined as separately evolving metapopulation lineage
Species delimitation based on multiple alternative lines of evidence including,

- Biological
- Ecological
- Geography
- Phylogenetic



De Queiroz 2007, *Syst. Biol.*

Molecular approaches

- Single markers - still useful in some general eg Pocillopora
- Haplowebs - three markers were sufficient to distinguish 3 table species in Japan (Ramirez-Portilla et al 2021), however, these three species are not closely related
- UCEs – (see next slide and Cowman et al 2020)
- Shallow genome skimming - data seems compatible with UCEs for producing phylogenies, however, possible issues with SNIPS
- RADseq – problems with compatibility i.e. not modular
- MIG-seq – popular in Japan. We have yet to test if the data produced is compatible with our UCE data

RESOURCE ARTICLE

WILEY MOLECULAR ECOLOGY RESOURCES

Universal target-enrichment baits for anthozoan (Cnidaria) phylogenomics: New approaches to long-standing problems

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An enhanced target-enrichment bait set for Hexacorallia provides phylogenomic resolution of the staghorn corals (Acroporidae) and close relatives

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Ultraconserved Elements (UCEs) are highly conserved regions of organismal genomes shared among evolutionary distant taxa

- Thousand of ‘markers’
- Good for degraded/old samples
- Deep and shallow divergence
- ‘Harvest’ UCEs from whole genomes

Types of coral collection

- Biodiversity survey
- Targeting topotypes
- Taxon specific eg revision of genus

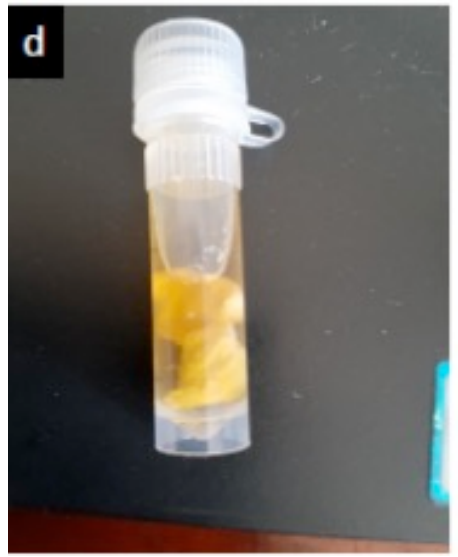
A Protocol for Coral Collection and Curation

An initiative of Project Phoenix by Andrew Baird & Hanaka Mera, Thursday, 6 August 2020

Project Phoenix is an international multidisciplinary collaboration among researches interested in the taxonomy, systematics and evolution of corals. The current focus is on the order Scleractinia and the goal is to develop a robust taxonomy using knowledge and technologies both old and new. Project Phoenix is supported by the ARC Centre of Excellence for Coral Reef Studies.

Coral collection: material

- Hammer and chisel
- Basket or catch bag
- Camera and UW light source
- Sharp nosed piers
- Material to tag specimens
- Chemicals to bleach and preserv
- Vials and plastic bags
- Permits!



Camera – Olympus TG series

Field images

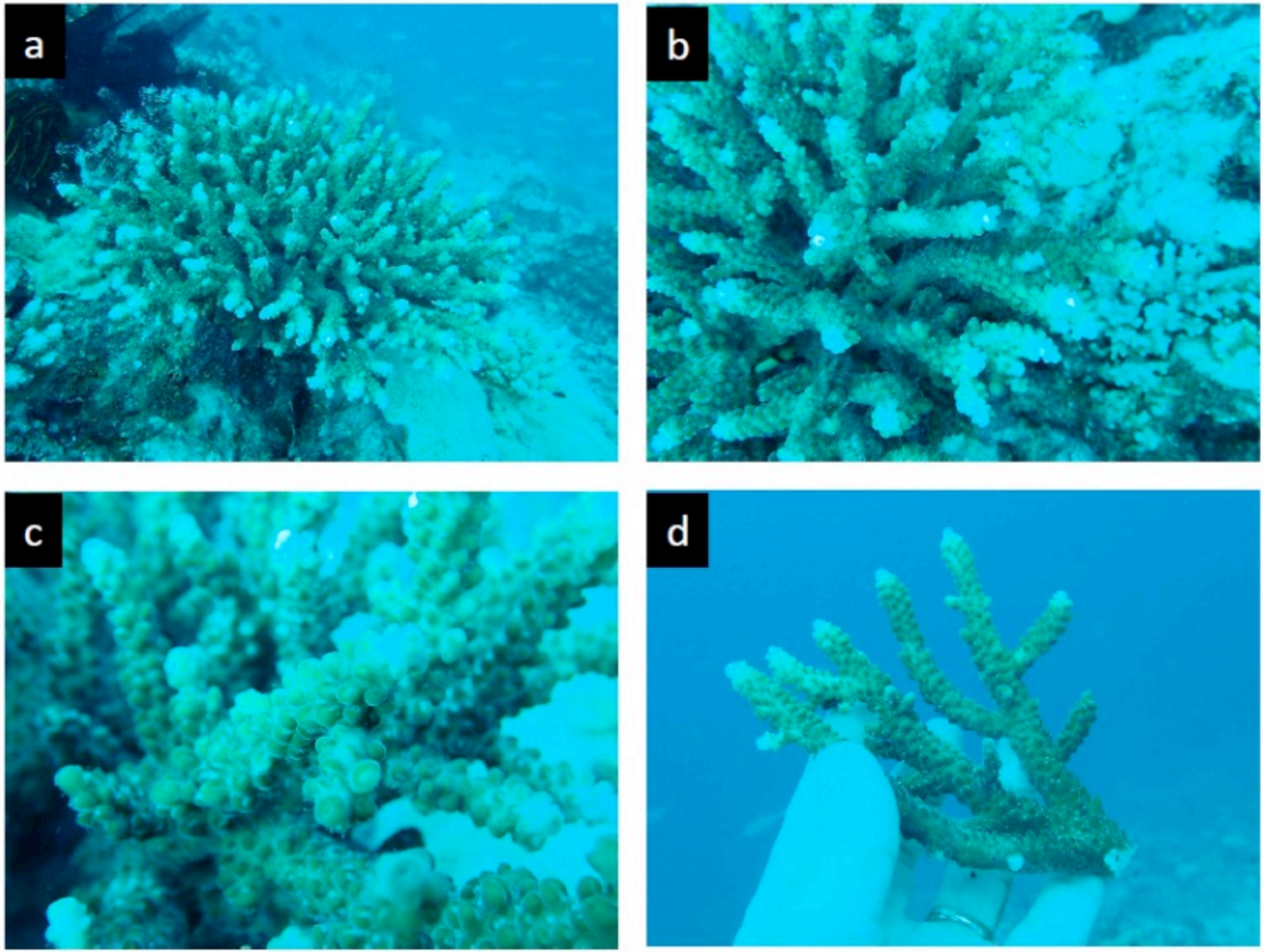


Figure 2. a) Habit photo; b) close up; c) macro showing radials; d) the nubbin collected from the colony

Images of the voucher

Why vouchers?

- Important back up for molecular ids
- Can help to clarify outliers or other weirdness in molecular
- Useful as reference for future studies
- Potential type material for new species

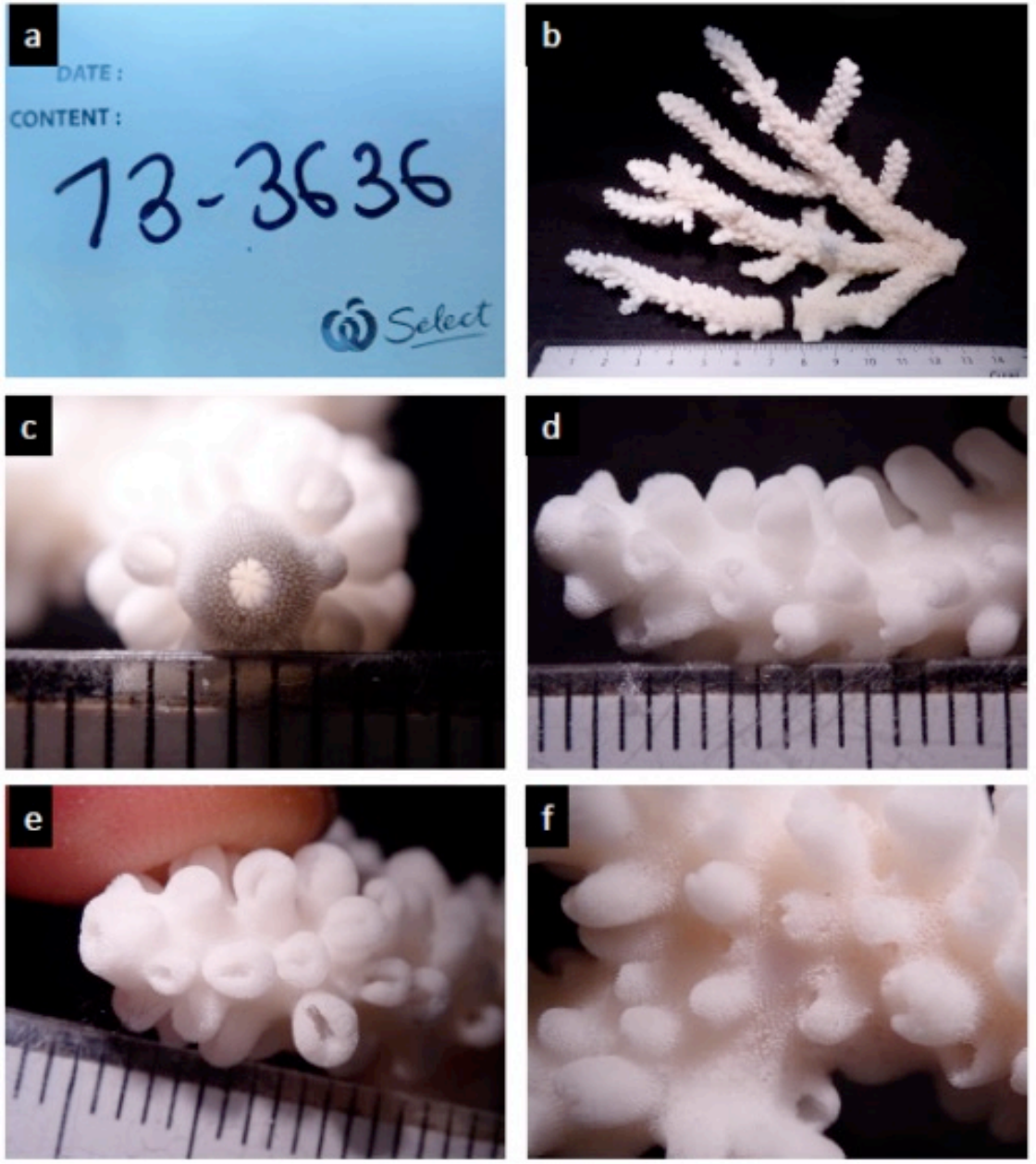


Figure 3. Images of coral skeletons

Biodiversity surveys

- Aim is to collect multiple replicates of all species in a given location
- Basically, just get in the water and collect all morpho-types encountered
- Make sure to visit the full range of habitats and across depth
- Nonetheless, some preparation is useful eg historical species lists, regional guides etc
- Also, you will need to collate the type material to identify specimens, start with the local nominal species because they should be there

Southern Kenya – *Acropora*

Species-WoRMS	authority	type location	comment
abrotanoides	(Larmarck)	Indian Ocean	maybe
aculeus	(Dana, 1846)	Fiji	no
appressa	(Ehrenbeg 1834)	unknown	maybe
arabensis	Hodgson & Carpenter, 1995	Kuwait	maybe
austera	(Dana, 1846)	unknown	maybe
branchi	Riegl (1995)	South Africa	maybe
cerealis	(Dana, 1846)	Sulu Sea, Philippines	no
clathrata	(Brook 1891)	Mauritius	maybe
copiosa	Nemenzo (1967)	Philippines	no
cytherea	(Dana, 1846)	Tahiti	no
digitifera	(Dana, 1846)	Fiji	no
divaricata	(Dana, 1846)	Fiji	no
donei	Veron & Wallace, 1984	Great Barrier Reef, Australia	no
florida	(Dana, 1846)	Fiji	no
gemmifera	(Brook, 1892)	Great Barrier Reef, Australia	no
grandis	(Brook, 1892)	Great Barrier Reef, Australia	no
granulosa	Milne-Edwards, 1860	Reunion	maybe
hemprichi	(Ehrenbeg 1834)	Red Sea	maybe
hyacinthus	(Dana, 1846)	Fiji	no
inermis	(Brook, 1891)	Fiji	no
intermedia	(Brook, 1891)	Maldives	maybe
latistella	(Brook, 1892)	Great Barrier Reef, Australia	no
listeri	(Brook, 1893)	Tonga	no
lutkeni	Crossland, 1952	Great Barrier Reef, Australia	no
microclados	(Ehrenbeg 1834)	nomen dubium	no
microphthalma	Verrill, 1869	Japan	maybe
millepora	(Ehrenbeg 1834)	unknown	maybe
muricata	(Linneaus 1878)	Banda Island, Indonesia	maybe
nana	(Dana, 1846)	Fiji	no
nasuta	(Dana, 1846)	Tahiti	no
pharaonis	(Milne-Edwards, 1860)	Red Sea	no
retusa	(Verrill, 1864)	Singapore	no
robusta	(Dana, 1846)	Fiji	no
nobilis	(Dana, 1846)	Singapore	maybe
rosaria	(Dana, 1846)	Fiji	no
samoensis	(Brook, 1891)	Samoa	no
secale	(Studer, 1878)	Singapore	maybe
selago	(Studer, 1878)	Papua New Guinea	no
squarrosa	(Ehrenbeg 1834)	Red Sea	no
subulata	(Dana, 1846)	Fiji	no
tenuis	(Dana, 1846)	Fiji	no
valida	(Dana, 1846)	Fiji	no

- 42 *Acropora* species
- 25 of these are from the Pacific and are therefore not in Kenya
- 2 are from the Red Sea and almost certainly don't occur in Kenya

Obura 2012

Acropora – Catalyst Science Fund Project

Species	Biological replicates
Acropora formosa	5 Fiji
Acropora tenuis	5 Fiji
Acropora verweyi	5 Coral Sea
Acropora divaricata	5 Fiji
Acropora divaricata / nasuta	5
Acropora glauca	5 Western Australia
Acropora latistella	5 Great Barrier Reef
Acropora nana	5 Fiji
Acropora rosaria	5 Fiji
Acropora valida	5 Fiji
Acropora forskali	5 Red Sea endemic
Acropora gemmifera	5 Great Barrier Reef
Acropora humilis	5 Fiji
Acropora hyacinthus	5 Fiji
Acropora microphthalma	5 Japan
Acropora nasuta	5 Tahiti
Acropora polystoma	5 Mauritius

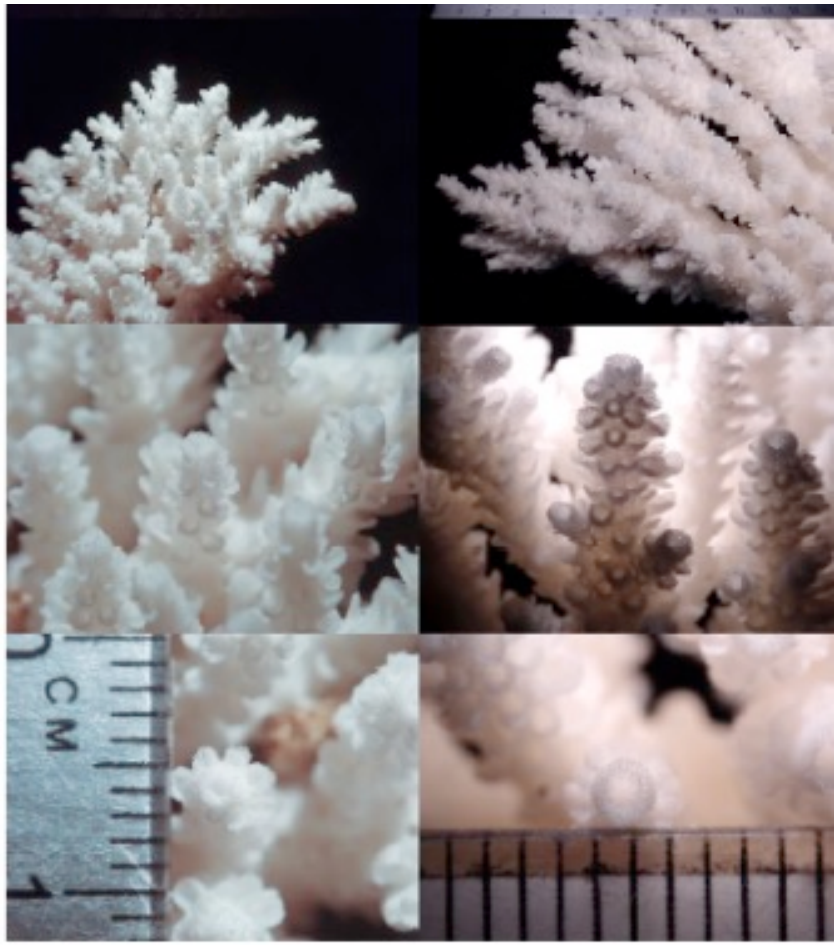
African-east coast nominal species (Crosbie et al 2026)

original_species	Authority_originalspecies	Type_Location_Current
Acorpora horizontalis	(Ortmann, 1892)	Tanzania, Dar es Salaam
Acropora africana	(Brook, 1893)	South Africa
Acropora branchi	Riegl, 1995	South Africa, Dolphin Coast, Shaka's Rock
Acropora lamarcki	Veron, 2000	Tanzania, Zanzibar
Acropora mossambica	Riegl, 1995	Mozambique, Xai Xai
Acropora natalensis	Riegl, 1995	South Africa, Sodwana Bay
Acropora sordiensis	Riegl, 1995	South Africa, Sodwana Bay
Acropora stellulata	Verrill, 1902	Tanzania, Zanzibar
Anomastraea irregularis	von Marenzeller, 1901	Tanzania, Zanzibar
Astraeosmilia connata	Ortmann, 1892	Tanzania, Dar es Salaam
Fungia concinna	Verrill, 1864	Tanzania, Zanzibar
Fungia haimei	Verrill, 1864	Tanzania, Zanzibar
Fungia valida	Verrill, 1864	Tanzania, Zanzibar
Goniastrea columella	Crossland, 1948	South Africa, Bhangazi Lake
Goniopora crassa	Crossland, 1948	South Africa, Bhangazi Lake
Goniopora paliformis	(Veron, 2000)	Tanzania, Zanzibar
Herpetolitha ampla	Verrill, 1864	Tanzania, Zanzibar
Isopora cylindrus	(Ortmann, 1892)	Tanzania, Dar es Salaam
Lobophyllia simplex	(Crossland, 1948)	South Africa, Umhlali
Lobophyllia studeri	(von Marenzeller, 1901)	Tanzania, Zanzibar
Montipora paupera	von Marenzeller, 1901	Tanzania, Zanzibar
Oulophyllia stuhlmanni	(Rehberg, 1892)	Tanzania, Zanzibar
Pectinia africana	Veron, 2000	Tanzania, Zanzibar, Changu Island
Pocillopora stellata	Verrill, 1864	Tanzania, Zanzibar
Porites reticulum	Ortmann, 1892	Tanzania, Dar es Salaam
Seriatopora stricta	Brüggemann, 1877b	South Africa, Cape of Good Hope

Topotype collection

- Collate a list of topotype for the location – Crosbie et al 2026
- Collate the type material and original description – coralprojectphoenix.org
- Prepare plates for each topotype with field images if available
- Some experience is useful to understand how a given skeleton might look underwater, this information often not available in the type description
- Synonymies can be useful for species you are not familiar with.
- Often the type material is not particularly useful eg Acropora teres; A. cardenae

Acropora hyacinthus (Dana 1846) - topotype

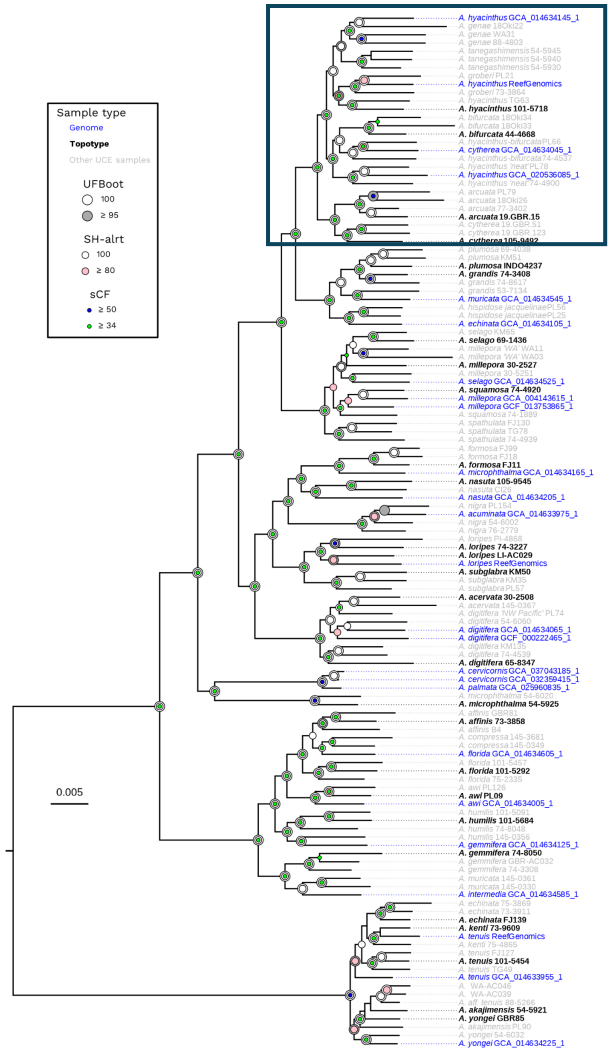


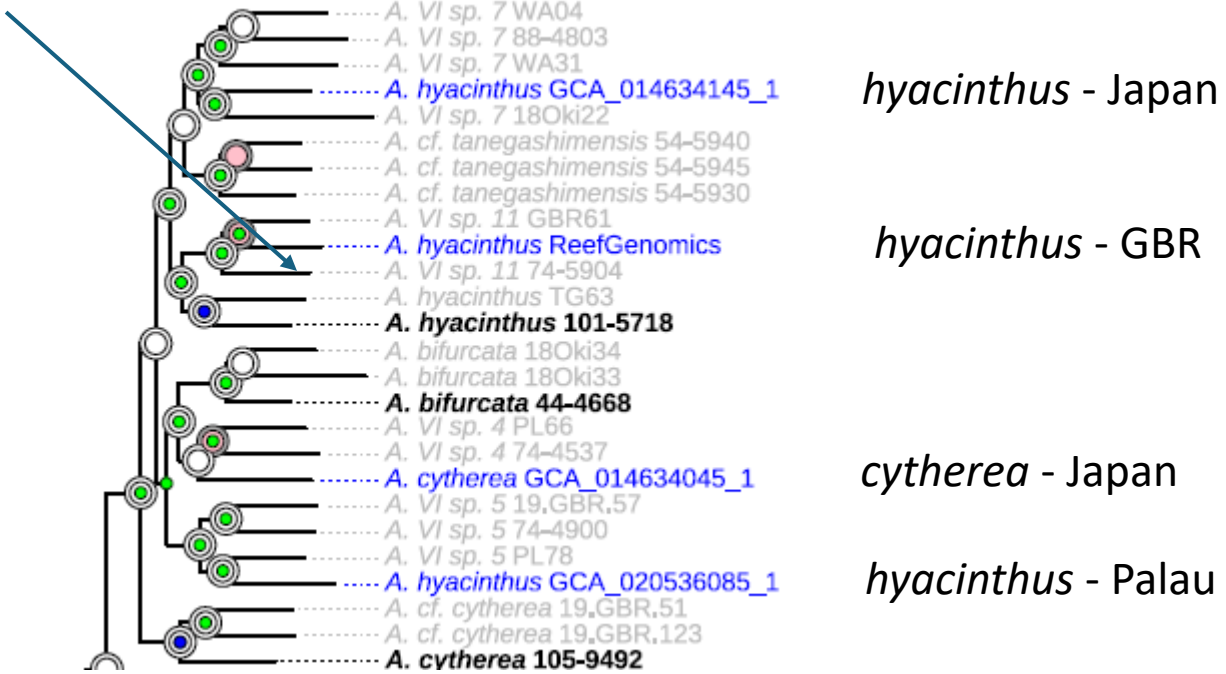
Madrepora hyacinthus Dana 1846
Lectotype USNM_246

101-5718

101-5718

Testing the genomes: results





hyacinthus - Japan

hyacinthus - GBR

cytherea - Japan

hyacinthus - Palau

Of 28 available Acropora genomes only 4-6 are correctly identified

More on topotypes

- Often difficult to find some topotypes, eg 5-6 on the GBR we have yet to find despite 100 of hours of looking
- Collectors chose species that were common and species that looked distinctive or different, which are likely to be rare
- Much of the type material was collected over 150 years ago so many species that were rare then are possibly extinct eg Acropora anothcercis (Brook 1892) (Rassmussen et al 2025).

Coral collections: genus revision

- Very difficult because most coral ***genera*** have remarkably widespread geographical distribution
- Therefore, testing all the nominal species via the collection of topotypes means visiting dozens of countries, or establishing effective collaborations – see coralprojectphoenix.org
- Galaxea – 16 nominal species in 12 different countries (Bonito et al 2021)

References cited

- Bonito VE, Baird AH, Bridge T, Cowman PF, Fenner D (2021) Types, topotypes and vouchers are the key to progress in coral taxonomy: Comment on Wepfer et al. (2020). Mol Phylogen Evol 159:107104
- Cowman PF, Baird AH, Bridge T, Quattrini AM, Etal (in review) Phylogenomics reveals the 'dark diversity' of staghorn corals.
- Cowman PF, Quattrini AM, Bridge TCL, Watkins-Colwell GJ, Fadli N, Grinblat M, Roberts TE, McFadden CS, Miller DJ, Baird AH (2020) An enhanced target-enrichment bait set for Hexacorallia provides phylogenomic resolution of the staghorn corals (Acroporidae) and close relatives. Mol Phylogen Evol 153:106944
- Crosbie AJ, Bridge TLC, Mera H, Rassmussen SH, Cabaitan PC, Cowan PF, Gress E, Grinblat M, Horowitz J, Camilleri RE, Baird AH (2026) A nomenclature for the extant hermatypic scleractinian corals including type locations and taxonomic status for 2,338 nominal species. Memoirs of the Queensland Museum – Nature 67:1–10
- De Queiroz K (2007) Species Concepts and Species Delimitation. Syst Biol 56:879-886
- Obura D (2012) The Diversity and Biogeography of Western Indian Ocean Reef-Building Corals. PLoS ONE 7:e45013
- Quattrini AM, Faircloth BC, Duenas LF, Bridge TCL, Brugler MR, Calixto-Botia IF, DeLeo DM, Foret S, Herrera S, Lee SMY, Miller DJ, Prada C, Radis-Baptista G, Ramirez-Portilla C, Sanchez JA, Rodriguez E, McFadden CS (2018) Universal target-enrichment baits for anthozoan (Cnidaria) phylogenomics: New approaches to long-standing problems. Molecular Ecology Resources 18:281-295
- Ramírez-Portilla C, Baird AH, Cowman PF, Quattrini AM, Harii S, Sinniger F, Flot J-F (2022) Solving the Coral Species Delimitation Conundrum. Syst Biol 71:461-475
- Rassmussen SH, Cowman PF, Baird AH, Crosbie AJ, Quattrini AM, Bonito V, Sinniger F, Harii S, Cabaitan PC, Fadli N, Tan C-H, Hung JY-H, Rongo T, Huang D, Halafihi T, Bridge TCL (2025) The tables have turned: taxonomy, systematics and biogeography of the *Acropora hyacinthus* (Scleractinia: Acroporidae) complex. Invertebr Syst 39:IS24049
- Veron JEN (2000) Corals of the world. AIMS, Townsville

Acknowledgements

- Catalyst Science Fund