Deep-sea protected coral reproduction study
POP2022_03

Jenny Beaumont, Peter Marriott, Di Tracey, Savannah Goode, Amelia Connell, Rhian Waller

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Climate, Freshwater & Ocean Science

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Project Objectives

- 1. Address knowledge gaps in reproductive strategies for protected coral species in the New Zealand region

- 2. Use available life history and reproductive data to inform relative productivity/vulnerability parameters for relevant concurrent and future research

Background

- New Zealand has a rich complement deep-sea corals
    - Studying deep-sea fauna is difficult
    - Little is known of their life histories
- Without this information we cannot fully understand:
    - Population dynamics,
    - Connectivity between suitable habitats,
    - Vulnerability and/or resilience to physical disturbance such as bottom trawling.

Summary of past research

This project follows DOC project (BCBC2020-01) which:

- Summarised existing knowledge of reproduction of protected deep-sea corals in NZ
    - Highlighted large knowledge gaps
- Summarised available preserved samples within NIWA's Invertebrate Collection and identified species for further study:
    - Scleractinians: *Desmophyllum dianthus*, *Goniocorella dumosa*, and *Enallopsammia rostrata*
    - Gorgonian octocorals: *Paragorgia arborea* and *Primnoa notialis*

Reproductive strategy: Branching Scleractinia

All NZ branching stony corals were thought to be seasonal gonochoric broadcast spawners:

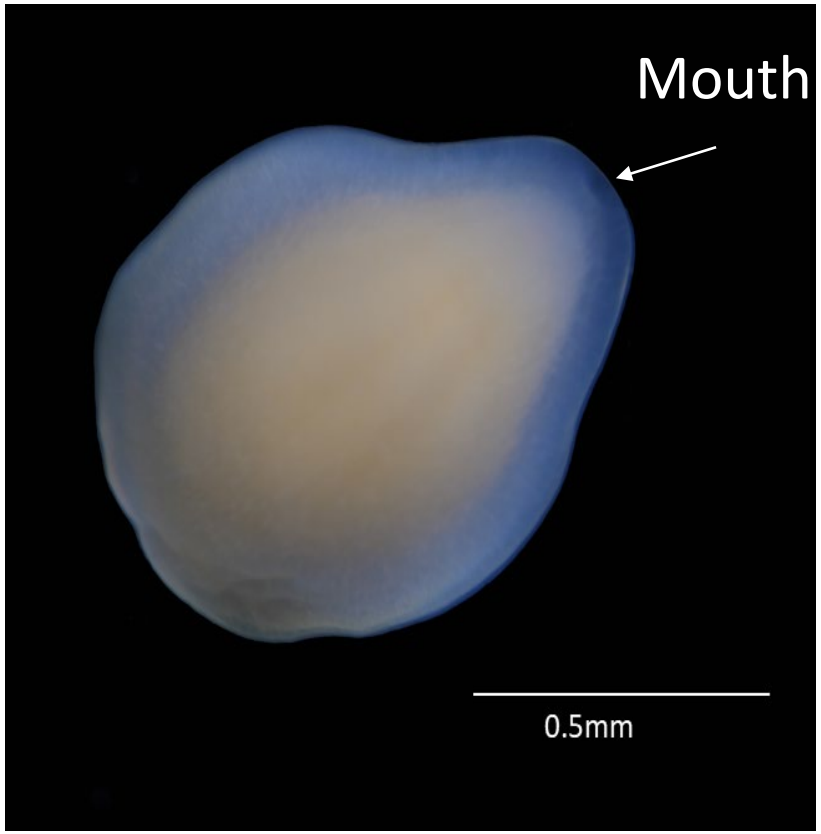
- Seasonal: spawns once per year at the same time of year
- Gonochoric: separate male and female polyps
- Broadcast spawners: male and female gametes are released into the water column. Fertilization is external and planula larvae drift in water column/ocean currents until they find a suitable substrate to settle and grow.

Some species also known to reproduce via budding (*Goniocorella dumosa* and *Solenosmillia variabilis*)

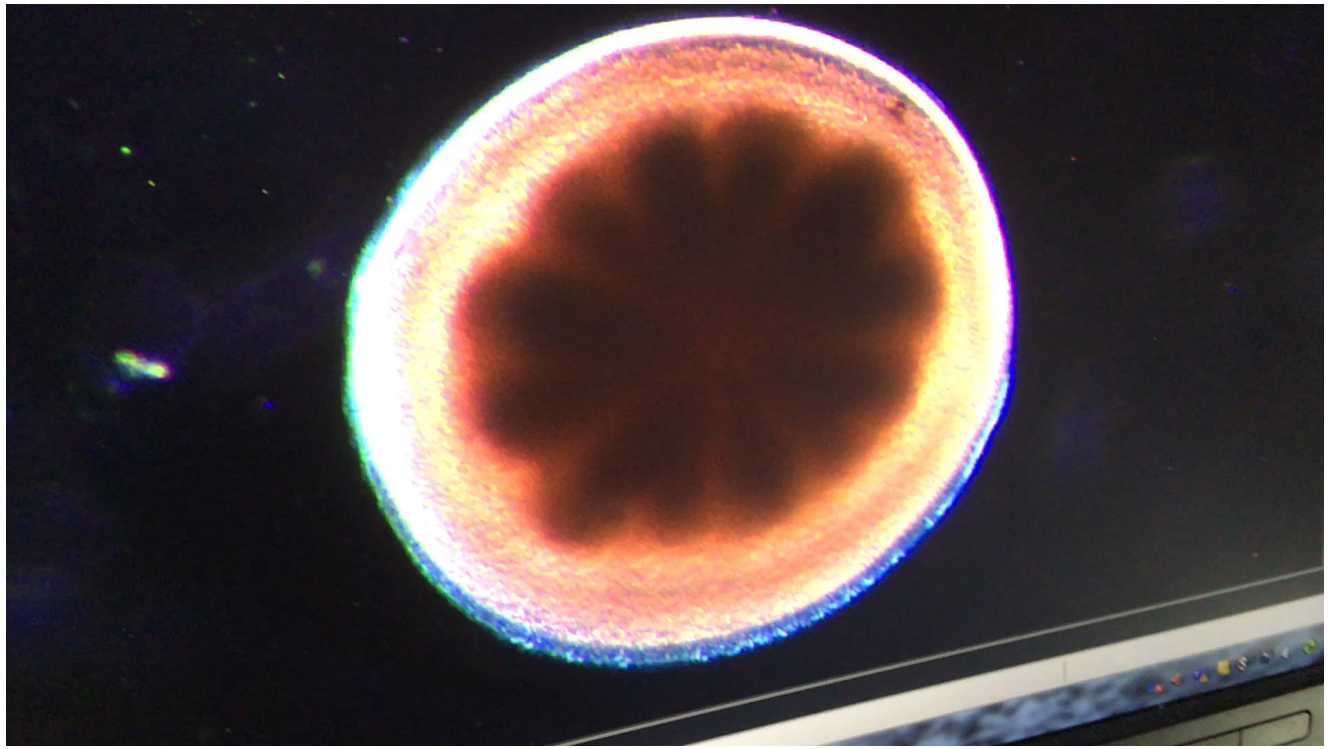
Goniocorella dumosa

Opportunistic observations of *G. dumosa* larvae in September 2020

- Large (approx. 1.1 x 0.8 mm in size)
- Covered in cilia
- Pear-shaped (when swimming)
- Formed mouth



A swimming *G. dumosa* larvae



Internal mesenteries and beating cilia

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Goniocorella dumosa are brooders!

- 17 polyps dissected (6 had larvae inside)
- Between 2 and 10 larvae inside a single polyp
- Previously considered a broadcast spawner with fertilization likely April/May (Burgess & Babcock 2005)
    - Highlights need for seasonal studies rather than single time-point samples

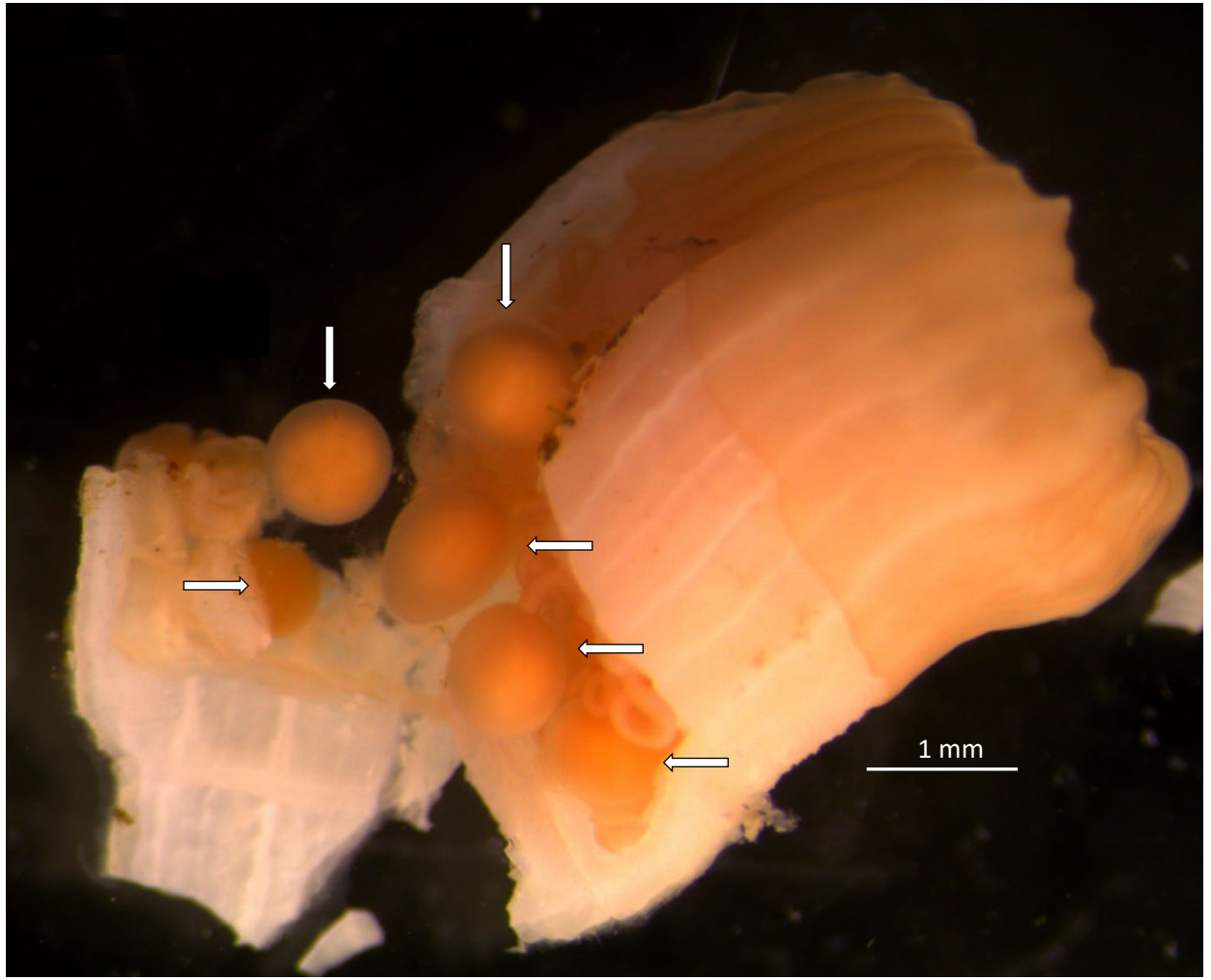


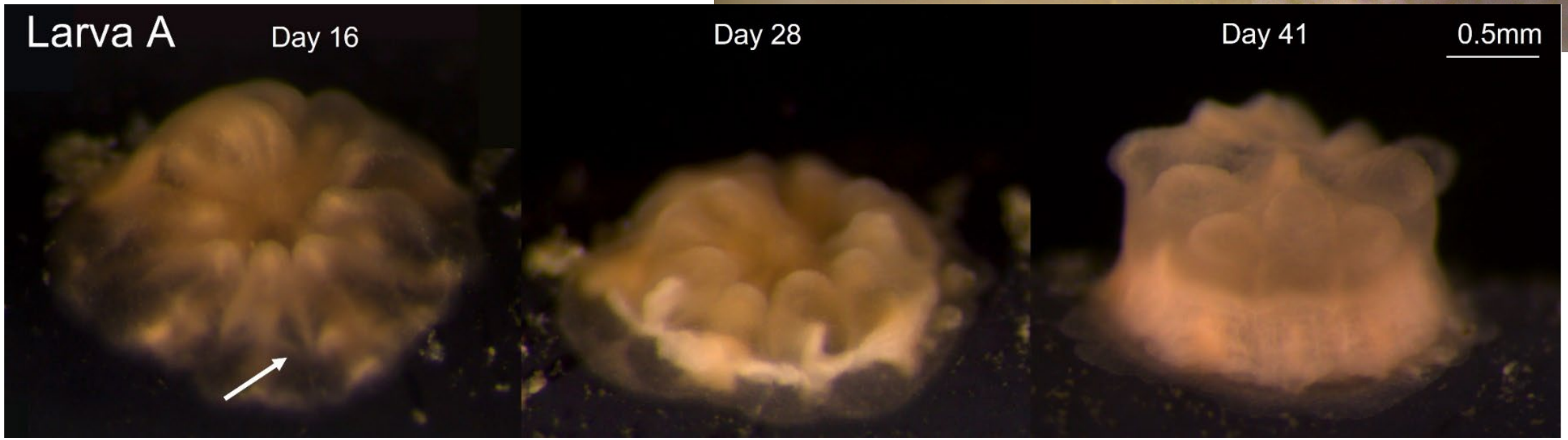
Image shows 6 of the 10 larvae in this single polyp.

G. dumosa settlement

Settlement after 2 days (n = 5)
and 8 days (n = 1)

Successful settlement to:

- Coral substrate
- Silicone tubing



Larval settlement (top images) and post-settlement development (bottom images)

Dispersal potential of *G. dumosa*?

We now know:

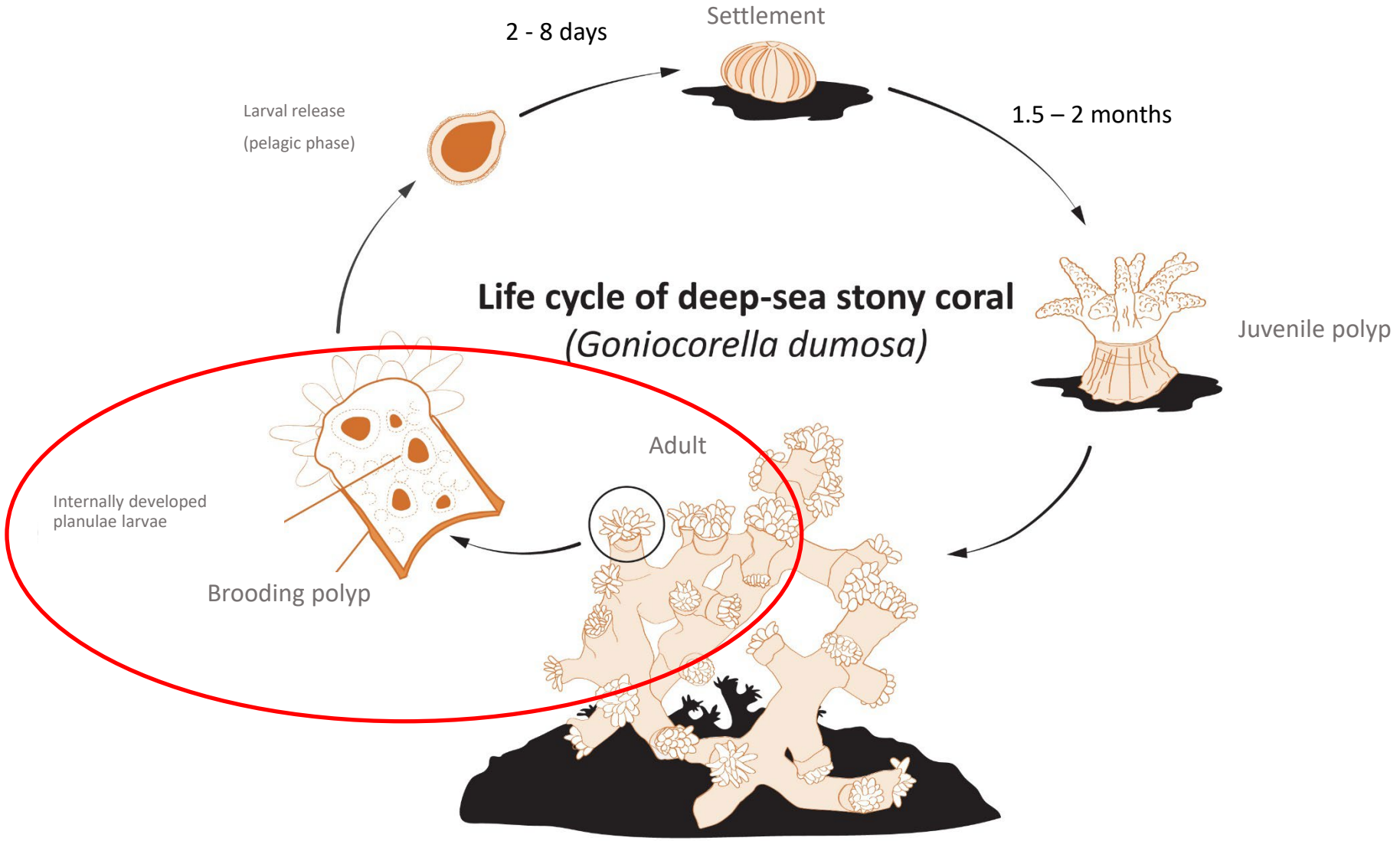
- Polyps release a few (up to 10 observed) free swimming larvae
- Observed Pelagic Larval Duration was 2 - 8 days
  - One larva still alive and swimming after 88 days
  - Maximum timeframe unknown
- Larval dispersal more limited than previously thought? (e.g. broadcast spawners)

Why is this important?

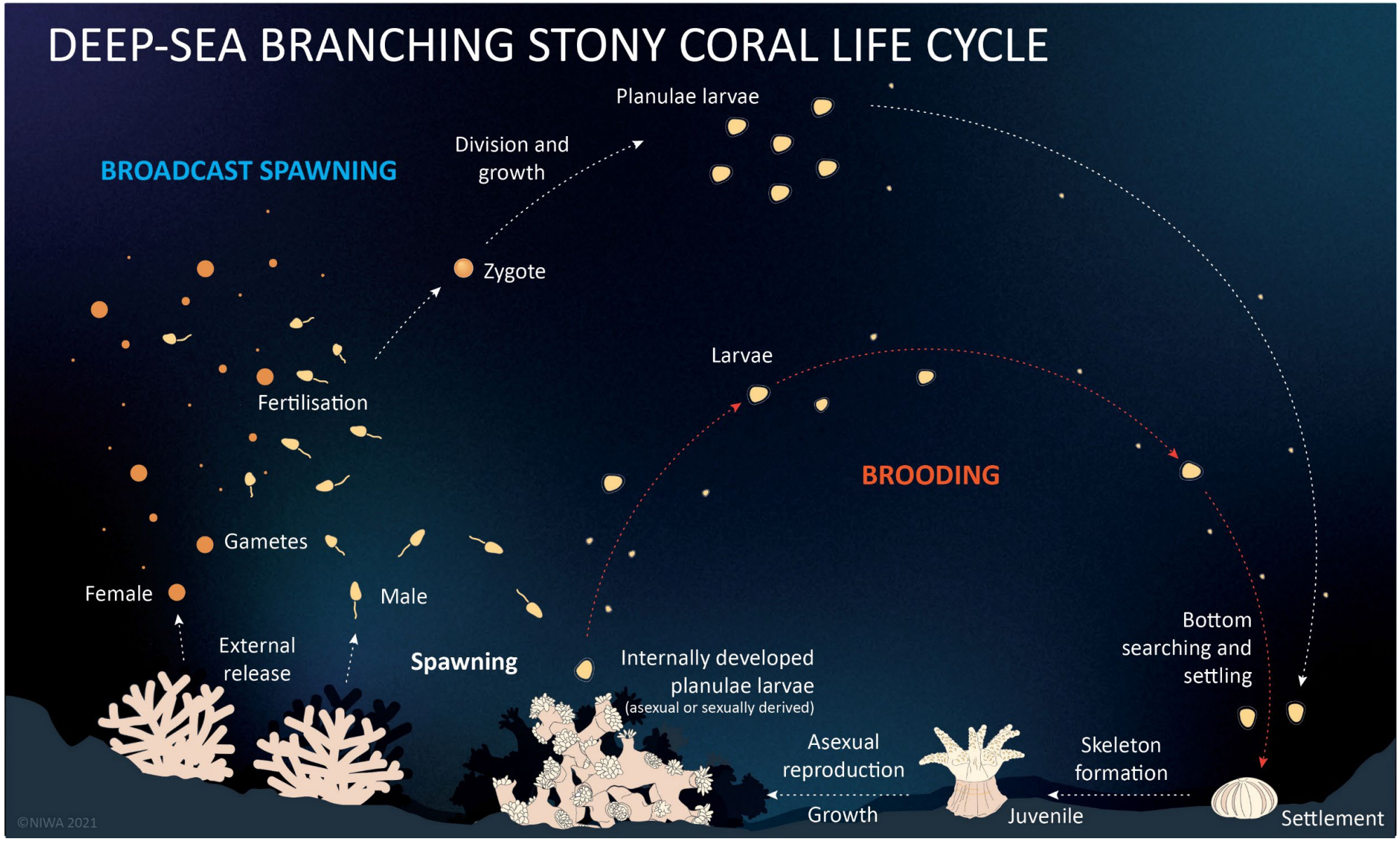
- *G. dumosa* habitats are spatially fragmented within New Zealand's EEZ
- Limited larval dispersal could indicate a more limited recovery potential following physical disturbance

What we still need to know:

- Seasonality/continuous spawner?
- Fecundity?



Life cycle of *Goniocorella dumosa.* Red circle highlights what we hope to learn in this project



Reproductive modes employed by deep-sea branching scleractinian corals

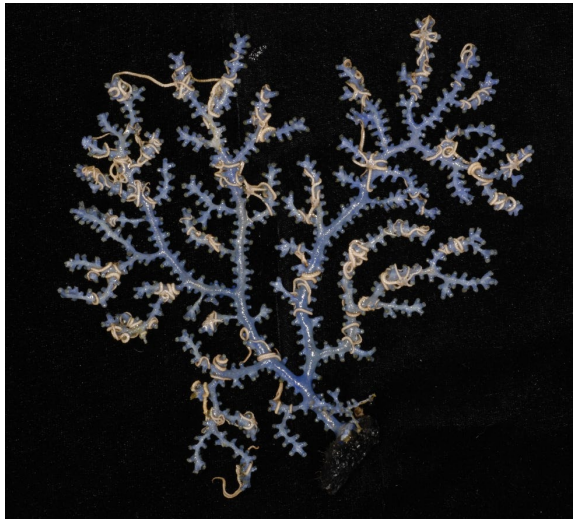
Reproductive strategies: Scleractinia – cup coral form

- No existing NZ deep-sea cup coral reproductive studies
  - Genetic data shows *Desmophyllum dianthus* undergoes sexual reproduction & has widespread dispersal

- Global studies show no generality in reproductive processes
  - *Caryophyllia* spp. can be gonochoric or hermaphroditic
  - *Flabellum* spp. from West Antarctic Peninsula are brooders
  - *Flabellum* spp. from NE Atlantic are broadcast spawners
  - High fecundity compared to other coral groups

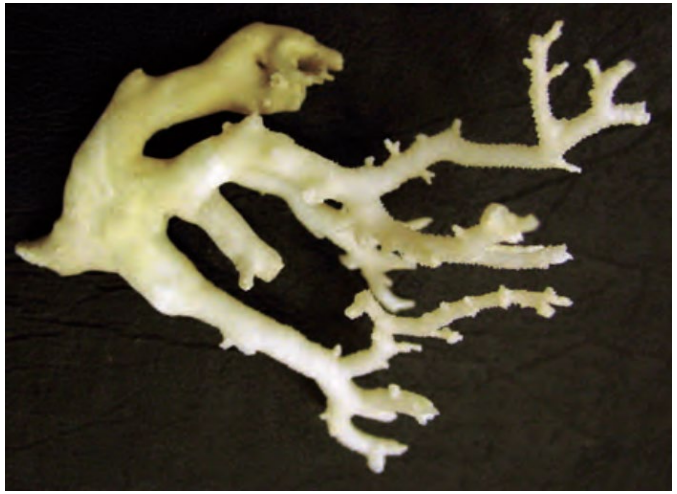
Reproduction strategies: Gorgonian octocorals

- Diverse group with broad range of reproductive strategies
- NZ morphological studies indicate several primnoids are gonochoric brooders
- Global studies indicate most octocorals are gonochoric with varying reproductive modes and periodicity
  - Continuous, quasi-continuous, seasonal spawners, and brooders
  - *Fanyella* and *Thouarella* spp. are brooders
  - Isidids (bamboo corals) and plexaurids appear to be mostly broadcast spawners
- Low polyp fecundity but potentially high colony fecundity



Reproduction strategies: Stylasteridae

- Limited reproductive knowledge
- NZ morphological studies show stylasterids are typically gonochoric brooders
  - similar to Alaskan study
- Predicted to have short dispersal due to brooding mode & crawling behaviour of larvae



Reproduction strategies: Antipatharia

- NZ Fiordland black coral *Antipathella fiordensis* is a gonochoric, broadcast spawner, produces lecithotrophic larvae with limited dispersal

- Globally nearly all black coral species are thought to be gonochoric broadcast spawners
  - more deep-sea studies needed to confirm

- Black corals have reduced fecundity compared to stony corals

Methods: Objective 1. Address knowledge gaps in reproductive strategies for protected coral species in the New Zealand region

Examine physical specimens of preserved corals

Morphometrics: polyp density, changes in polyp density across the colony

Histology: sex ratios, oocyte size, fecundity, reproductive seasonality

Note: main focus of study likely to be the scleractinians and octocorals. Hydrocorals and black corals have been included but mostly as proof of concept rather than a detailed study.

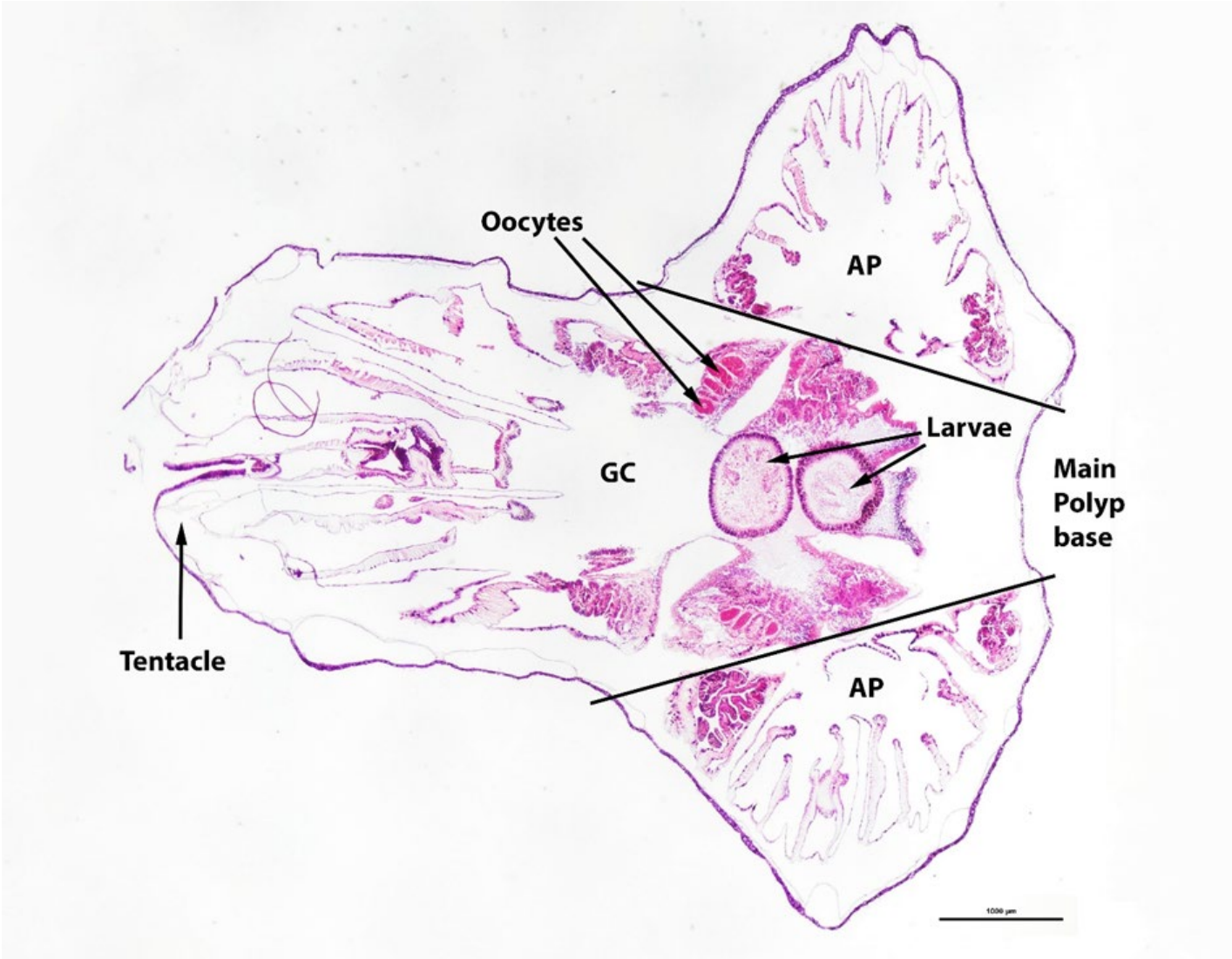
- Histology slides will be examined to collect data on
- male to female sex ratios
- oocyte stage and size distributions
- fecundity per polyp
- spermatocyst stage

Developmental stages of oocytes and spermatocytes (adapted from Burgess 2002)

Stage	Oocytes/Larvae	Spermaries
I	Oogonia: Enlarged interstitial cells, with large nuclei in mesoglea of mesenteries	Small clusters of interstitial cells
II	Immature Oocytes (previtellogenic): Accumulation of small amount of cytoplasm around nuclei	Spermatocytes smaller with small nuclei, number of cells within spermatocyst much larger
III	Oocytes undergoing Vitellogenesis: variable size, main period of vitellogenesis	Spermatocytes with little cytoplasm, developed flagella not evident, lumen usually present
IV	Vitellogenic Oocytes: full sized with indented nucleus migrating to edge of oocyte, large vitellogenin bodies fill the cytoplasm, cortical granular layer may be seen	Spermatozoa with fully developed flagella, ready to spawn
V	Brooding larvae of various stages of development	

Polyp morphology

- Two mature larvae in the basal gut mesenteries
- Clusters of Stage III oocytes
- Accessory polyps



Histological section of a *G. dumosa* polyp

Species selected: Scleractinia

Cup coral: *Desmophyllum dianthus*
Branching corals: *Goniocorella dumosa*
Enallopsammia rostrata

Selection criteria:
- recent samples (2010 onwards)
- fixed in formalin then transferred reasonably quickly post collection into 80% ethanol
- potential to use samples only fixed in ethanol
- samples size

E. rostrata

D. dianthus

G. dumosa

Formalin-preserved samples: Scleractinia

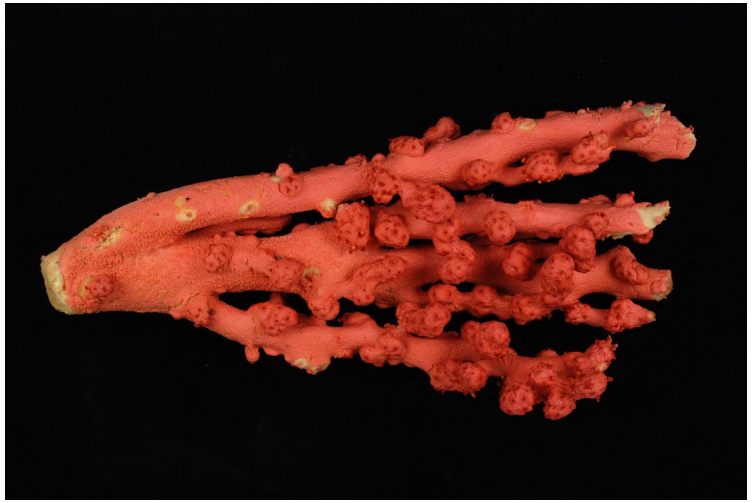
Catalogue Number	Family	Genus	Species	Station ID	Date	Start depth	End depth	Count	Preservation method	Tissue Condition
71137	Dendrophylliidae	Enallopsammia	rostrata	TAN0104/336	20/04/2001	955	890	1	Ethanol - orig formalin	DEAD
148158	Dendrophylliidae	Enallopsammia	rostrata	TAN2009/80	19/08/2020	640	622	10	Ethanol - orig formalin	Good
148159	Dendrophylliidae	Enallopsammia	rostrata	TAN2009/80	19/08/2020	640	622	10	Ethanol - orig formalin	Good
81281	Caryophylliidae	Goniocorella	dumosa	TAN0104/116	17/04/2001	1000	922	1	Ethanol - orig formalin	Okay
140313	Caryophylliidae	Goniocorella	dumosa	TAN1903/106	21/06/2019	396	396	1	Formalin	Poor
140326	Caryophylliidae	Goniocorella	dumosa	TAN1903/108	21/06/2019	387	380	1	Formalin	Poor
140346	Caryophylliidae	Goniocorella	dumosa	TAN1903/110	22/06/2019	461	450	1	Formalin	Good
140375	Caryophylliidae	Goniocorella	dumosa	TAN1903/153	25/06/2019	390	390	1	Formalin	Good
54068	Caryophylliidae	Goniocorella	dumosa	TAN0905/113	27/06/2009	519	609	30	Ethanol - orig formalin	Poor
147900	Caryophylliidae	Goniocorella	dumosa	TAN2001/81	22/01/2020	279	263	1	Ethanol - orig formalin	Poor
148101	Caryophylliidae	Goniocorella	dumosa	TAN2009/57	16/08/2020	486	659	10	Ethanol - orig formalin	Okay
148157	Caryophylliidae	Goniocorella	dumosa	TAN2009/80	19/08/2020	640	622	10	Ethanol - orig formalin	Good

Species selected: gorgonian octocorals

Species: *Paragorgia arborea, Primnoa notialis*

Selection criteria:

- recent samples (2010 onwards)
- fixed in formalin then transferred reasonably quickly post collection into 80% ethanol
- sample size



P. arborea

P. notialis

Formalin-preserved samples: octocorals

Catalogue Number	Order	Family	Genus	Species	Station ID	Date	Start depth	End depth	Count	Preservation method
46377	Alcyonacea	Paragorgiidae	Paragorgia	arborea	TRIP2571/53	29/2/2008	952	1118	1	Ethanol - orig formalin
66274	Alcyonacea	Paragorgiidae	Paragorgia	arborea	TRIP3028/136	10/01/2010	735		1	Ethanol - orig formalin
61920	Alcyonacea	Primnoidae	Primnoa	notialis	TRIP3065/214	09/03/2010	1070	1100	1	Ethanol - orig formalin
61980	Alcyonacea	Primnoidae	Primnoa	notialis	TRIP3077/127	31/03/2010	769	767	1	Ethanol - orig formalin

Species selected: hydrocorals and black corals

Species: Hydrocorals: *Stylaster sp./Errina sp*.
Black corals: Sibopathes sp./Leiopathes sp.

Selection criteria:

- Available samples

Preserved samples: Hydrocorals and black corals

Class	Order	Family	Genus	Species	# Specimens available		
					E/F	F	Sum
Hydrozoa	Anthoathecata	Stylasteridae	Adelopora	moseleyi	2		2
Hydrozoa	Anthoathecata	Stylasteridae	Conopora	laevis	1		1
Hydrozoa	Anthoathecata	Stylasteridae	Conopora	verrucosa	2		2
Hydrozoa	Anthoathecata	Stylasteridae	Crypthelia	robusta	1		1
Hydrozoa	Anthoathecata	Stylasteridae	Crypthelia		1		1
Hydrozoa	Anthoathecata	Stylasteridae	Errina	fissurata	14		14
Hydrozoa	Anthoathecata	Stylasteridae	Errina	laterorifa	1		1
Hydrozoa	Anthoathecata	Stylasteridae	Errina		1	1	2
Hydrozoa	Anthoathecata	Stylasteridae	Lepidotheca	chauliostylus	1		1
Hydrozoa	Anthoathecata	Stylasteridae	Lepidotheca	fascicularis	1		1
Hydrozoa	Anthoathecata	Stylasteridae	Lepidotheca		3		3
Hydrozoa	Anthoathecata	Stylasteridae	Stylaster		10		10
Hydrozoa	Anthoathecata	Stylasteridae			17	1	18
Anthozoa	Antipatharia	Antipathidae	Cirrhipathes	propinqua	1		1
Anthozoa	Antipatharia	Cladopathidae	Cladopathes		1		1
Anthozoa	Antipatharia	Myriopathidae	Antipathella	fiordensis	5		5
Anthozoa	Antipatharia	Schizopathidae	Bathypathes	patula	1		1
Anthozoa	Antipatharia	Schizopathidae	Bathypathes		1		1
Anthozoa	Antipatharia	Schizopathidae	Parantipathes		1		1
Anthozoa	Antipatharia	Antipathidae	Stichopathes	variabilis		1	1
Anthozoa	Antipatharia	Cladopathidae	Sibopathes			1	1
Anthozoa	Antipatharia				2		2

Initial findings: histology trials

Stony corals

- Good sections from scleractinian samples preserved in formalin then ethanol
- Acceptable sections from branching scleractinian specimens preserved in ethanol and post-fixed in formalin.
- This will increase the available samples to help with selecting specimens sampled at appropriate times (seasonality)

Black corals

- Good sections from the black coral trials (Leiopathes sp. and Sibopathes sp.). No de-calcification required.

Hydrocorals

- Poor sections from hydrocoral samples due to large amount of hard skeleton. The de-calcification process used for other species is not suitable for hydrocorals.

Objective 1. Next steps

- Examine recent histology (trial) slides to determine how many sections are needed per coral polyp
- Examine ethanol-only preserved Scleractinia specimens for tissue quality
- Morphological work
- Continue with histology on scleractinians and octocorals
- More histological trials on stylasterid hydrocorals using “Osteosoft” solution
- Liase with our international collaborator (Rhian Waller, University of Gothenburg)

Objective 2. Use available life history and reproductive data to inform relative productivity/vulnerability parameters for relevant concurrent and future research

Results from Objective 1 (histological and morphological work) will be used to inform concurrent projects such as INT2022-04 - Risk assessment for protected corals.

Acknowledgements

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Ngā mihi nui ki a koe

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