Identifying characteristics of artificial reef design that determine chances of deployment success and fisheries benefit

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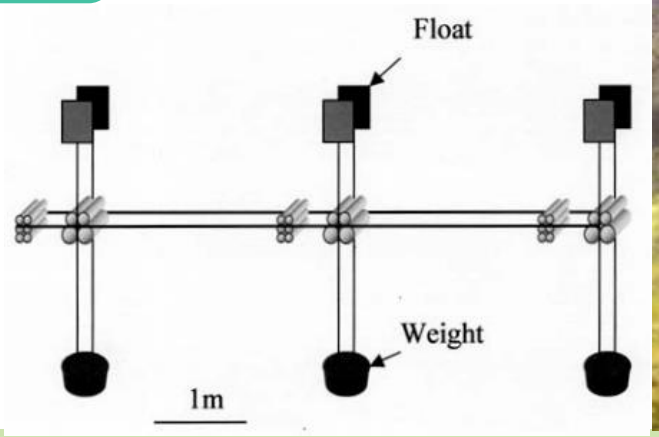
Artificial reefs

Size = 1m – 100s of km

Cost = >$100 (DIY) → $10,000 (Reef ball deployments) → $2mil (Sunken ship)



Rilov and Benayahu, 2002

Gaps in the literature and justification

Focused mainly on richness and diversity

Are they successful..?

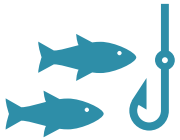
Are they equal to natural reefs..?

Don’t know which design characteristics are the most important

Reduce costs due to failed deployments

Reduce invasive species

Successful habitat



Fisheries enhancement

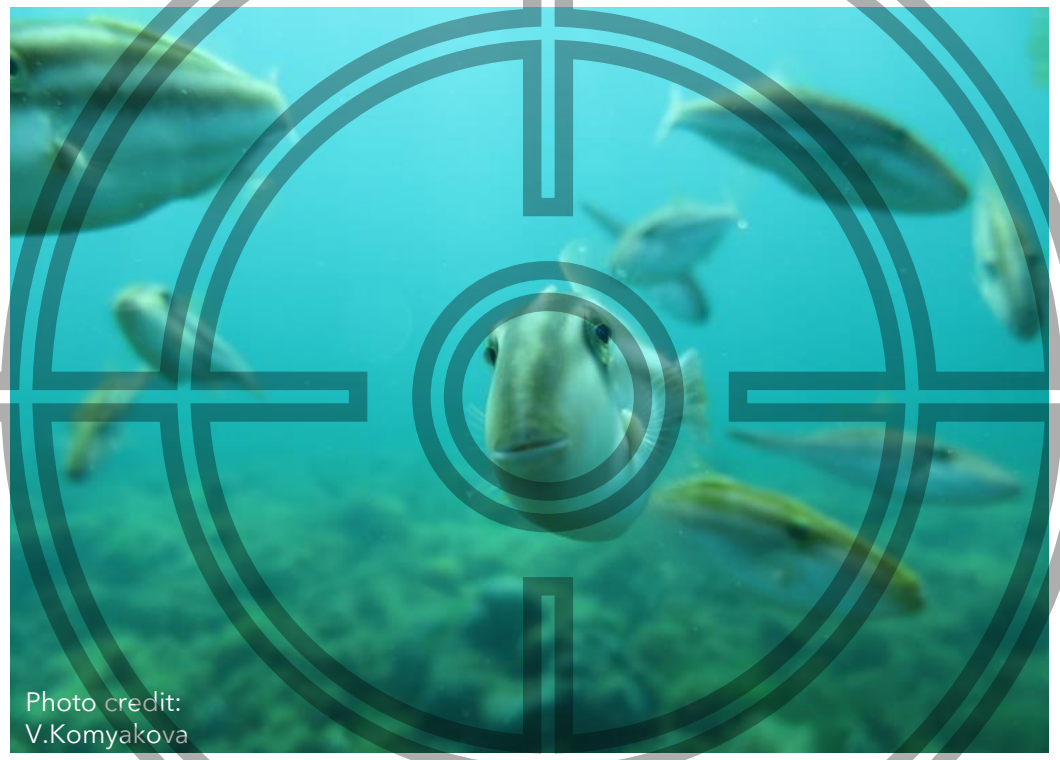
Stakeholder engagement

Aims

Juvenile fish recruitment & Fish community composition

Artificial Reef

Included	Excluded
Seawall	Man-made Oyster reef
Breakwater	Man-made Coral reef
Groyne	
Oil and gas platforms	
Marina/Jetty/Pier	
Wreck – Ship/Plane/Car	
Man-made	



Methods – Literature review

Refining criteria

- Published journal articles
- English
- 1980 onwards
- Top 9 subject areas:
  - Agriculture and biological sciences
  - Environmental science
  - Earth and planetary science
  - Engineering, social science
  - Biochemistry, Genetics and Molecular biology
  - Energy
  - Multidisciplinary
  - Materials science

Target Keywords

artificial reef, coastal, community composition, design, fisheries, juvenile, natural reef, recruitment, shipwreck, reef

Naïve search	With exclusions applied	Targeted search	With exclusions applied	Screened results
2330	1631	1449	955	135
2330	1631	80	77	41

Total = 176

Methods – data extraction

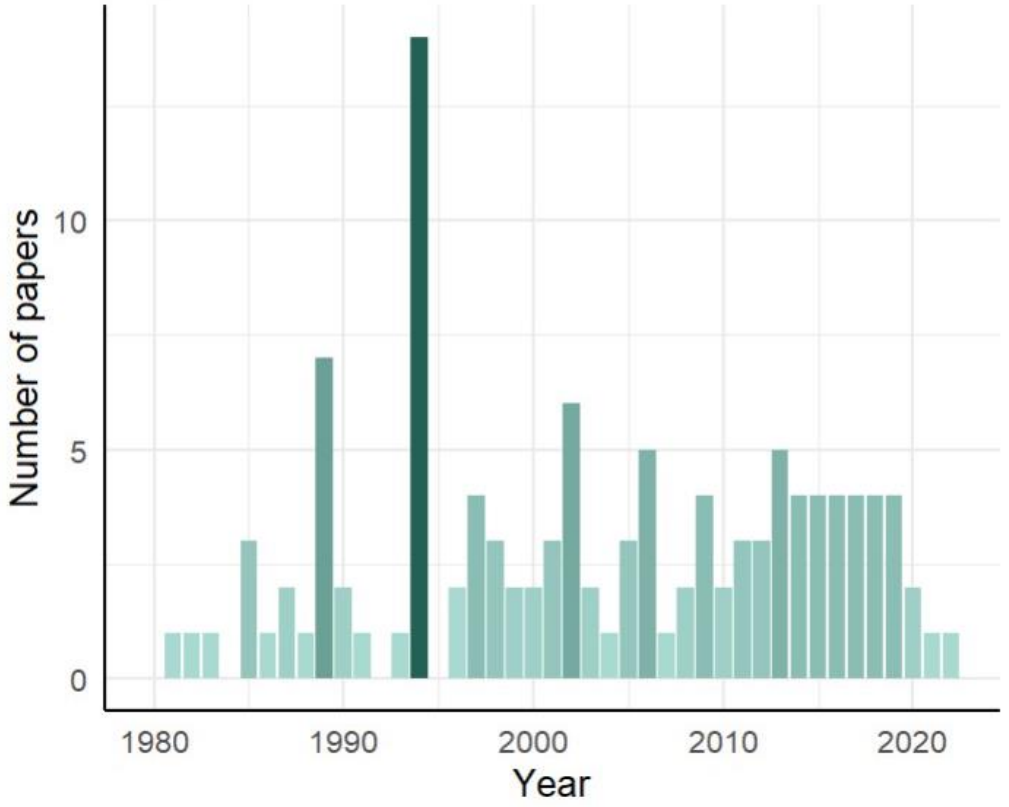
Category
Study characteristics
Artificial reef type
Artificial reef structural characteristics
Artificial reef geographical characteristics
Artificial reef design characteristics
Artificial reef environment characteristics

Reef Arabia
ريف العربية

CRC Reef Research Centre

California Department of Fish and Wildlife

Australian Government
Fisheries Research and Development Corporation



Methods – meta-analysis

Data collected for meta-analysis
ID: study name
Rep_AR/NR
Mean_AR/NR
SD_AR/NR
Target Group: community (whole) or species (individual)
Measure: community abundance or species abundance

natural

vs

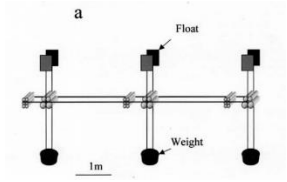
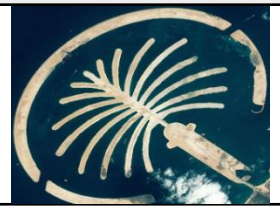
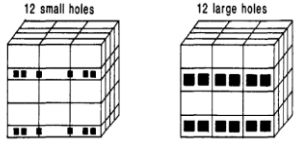
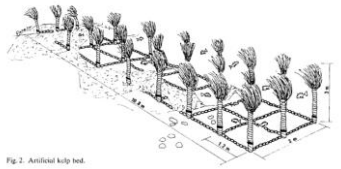
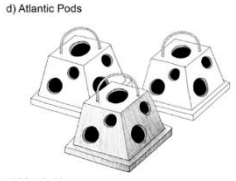
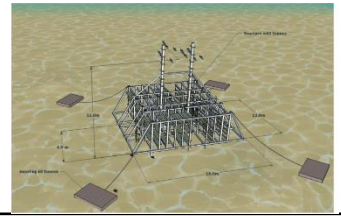
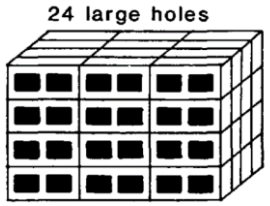
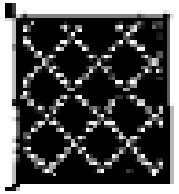
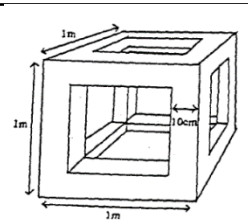
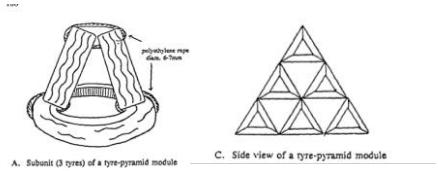
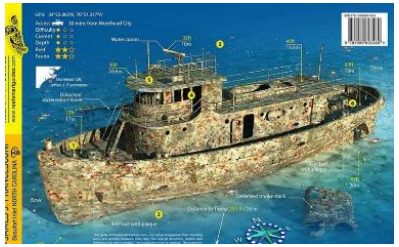
artificial

Methods - classification analysis

NR type	Vegetation Rocky Coral None	Size (m^2)	Small = ≤20m^2 Medium = 20.01-99.9 m^2 Large = 100-999.9m^2 Extra-large = 1000m^2+	Success	Y = better N = similar/same F = worse	Material	**Concrete** – block/cinderblock/culvert/slab/rubble **Metal** – steel/iron **Rock** –quarry/boulder/limestone/ gabbro/ceramic/granite **Mix** – combinations (e.g. rock + concrete, metal + concrete) **Other** – styrofoam/biotic material/astroturf/wood /PVC/geotextile/tyre/bamboo		
Fragm-entation	Single unit Compound	Reason sunk	Experimental Artificial reef (AR) Fisheries enhancement Infrastructure Accidental	Depth (m)	Intertidal = <1m Shallow = 1-4.99m Midwater = 5-19.9m Deep = 20m+	Vertical relief (m)	Low = ≤1 Medium >1-4m High = >4m	Complexity	1 - Low 2 - Medium 3 - High 4 – Very high

***This is only a portion of explanatory variables**

Complexity

Low complexity (1)	Medium complexity (2)	High complexity (3)	Very high complexity (4)
(Rilov and Benayahu, 2002) 	(Burt et al., 2013)* 	(Komyakova and Swearer, 2019) 	(Komyakova and Swearer, 2019) 
(Hixon and Beets, 1989) 	(Spanier et al., 1990) 	(Lemoine et al., 2019) 	*(Becker et al., 2017) 
(Hylkema et al., 2020) 	(Hixon and Beets, 1989) 	*(Fowler and Booth, 2012) 	(Edelist and Spanier, 2009) 
(Heise and Bortone, 1999) 	(Chua and Chou, 1994) 	(Chua and Chou, 1994) 	*(Bulger et al., 2019) 

Results – Fish juvenile recruitment

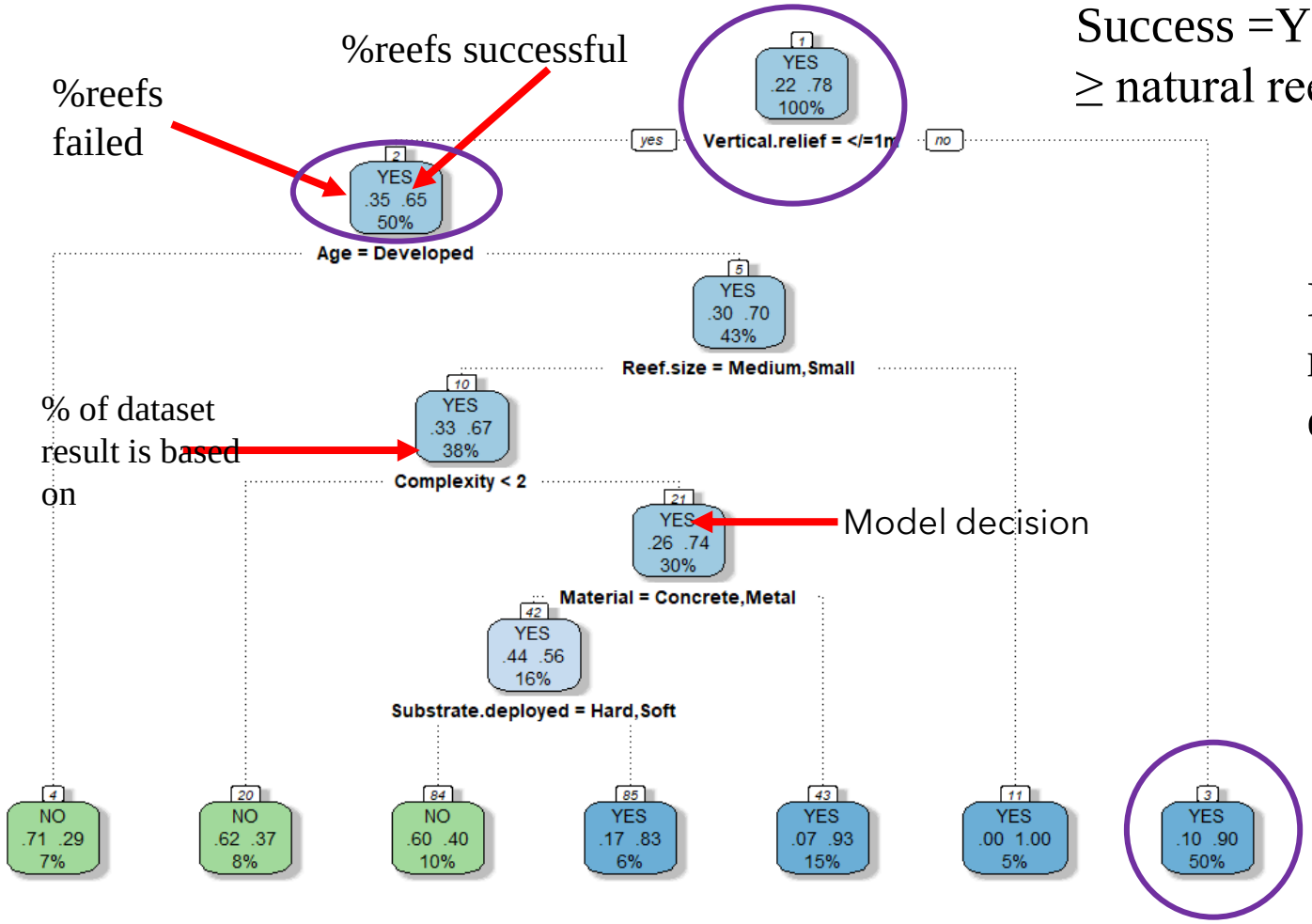
	Estimate	SE	p-value	CI upper	CI lower
Model results	0.639	0.246	0.009	0.157	1.121
Test for Heterogeneity					
Q(df = 90) = 21765			p-value < .0001		

Meta-analysis: testing how much difference there is

multilevel meta-analysis model with random effects

Results – Fish juvenile recruitment

Follow along!
If I meet the variable criteria → follow the left line



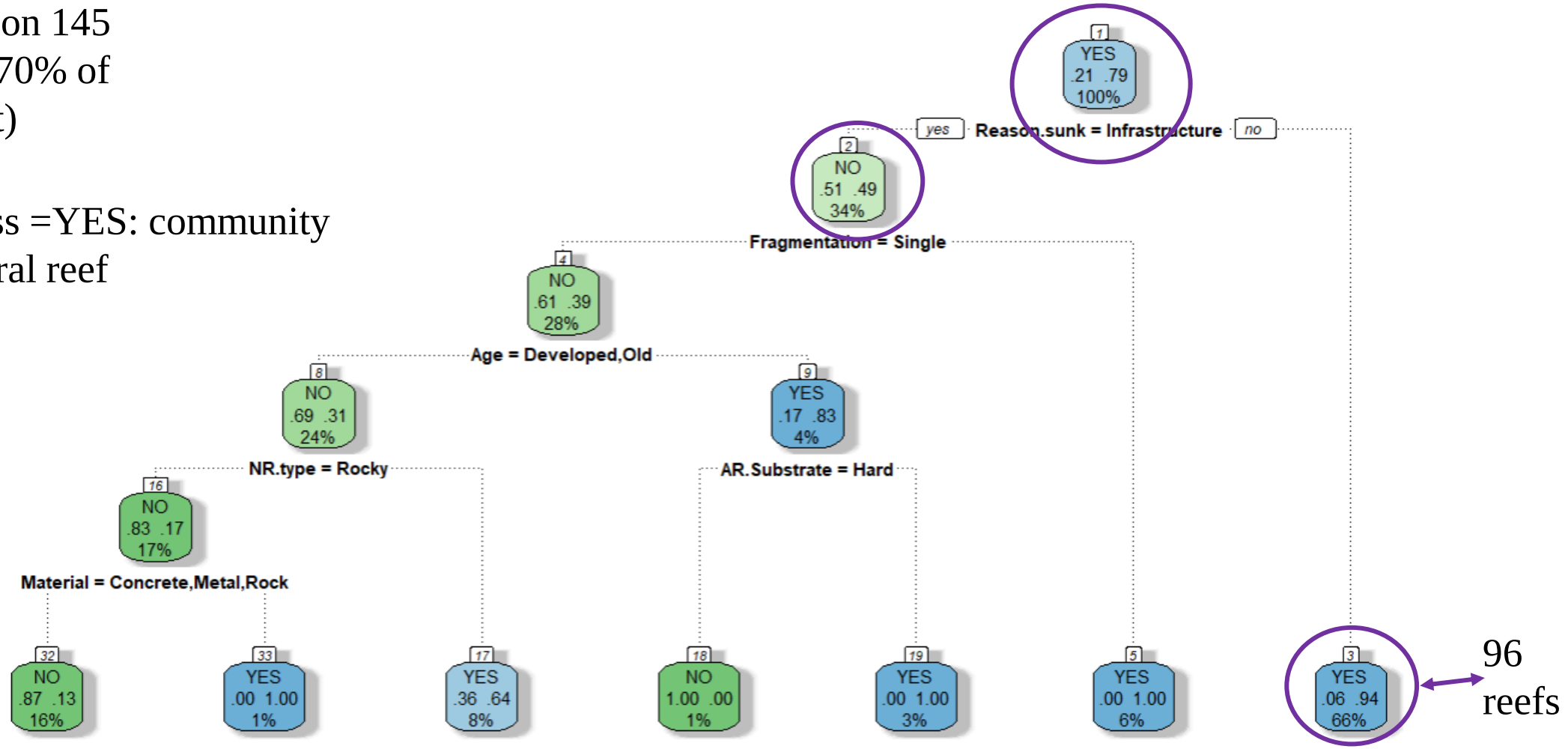
Success =YES: recruitment ≥ natural reef

Based on 103 reefs (70% of dataset)

Results – Fish community composition

Based on 145 reefs (70% of dataset)

Success =YES: community = natural reef



Characteristics that affect juvenile recruitment

- First study that attempted to quantify complexity of artificial reef designs
- Juvenile fish recruit more to high relief reefs – except when low relief reefs are more complex
- Complex reefs tend to support higher fish abundance, diversity and richness

Artificial reef with high relief

Photo credit: Tom Coughlin

Complex reef

Natural reef with low relief

Photo credit: Tom Coughlin

Characteristics that affect community composition

- Artificial reefs designed to mimic natural reefs have been shown to support similar communities
- Infrastructure can be less complex/featureless which is why they might not be successful
- Oil and gas platforms are often dissimilar to natural reefs

Recommendations

For juvenile recruitment: Vertical relief >1m, Complexity (>2 from this study), mixed materials

- Note: Small to medium reefs (<99.9m^2) more sensitive than larger reefs

For community composition: Compound fragmentation, mixed materials

- Note: Success may be effected by tropical or temperate location (e.g. reference reef rocky or coral)

Thank you

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