Coral restoration using sexual recruits: state of knowledge, best practices, current techniques

Anastazia Banaszak
Rita Sellares
Elvira Alvarado



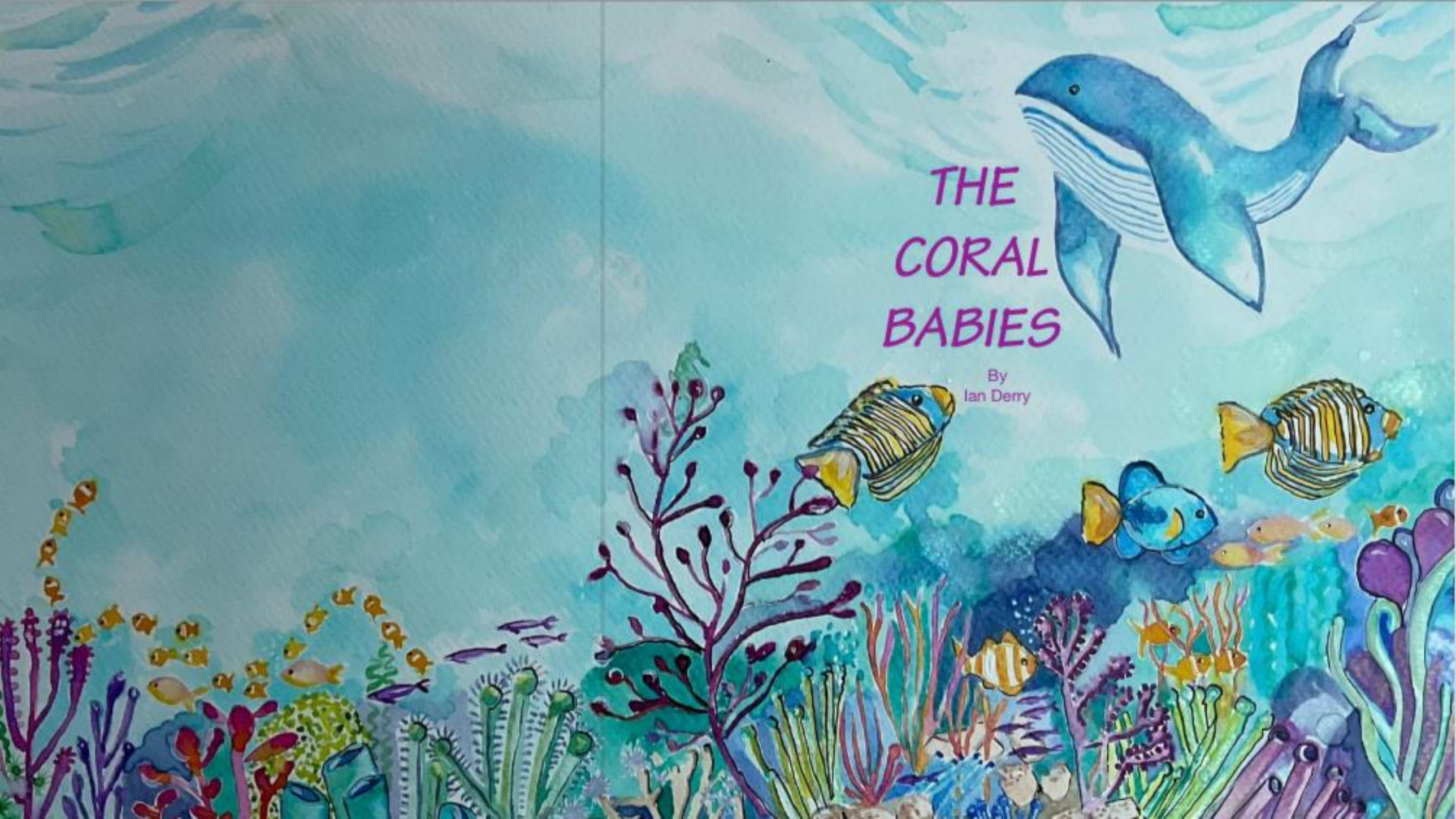

Coral restoration using sexual recruits: state of knowledge, best practices, current techniques

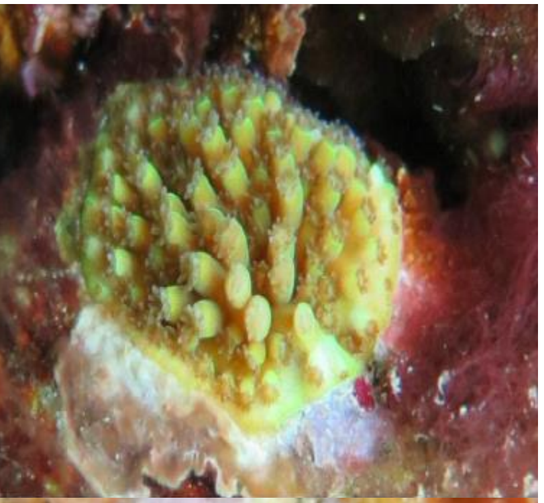
- **A** Reproductive biology and ecological status
- **B** Steps for Coral Assisted Sexual Reproduction
- **C** Current techniques for coral larval propagation

Anastazia Banaszak
Rita Sellares
Elvira Alvarado

A.-Reproductive biology and ecological status

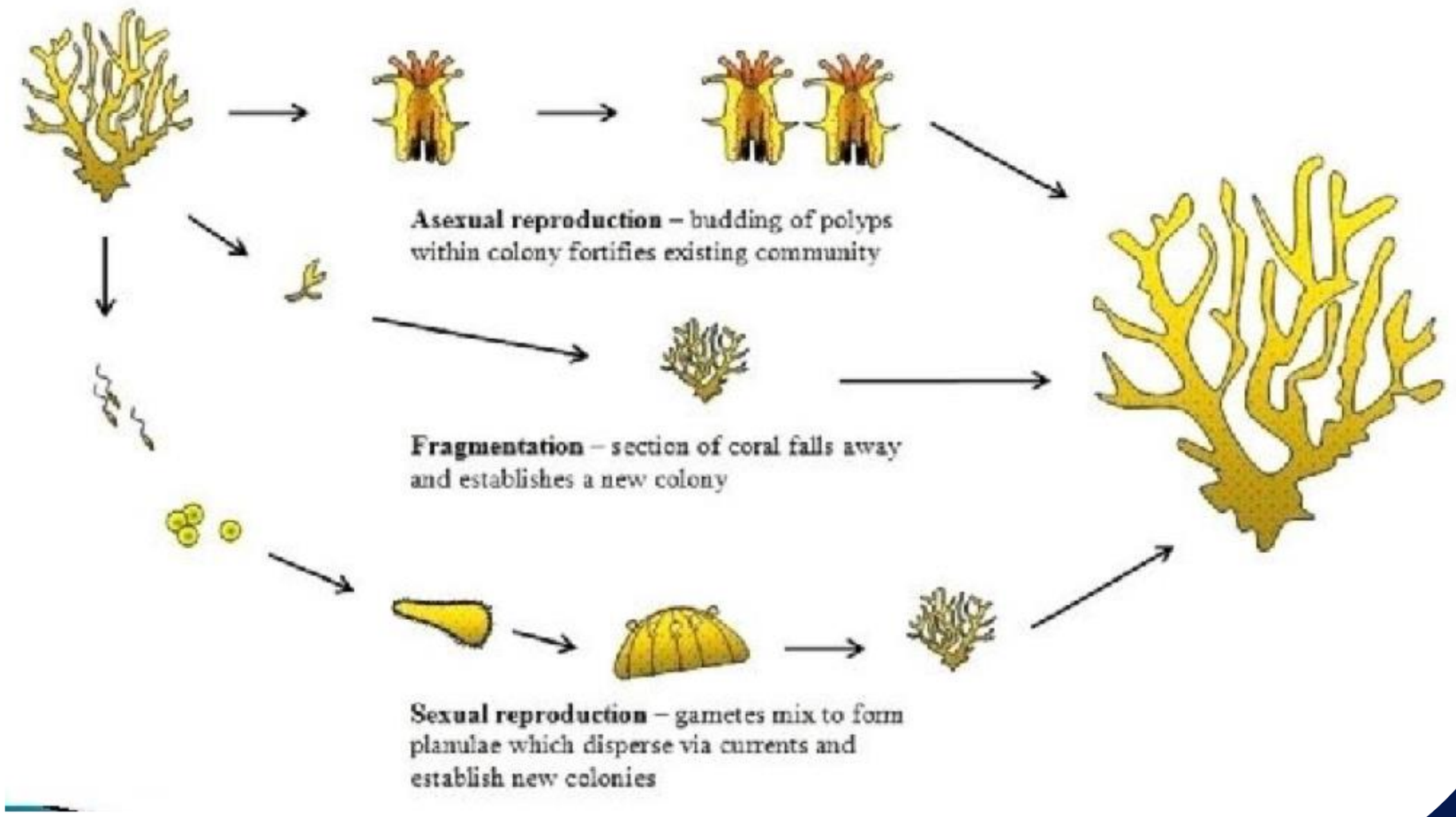
1. Coral reproduction
2. Acropora spp.
3. Orbicella spp.
4. *Diploria labyrinthiformis*
5. *Dendrogyra cylindrus*


THE
CORAL
BABIES
By
Ian Derry



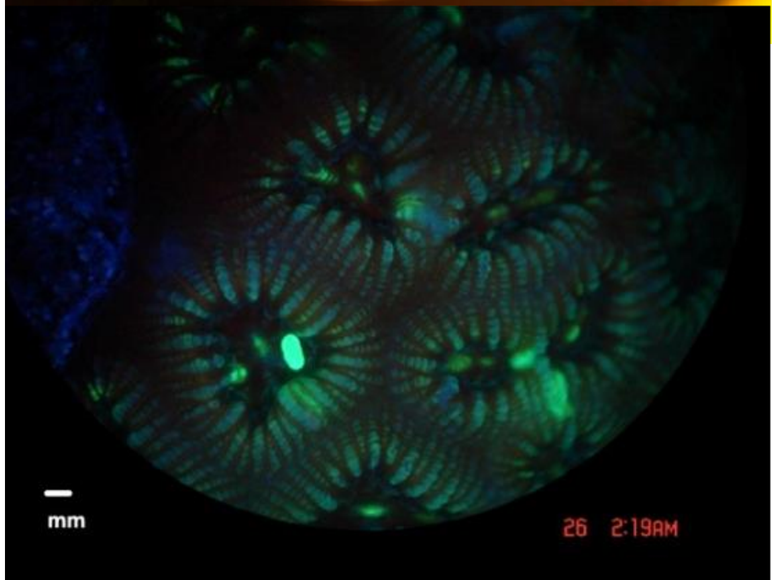
1

Coral Reproduction

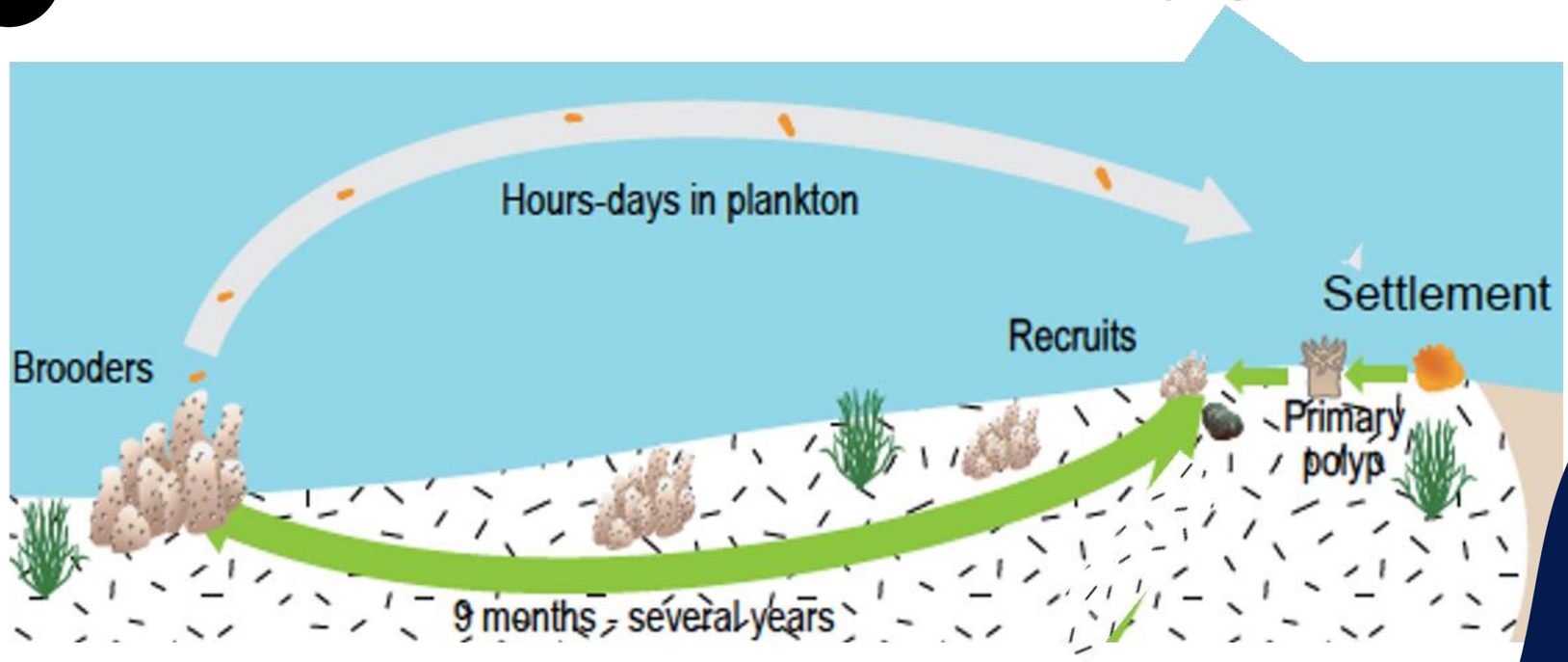


1 Coral Reproduction

Coral life cycle – alternating benthic and planktonic phases

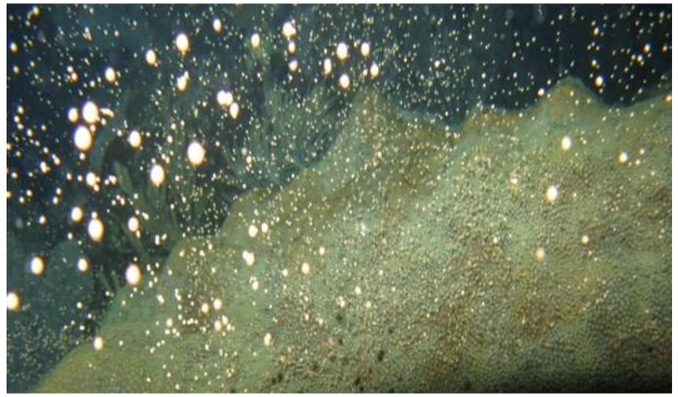


1.1 Brooders: Internal fertilization and embryogenesis



1.2 Spawners: External fertilization and embryogenesis

Hermaphroditic: eggs and sperm spawned together



Gonochoric: separate sexes

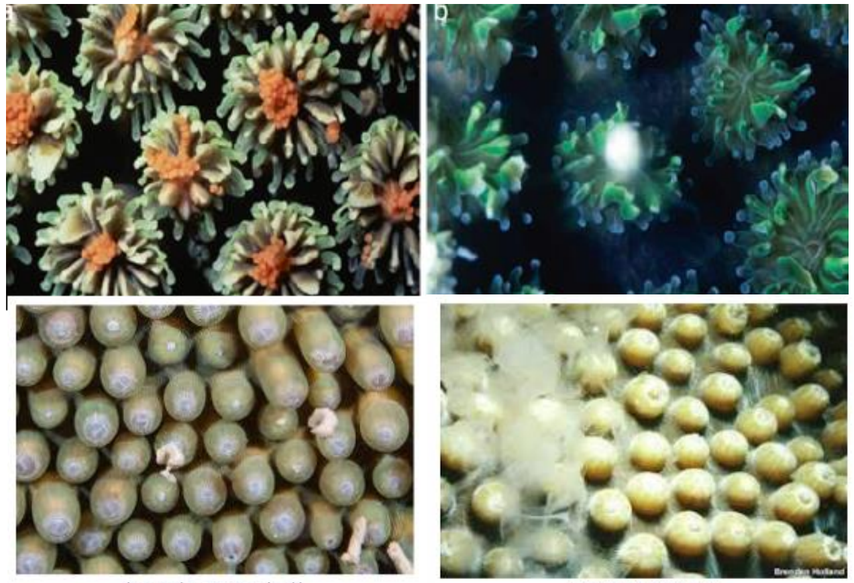
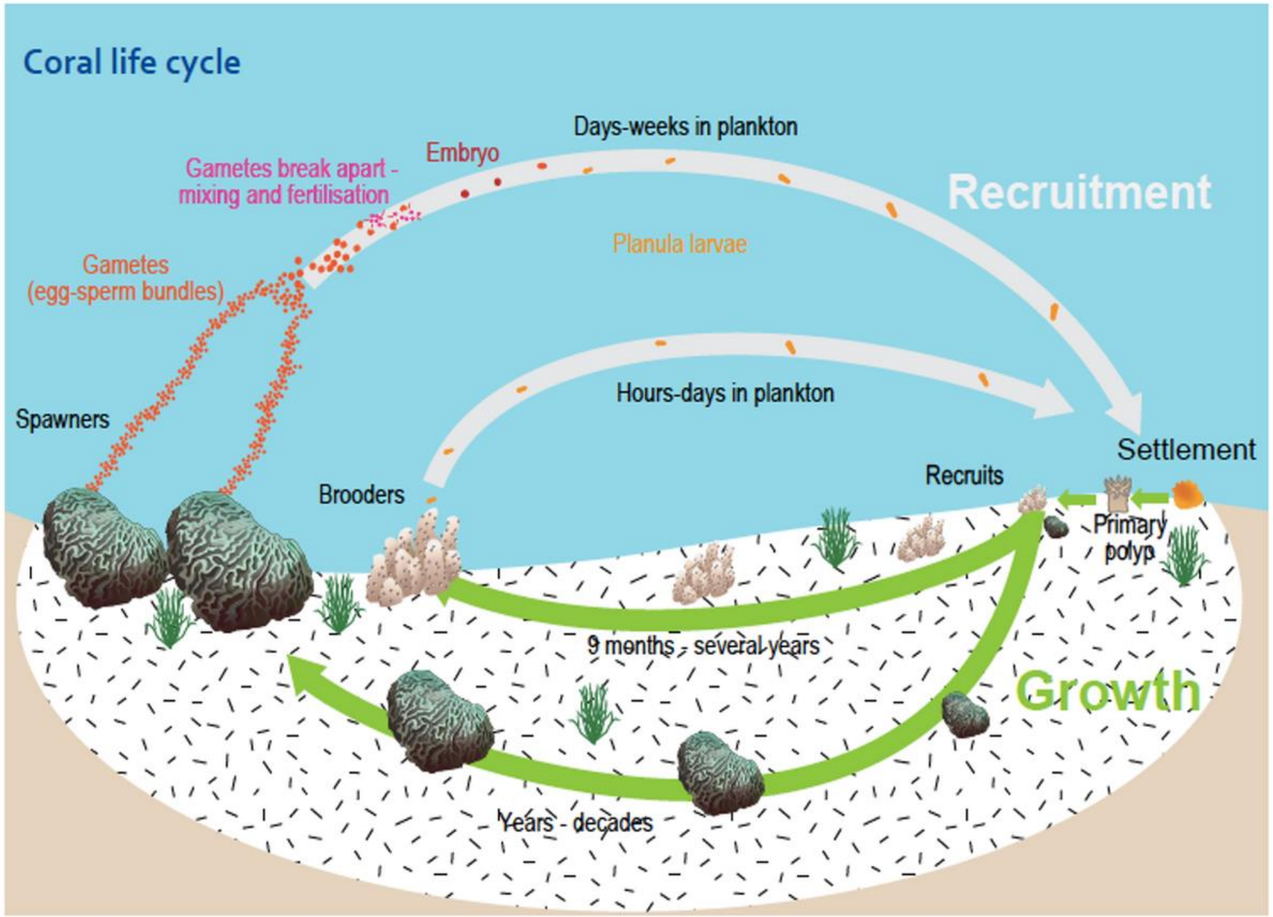


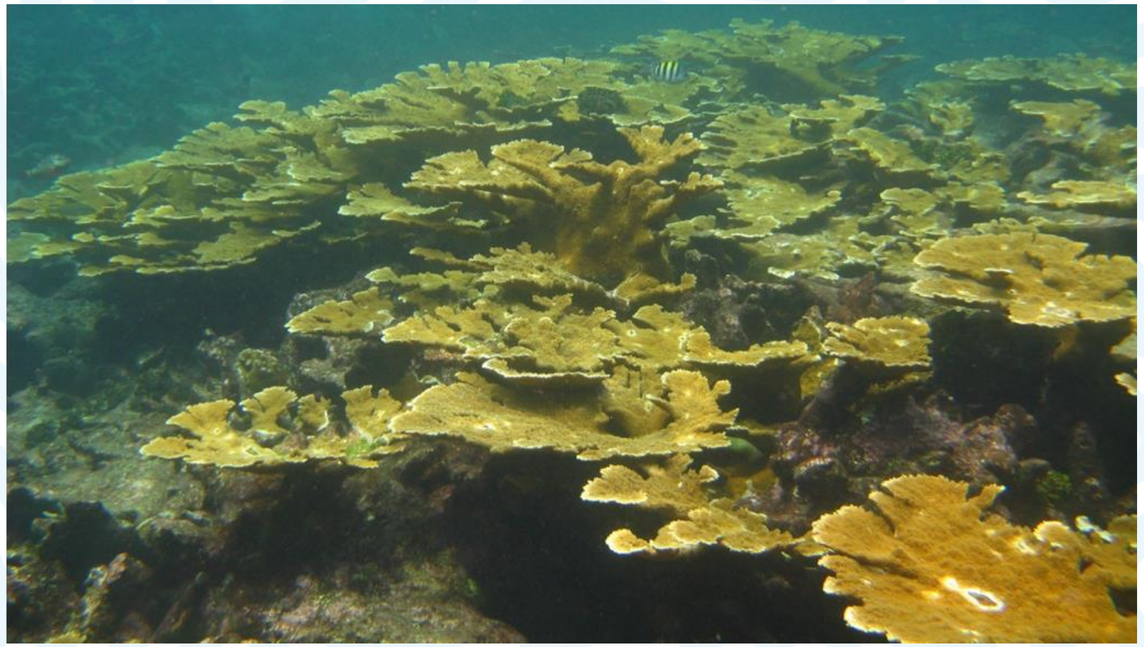
Photo credit: FGBNMS/Schmahl

Photo credit: B. Holland



2 Acropora spp.- Ecological status

- Shallow (1-5m) reef crests (Apal, Acer)
- Deeper colonies (15m Acer)
- Fewer colonies, more dispersed
- Very popular genus for restoration by fragmentation
- Seriously affected by unidentified disease in the 1970s
- Also affected by White Pox
- Voracious predator is Hermodice, Also Drupella and flatworms
- Affected by bleaching event of 2023 and will probably repeat in 2024

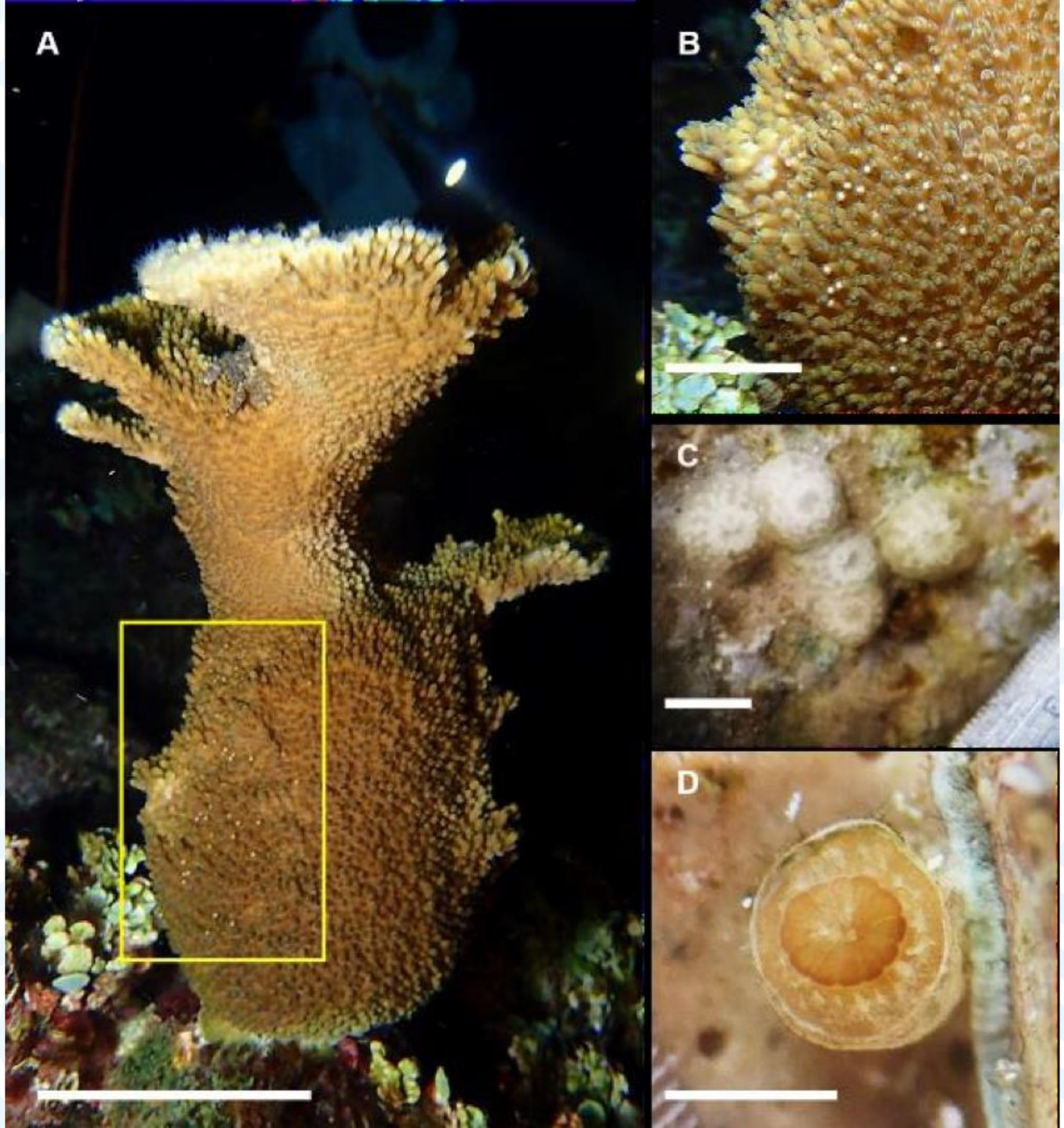


2 Acropora spp.- Reproductive Biology

- Broadcast spawner
- Hermaphroditic sexual system
- Timing for gamete collection
- late July, August, early September
- Most likely: 3-7 NAFM, 140-190 min after sunset
- Spawning window is very wide in some areas (e.g. Curaçao, -2 to 14 NAFM)
- Patch-specific spawning windows in Mexico
- Consult Coral Breeding Reference Sheet for Acropora palmata for more details

2 Acropora spp.- Breeding under controlled conditions

- Well established for fertilization, embryogenesis, larval behaviour, settlement and metamorphosis
- Well established for early-stage and long-term rearing under controlled ex-situ and in-situ conditions (CRIBs)
- Consult Coral Breeding Reference Sheet for *Acropora palmata* for more details
- Can use same reference sheet for *Acropora cervicornis*
- Reproductively viable at 4 years old
- F1 and F2 generation has been bred under controlled conditions (see Mendoza-Quiroz *et al.* 2023)
- Coralium has many recruits of Apal outplanted on different reefs (survived last year´s bleaching event)


A
B
C
D

3 Orbicella spp.- Ecological status

- Colonies generally deeper than Acropora
- Affected by SCTLD and other diseases
- Fewer colonies, more dispersed
- Very popular genus for micro-fragmentation
- Seriously affected by bleaching events, especially that of 2023 and will probably repeat in 2024

3 Orbicella spp.- Eeproductive Biology

- Broadcast spawner
- Hermaphroditic sexual system
- Timing for gamete collection
- July, August, September, October
- 6-7 NAFM, 185-250 min after sunset
- Consult Coral Breeding Reference Sheet for Orbicella faveolata for more details
- Can use same reference sheet for O. annularis and probably for O. franksi

Photo credit: E. Hickerson

Orbicella franksi
DAFM: 5-10; peak 6-8
MAS: 100-250; peak 110-200
August-September-October

Photo credit: K. Marhaver

Orbicella annularis
DAFM: 5-8; peak 6-7
MAS: 150-275; peak 190-250
August-September-October

Photo credit: FGBNMS

Orbicella faveolata
DAFM: 5-9; peak 6-8
MAS: 100-275; peak 175-250
August-September-October

3 Orbicella spp.- Breeding under controlled conditions

- Well established for fertilization, embryogenesis, larval behaviour, settlement and metamorphosis, but is a difficult species to breed
- Well established for early-stage and long-term rearing under controlled ex-situ and in-situ conditions (CRIBs)
- Consult Coral Breeding Reference Sheet for Orbicella faveolata for more details
- Can use same reference sheet for O. annularis and probably for O. franksi
- Coralium has Ofav colonies that are now 13 years old under controlled, natural light conditions and have not yet spawned + many recruits of Ofav and Oann outplanted on different reefs (survived last year´s bleaching event)

3 Orbicella spp.- Experience in culturing Orbicella

13 year old colonies

OFAV 1.5 yr old (2019)

OANN 2.5 yr old (2020)

OFAV 2.5 yr old (2020)

OANN 3.5 yr old (2019)

- 2011-2024 ex situ culturing of O. faveolata
- 2019-2024 ex situ culturing of O. annularis

4 *Diploria labyrinthiformis*- Ecological status

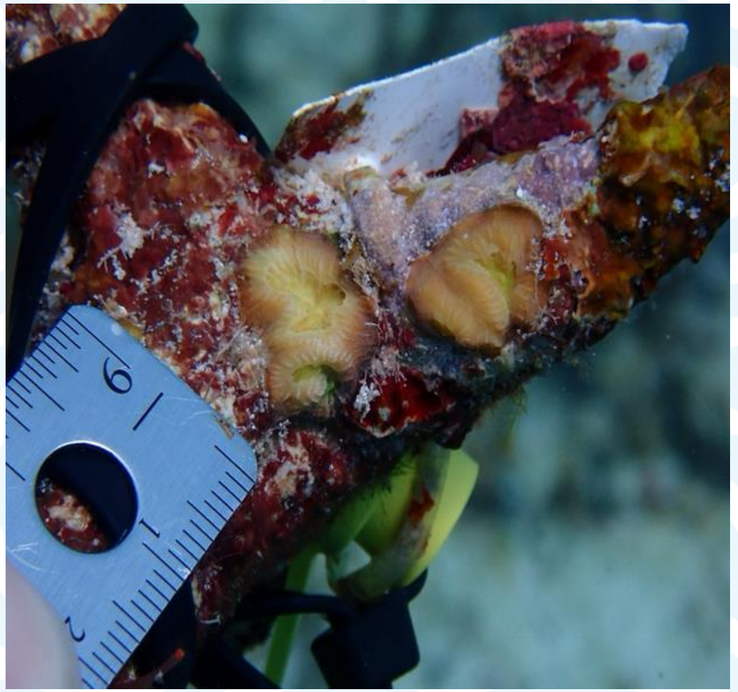
- Colonies generally deeper than *Acropora,* similar to *Orbicella*
- Affected by SCTLD and other diseases
- Fewer colonies, more dispersed
- Popular genera for micro-fragmentation
- Seriously affected by bleaching events, especially that of 2023 and will probably repeat in 2024
- Similar issues for other brain corals e.g., *Pseudodiploria* spp., *Colpophyllia*

4 *Diploria labyrinthiformis* - Reproductive Biology

- Broadcast spawner
- Hermaphroditic sexual system
- Timing for gamete collection
- April to November (Curaçao) July and August (Mexico)
- 9-14 NAFM, -90 to 15 min after sunset (Curaçao)
- 9-11 NAFM, -60 to 14 min after sunset (Mexico)
- Consult Coral Breeding Reference Sheet for Diploria labyrinthiformis for more details
- Can probably use same reference sheet for Pseudodiploria and Colpophyllia(except for spawning times)

4 *Diploria labyrinthiformis*- Breeding under controlled conditions

- Easiest species to breed
- Well established for fertilization, embryogenesis, larval behaviour, settlement and metamorphosis
- Well established for early-stage and long-term rearing under controlled ex-situ and in-situ conditions (CRIBs)
- Consult Coral Breeding Reference Sheet for Diploria labyrinthiformis for more details
- Can probably use same reference sheet for Pseudodiploria and Colpophyllia
- Coralium has many recruits of Dlab and Pstr outplanted on different reefs (survived last year´s bleaching event)



5 *Dendrogyra cylindrus*- Ecological status

- Colonies generally deeper than Acropora, similar to Orbicella
- Seriously affected by SCTLD
- Potentially ecologically extinct

4 *Dendrogyra cylindrus* - Reproductive Biology

- Broadcast spawner
- Gonochoric sexual system
- Gamete collection system distinct to hermaphroditic species
- Timing for gamete collection
- July and August (Dominican Republic)
- 2-5 NAFM, 65 to 130 min after sunset (Dominican Republic)
- No Coral Breeding Reference Sheet available but consult with Rita Sellares (Fundemar)

Photo credit: Neely et al. 2013 Coral Reefs 32: 813

***Dendrogyra cylindrus* - males**
DAFM: 2-5; peak 2-4
MAS: 58-134; peak 93-119
August-September

Photo credit: Neely et al. 2013 Coral Reefs 32: 813

***Dendrogyra cylindrus* - females**
DAFM: 1-4; peak 2-3
MAS: 58-142; peak 102-134
August-September

4 *Dendrogyra cylindrus* Breeding under controlled conditions

- Well established for fertilization, embryogenesis, larval behaviour, settlement and metamorphosis
- Well established for early-stage and long-term rearing under controlled ex-situ and in-situ conditions (CRIBs)
- Coralium has many recruits outplanted on reefs (survived last year's bleaching event)
- Consult Rita Sellares (Fundemar) for more information

fundemar
Fundación Dominicana de Estudios Marinos, Inc.

Steps for Coral Assisted Sexual Reproduction

fundemar
Fundación Dominicana de Estudios Marinos, Inc.

B.-Steps for Coral Assisted Sexual Reproduction

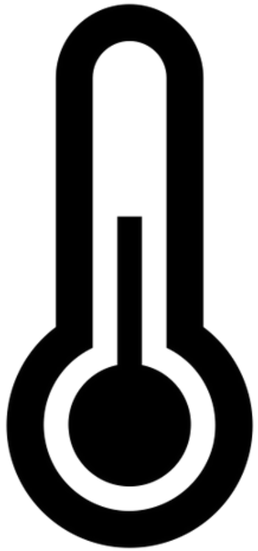
Fundación Dominicana de Estudios Marinos, Inc.

1. Spawning calendar
2. Gamete collection: type of collector, data, logistics
3. Fertilization and culture
4. Settlement
5. Outplant and monitoring

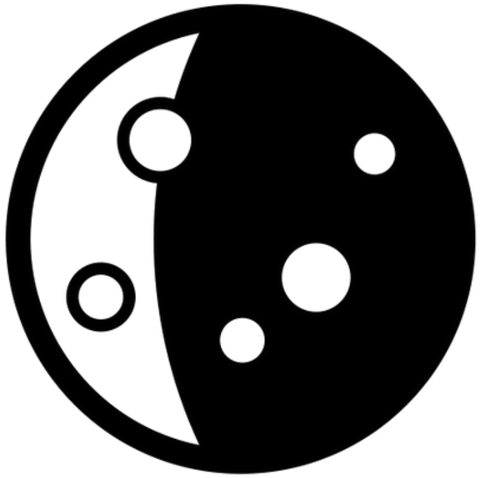
1 Spawning calendar

Fundación Dominicana de Estudios Marinos, Inc.

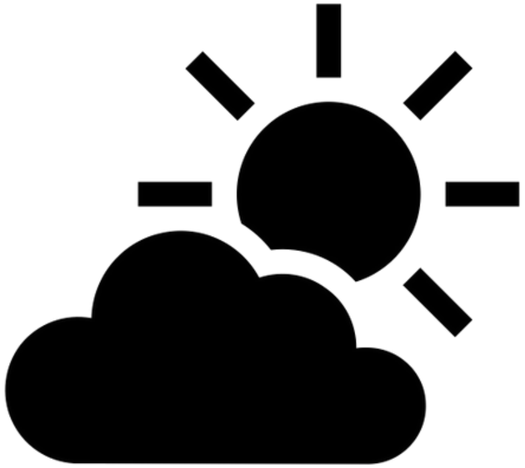
Month



Day

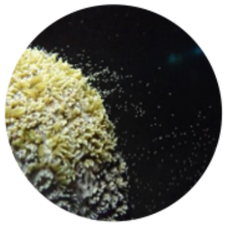


Time



PREDICCIÓN DESOVES DE CORAL
2024 REPÚBLICA DOMINICANA

BAYAHIBE



MAY JUN JUL

Días después de la luna llena	9	10	11	12
Fecha	2-may 1-jun 30-jun	3-may 2-jun 1-jul	4-may 3-jun 2-jul	5-may 4-jun 3-jul
Hora del atardecer	18:57 19:08 19:16	18:58 19:09 19:16	18:58 19:09 19:16	18:58 19:10 19:16
Diploria labyrinthiformis (5-70 minutos **antes** del atardecer)		17:45 – 18:55 17:55 – 19:05 18:05 – 19:15		

Posible desove bajo mismo patrón (en menor cantidad) hasta octubre.

JUL

Días después de la luna llena	0	1	2	3	4	5	6	7	8
Fecha	20-jul	21-jul	22-jul	23-jul	24-jul	25-jul	26-jul	27-jul	28-jul
Hora del atardecer	19:14	19:14	19:14	19:13	19:13	19:13	19:12	19:12	19:11
Acropora palmata (120-185 minutos **después** del atardecer)				21:10 – 22:20					
Dendrogyra cylindrus (80-140 minutos **después** del atardecer)				20:30 – 21:30					

AGO

Días después de la luna llena	1	2	3	4	5	6	7	8	9
Fecha	20-ago	21-ago	22-ago	23-ago	24-ago	25-ago	26-ago	27-ago	28-ago
Hora del atardecer	18:58	18:58	18:57	18:56	18:55	18:55	18:54	18:53	18:52
Acropora cervicornis (150-195 minutos **después** del atardecer)					21:25 – 22:10				
Acropora palmata (120-185 minutos **después** del atardecer)			20:55 – 22:00						
Dendrogyra cylindrus (80-140 minutos **después** del atardecer)			20:15 – 21:15						
Meandrina meandrites* (55-65 minutos **después** del atardecer)					19:50 – 20:00				
Pseudodiploria strigosa* (40-60 y 125-150 min **después** del atardecer)						19:35 – 19:55 21:00 – 22:25			

SEP

Días después de la luna llena	3	4	5	6	7	8	9	10
Fecha	20-sep	21-sep	22-sep	23-sep	24-sep	25-sep	26-sep	27-sep
Hora del atardecer	18:33	18:32	18:31	18:30	18:29	18:28	18:28	18:27
Colpophyllia natans (30-85 minutos **después** del atardecer)				19:00 – 20:00				
Meandrina meandrites* (55-65 minutos **después** del atardecer)			19:25 – 19:35					
Montastraea cavernosa (15-85 minutos **después** del atardecer)			18:45 – 20:00					
Orbicella annularis (190-240 minutos **después** del atardecer)				21:40 – 22:30				
Orbicella faveolata (145-235 min. **después** del atardecer)				20:55 – 22:25				
Orbicella franksi* (145-155 minutos **después** del atardecer)				20:55 – 21:05				
Pseudodiploria strigosa* (40-60 y 125-150 min. **después** del atardecer)				19:10 – 19:30 20:35 – 21:00				
Pseudodiploria clivosa* (90-150 minutos **después** del atardecer)				20:00 – 21:00				

Fechas establecidas basado en días donde se han registrado más desoves en rojo, algunos desoves en naranja y de monitoreo general y posible desove en amarillo.
(*) Desove solo se ha registrado en una ocasión.

Se recomienda salir a monitorear de 1-2 días antes y después de las fechas predichas. Los horarios se establecieron cómo hora más probable en que comience y termine el desove.
De ser posible, se recomienda monitorear al menos media hora antes y después de la hora predicha, haciendo múltiples buceos.

Contacto: info@fundemardr.org

Cita: Sellares, R.I., Villalpando, M.F. & Valdez, A. "Predicción desoves de coral, República Dominicana 2019-2024." FUNDEMAR, República Dominicana.

De acuerdo a lo recomendado por:
Vermeij MJA, Chamberland VF, and Marhaver KL, "Coral Spawning Predictions, Southern Caribbean, 2007–2023." CARMABI, Curacao.
Banaszak AT, "Coral Spawning Predictions, México, 2007–2023." CORALIUM-UNAM, Mexico

PREDICCIÓN DESOVES DE CORAL
2024 REPÚBLICA DOMINICANA

BANÍ reportado por Buceo Ecológico RD

MAY JUN

Días después de la luna llena	9	10	11	12
Fecha	2-may 1-jun	3-may 2-jun	4-may 3-jun	5-may 4-jun
Hora del atardecer	19:03 19:14	19:03 19:14	19:03 19:14	19:04 19:15
Diploria labyrinthiformis* (65-80 minutos **antes** del atardecer)		17:35 – 17:55 17:45 – 18:05		

Posible desove bajo mismo patrón (en menor cantidad) hasta octubre.

AGO

Días después de la luna llena	0	1	2	3	4	5	6	7	8
Fecha	19-ago	20-ago	21-ago	22-ago	23-ago	24-ago	25-ago	26-ago	27-ago
Hora del atardecer	19:04	19:04	19:03	19:02	19:02	19:01	19:00	18:59	18:58
Acropora palmata (145-155 minutos **después** del atardecer)			21:25 – 21:40						

PUNTA CANA reportado por Fundación Grupo Punta Cana (FGPC) y Fundación Cap Cana

AGO

Días después de la luna llena	0	1	2	3	4	5	6	7	8
Fecha	19-ago	20-ago	21-ago	22-ago	23-ago	24-ago	25-ago	26-ago	27-ago
Hora del atardecer	18:57	18:56	18:55	18:55	18:54	18:53	18:52	18:52	18:51
Acropora cervicornis (165-215 minutos **después** del atardecer)								21:40 – 22:30	
Acropora palmata (100-190 minutos **después** del atardecer)		20:30 – 22:05							

SEP

Días después de la luna llena	1	2	3	4	5	6	7	8	9
Fecha	18-sep	19-sep	20-sep	21-sep	22-sep	23-sep	24-sep	25-sep	26-sep
Hora del atardecer	18:32	18:31	18:30	18:29	18:29	18:28	18:27	18:26	18:25
Acropora cervicornis (165-215 minutos **después** del atardecer)							21:10 – 22:00		
Acropora palmata (145-185 minutos **después** del atardecer)			20:55 – 21:35						

SAMANÁ reportado por Centro para la Conservación y Ecodesarrollo de la Bahía de Samaná y su Entorno (CEBSE)

AGO

Días después de la luna llena	0	1	2	3	4	5	6	7	8
Fecha	19-ago	20-ago	21-ago	22-ago	23-ago	24-ago	25-ago	26-ago	27-ago
Hora del atardecer	19:02	19:01	19:00	18:59	18:59	18:58	18:57	18:56	18:56
Acropora cervicornis (160-190 minutos **después** del atardecer)			21:40 – 22:10						
Acropora palmata (145-230 minutos **después** del atardecer)				20:55 – 22:25					

Fechas establecidas basado en días donde se han registrado más desoves en rojo, algunos desoves en naranja y de monitoreo general y posible desove en amarillo.
(*) Desove solo se ha registrado en una ocasión.

Se recomienda salir a monitorear de 1-2 días antes y después de las fechas predichas. Los horarios se establecieron cómo hora más probable en que comience y termine el desove.
De ser posible, se recomienda monitorear al menos media hora antes y después de la hora predicha, haciendo múltiples buceos.

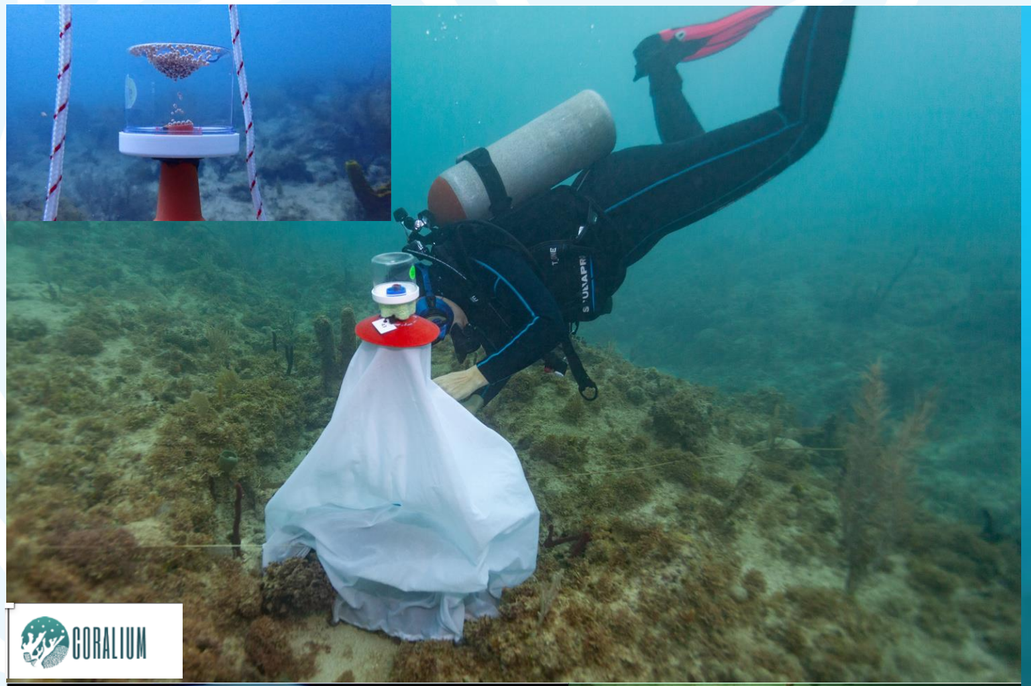
Contacto: info@fundemardr.org

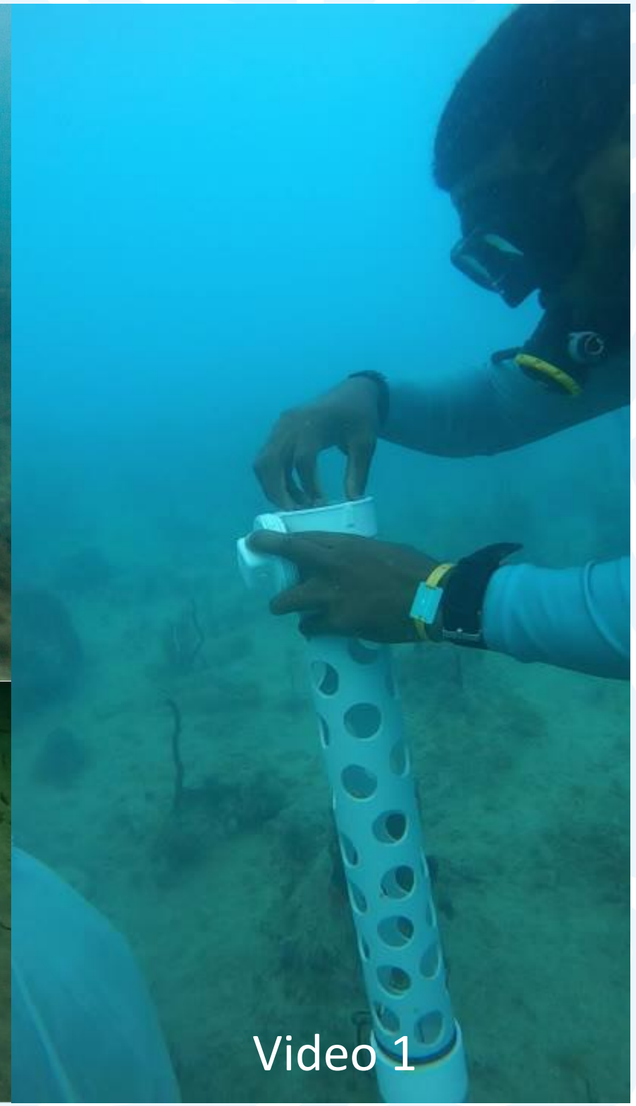
Cita: Sellares, R.I., Villalpando, M.F. & Valdez, A. "Predicción desoves de coral, República Dominicana 2019-2024." FUNDEMAR, República Dominicana.

De acuerdo a lo recomendado por:
Vermeij MJA, Chamberland VF, and Marhaver KL, "Coral Spawning Predictions, Southern Caribbean, 2007–2023." CARMABI, Curacao.
Banaszak AT, "Coral Spawning Predictions, México, 2007–2023." CORALIUM-UNAM, Mexico

2 Gamet collection: type of collector/ data/logistics

2.1 Type of collector





Video 2

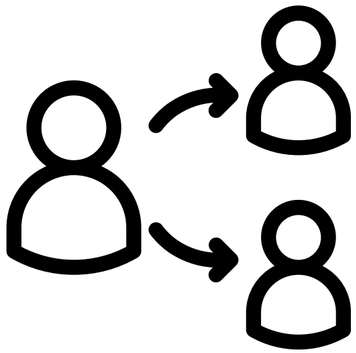
Video 3

Video 4

2 Gamet collection: type of collector/data/ logistics

Fundación Dominicana de Estudios Marinos, Inc.

2.2 Data to collect



Registro Desove

Fecha: 14 abr 23
Sitio: Playita
Profundidad: 5-6m
Area (m^2):
Observador(es): Mich y Sam
Inicio monitoreo: 5:10
Final monitoreo: 6:25

Especie: Dlab
d AFM: 9
Hora atardecer: 18:50
colonias monitoreo: 10
colonies desovaron:

# Colonia	# Pote	Hora setting	Hora inicio desove	Hora final desove
1	52			
2	8, 61	5:50	5:55	6:10
3	13			
4	45			
5	30			
6	102		5:20	5:30
7	67			
8	90			
9	4			
10	78			

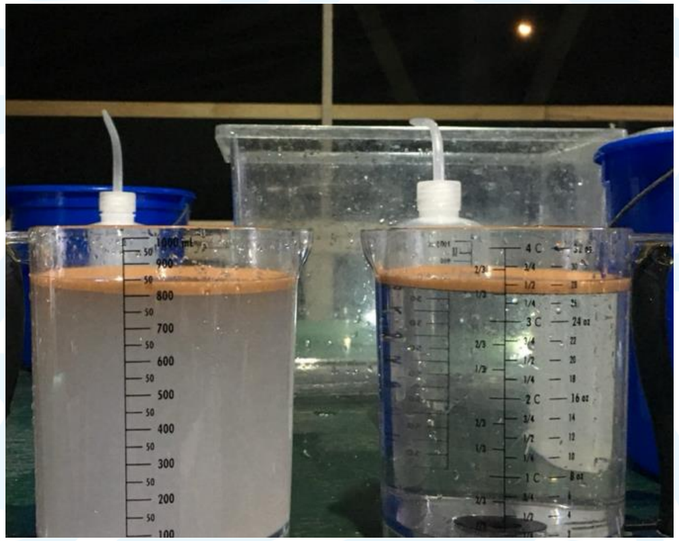
2 Gamet collection: type of collector/data/ logistics

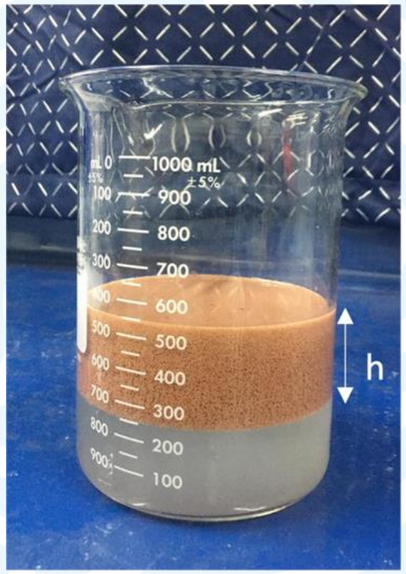
Fundación Dominicana de Estudios Marinos, Inc.

2.3 Logistics

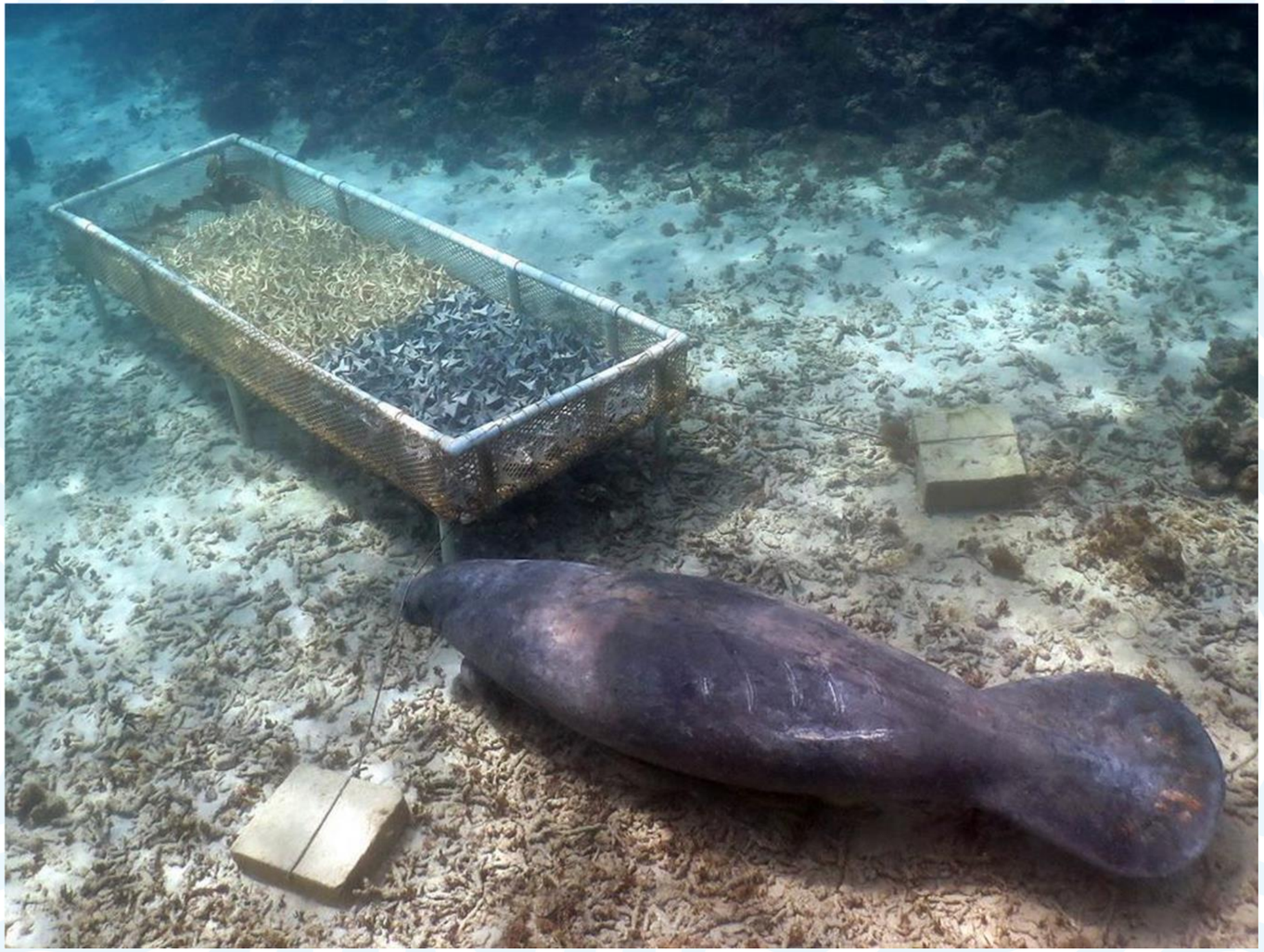
- Permit (DR: Enviornmental minitsry, Navy)
- Plan your team and sites:
  - Make sure the team knows the area and the sps
  - Premark and prepare the site if necessary
  - Divide the site by team
  - Divide functions
  - Do a diving training before spawning
- Materials:
  - collectors
  - fertilization kit (filter sea water, bucket, something to mix, pipette, wash bottle)
  - GPS
  - Water to drink

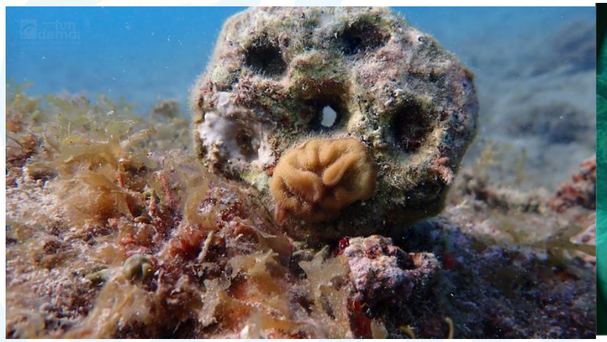
3 Fertilization and culture





3 Fertilization and culture

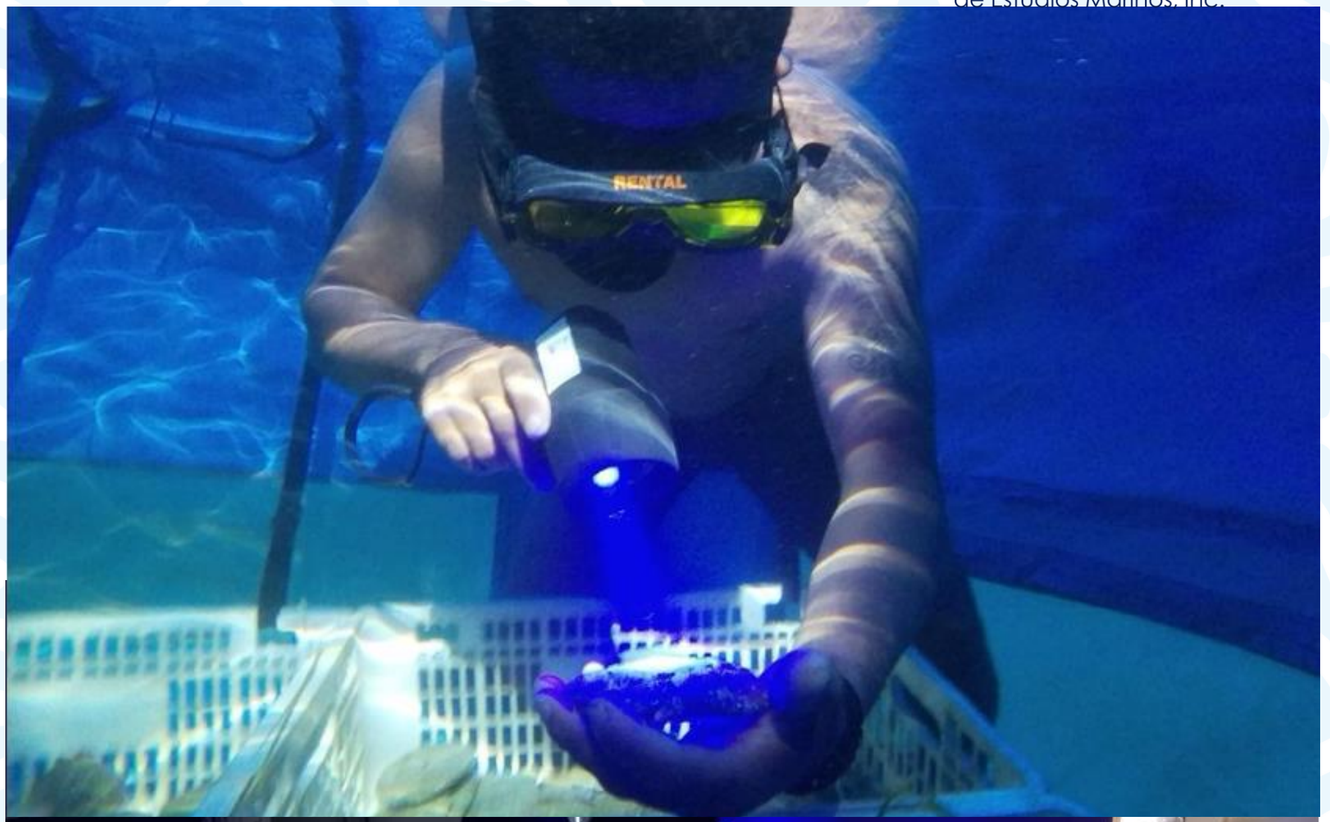




Secore International

4 Settlement

Fundación Dominicana de Estudios Marinos, Inc.

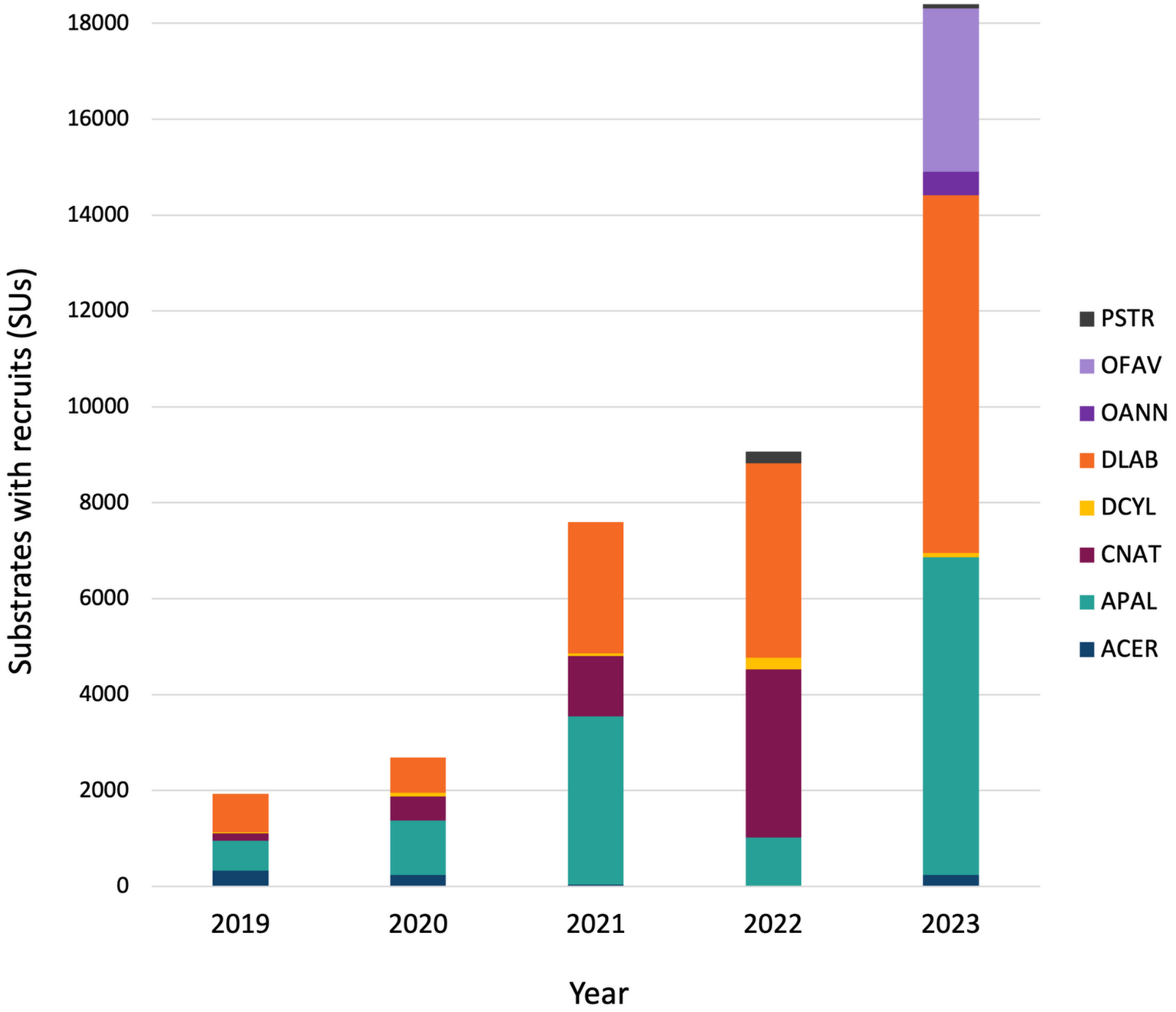


4 Settlement

Video 5

5 Outplant and monitoring

Video 6



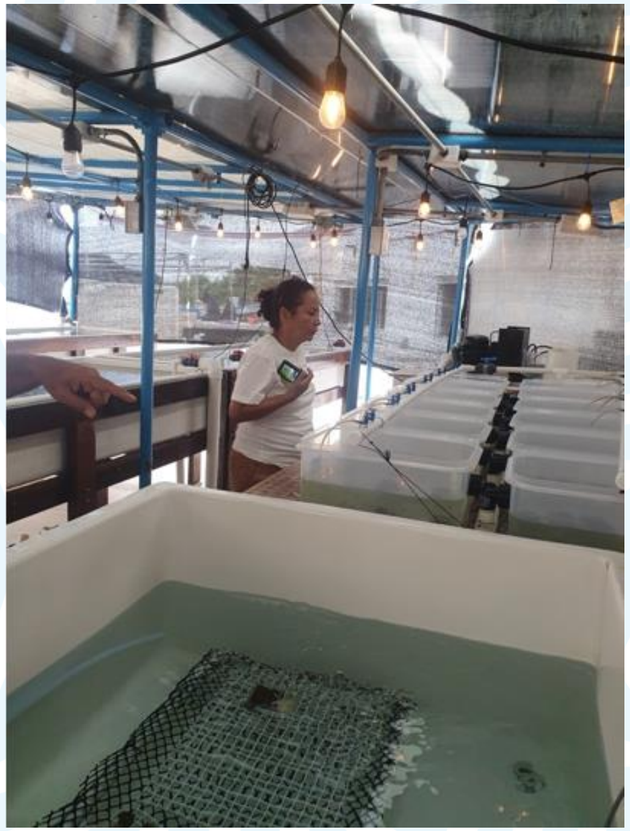
fundemar
Fundación Dominicana
de Estudios Marinos, Inc.

Video 7

Fundación Dominicana
de Estudios Marinos, Inc.

C.-Current techniques for coral larval propagation

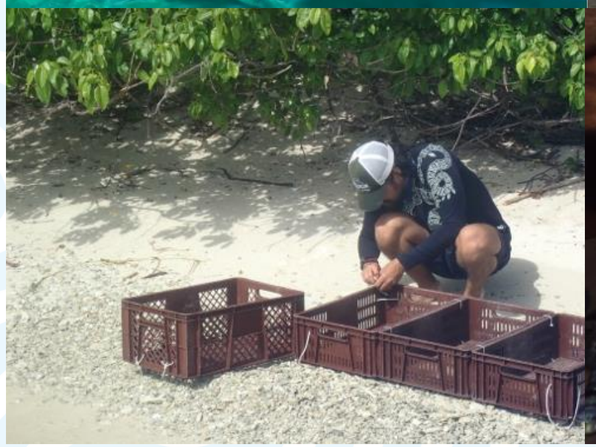
In Situ, Ex Situ larval rearing facilities



Larval rearing facilities

1. In situ
2. Ex situ

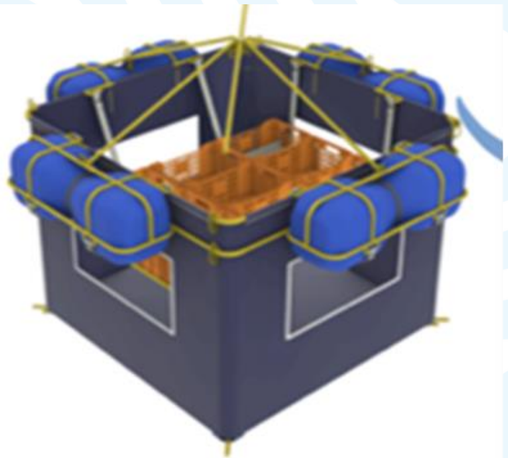
1.1 In situ- SECORE´s CRIB



Materials and Equipement		
Item	#	cost US$
CRIB	1	$ 5.600
SECORE substrates	720	$ 720
incubators	9	$ 78
buckets	2	$ 9
Brushees	20	$ 67
Gravys 1 L Norpro	1	$ 23
graduated cylinder	1	$ 16
pasteur pipette pack 100	1	$ 18
Beaker graduado plástico 1000 ml	1	$ 4
submersible white light lantern	2	$ 140
wash bottle500 ml	1	$ 7
Microscope with cámara	1	$ 3.778
plastic tables	1	$ 29
diving tanks (inflate CRIB)	3	$ 47
marine rope (1.2 mm_100m)	1	$ 87
Hydraulic PVC tubes for CRIB of 1 1/2" , other gears	1	$ 111
boat	10	$ 3.333
total basic materials and equipment		$ 14.066

Honoraries	people	days	cost
CRIB Assemblage	1	3	135
supervision	1	30	480
personal especializado conteo, siembra	5	10	4650
Toal cost			5265

1.2 In situ- Colombian CRIB (Universidad Tadeo Lozano)



Materials and Equipement		
Item	#	cost US
CRIB	1	$ 1.200
SECORE substrates	720	$ 864
incubators	9	$ 78
buckets	2	$ 9
Brushees	20	$ 67
Gravys 1 L Norpro	1	$ 23
graduated cylinder	1	$ 16
pasteur pipette pack 100	1	$ 18
Beaker graduado plástico 1000 ml	1	$ 4
submersible white light lantern	2	$ 140
wash bottle500 ml	1	$ 7
Microscope with cámara	1	$ 3.778
plastic tables	1	$ 29
diving tanks (inflate CRIB)	3	
marine rope (1.2 mm_100m)	1	$ 87
Hydraulic PVC tubes for CRIB of 1 1/2" , other gears	1	
boat	10	$ 3.333
total basic materials and equipment		$ 9.652

Honoraries	people	days	cost
CRIB Assemblage	3	3	405
supervision	1	30	480
personal especializado conteo, siembra	5	10	4650
Toal cost			5535

1.3 In situ-Tents for direct seeding / tents for larval rearing

60

US$

ITEMS FOR 2	#	VALOR UNITARIO	SUBTOTAL	US$
Varilla de hierro ½" (6m)	12	6.620	79.440	17,7
Codo de PVC de ½"	8	450	1800	0,4
Tubo de PVC de ½ " (3m)	5	8.000	40.000	8,9
Codo de PVC de 1.1/2"	24	2.600	62.400	13,9
T de PVC de 1.1/2"	24	5.500	132.000	29,3
Tubo de PVC 1.1/2" (3 m)	16	21.900	350.400	77,9
Uniones de PVC de ½"	10	450	4.500	1,0
T de PVC de ½"	8	850	6.800	1,5
Velo para encierro (2.3m)	20	15.000	300.000	66,7
subtotal			**979.140**	217,2
Diseño y mano de obra	1		400.000	88,9
TOTAL			**1.200.000**	**306,1**

2.1 Ex situ -Oceanario, Islas del Rosario, Cartagena

US$120

0

2.2 Ex situ- Open temporal lab

Materiales y equipos

Item	#	US$
colombian substrates	960	$ 756
incubators	12	$ 104
water flow valves	12	$ 40
wooden boards	6	$ 80
concrete blocks	90	$ 82
Canastas CRIB	12	$ 77
plastic organizing boxes	4	$ 139
250 l water storage tanks	2	$ 143
100 l water tanks to store water	2	$ 33
buckets	2	$ 9
20 l drums with shut-off valve	5	$ 89
Gravys 1 L Norpro	5	$ 116
Cinta metalizada Tesa x 25m	1	$ 18
Beaker 1000 ml	2	$ 9
Plug adapter	1	$ 3
Thermometer	2	$ 18
Washing bottle 500 ml	3	$ 20
aerators and air stones	6	$ 40
Plastic hose (6 m)	6	$ 67
mesh of 10,30 and 100 microns	2	$ 45
Microscope with cámara	1	$ 6.444
Stereoscope with cámara	1	$ 6.000
glass and others		$ 89
polypropylene salad bowls	200	$ 67
cheicals for washing and desinfecting		$ 67
plastic tables	5	$ 147
plastic seats	2	$ 18
fans	4	$ 124
Microfiltrartion system	1	$ 4.000
Total basic materials and equipment		**$ 18.841**

	people	days	total US
assemblage	3	2	267
operation	2	30	934
trained personell	5	10	2222
Total			3423

2.3 Ex situ- Closed lab in a Container

	people	days	cost
assemblage	3	2	267
operation	2	30	934
trained personell	5	10	2222
Total			3423

Estereoscopio (Amscope SM-1TSW2-L6W-5M)	908,64
Copias llaves y carabiners	13,23
Nasas materiales	15,27
hermetico	15,88
Regleta	6,62
Martillos (Monas)	23,92
Envío equipos de buceo	20,2
Gravy Norpro	43,02
Vaso precipitado 1000ml + probetas 250 y 25 ml	32,66
Vaso precipitado 500 ml	11,11
Mallas para filtros	42,75
Compra containers	12500
Compra sistema de filtración	4835,43
Tubos falcon, cajas petri, frasco lavador, jarra medidora	37,87
Pipetas pasteur, jabon	13,98
Bombas de aireación	104,22
Canastas	232,82
Materiales laboratorio	331,09
Tanques de 250 L	130,15
Clavos de acero, pistola silicona	12,76
Baldes y cepillos	20,64
Flete envio sistema microfiltración	158,81
Tiosulfato de sodio	34,79
Laminación y marcadores	7,39
malla, pegante pvc y otros	15,76
Lona, tubos, cegueta, tijera	28,7
Kit de destornilladores	6,35
Capital equipment	12500
Total	**32104,1**

2.4 In situ- building facilities CORALIUM LAB -UNAM

Much..
but
permanent

Anastazia Banaszak
Rita Sellares
Elvira Alvarado