atlas

UNDERSTANDING DEEP ATLANTIC ECOSYSTEMS

INSTITUTO ESPAÑOL DE OCEANOGRAFÍA 1914

UNIVERSITY OF GOTHENBURG

Reproductive traits and larval ecology. Some potential relevant aspects to feed predictive dispersal models

ATLAS 3rd General Assembly

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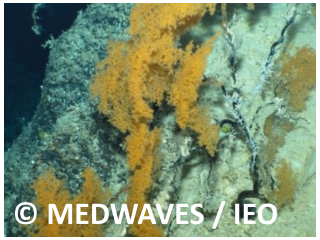
Bibliographic compilation on information on reproduction of CWCs

- Data from 16 scleractinian corals

- Data from 21 octocorals

- Data from 33 antipatharians



Scleractinians

Species	Oocyte size (µm)	Nr Oocyte/Polyp	Incubation mode (reproductive strategy)
Lophelia pertusa	60-140	3000	♀♂, anual broadcaster spawner
Lophelia pertusa (Brazil)	145.03 ± 733.52	--	♀♂, broadcaster spawner, some hermaphrodits
Enallopsammia rostrata	400	144	♀♂, broadcast spawner
Enallopsammia rostrata (Brazil)	457.60 ± 7150.96	--	♀♂, broadcast spawner
Madrepora oculata	350	40-60	♀♂, broadcaster spawner
Madrepora oculata, (Brazil)	271.40 ± 783.54	--	♀♂, broadcaster spawner, some hermaphrodits
Oculina varicosa	100	--	♀♂, broadcast spawner, 22 d. planula
Solenosmilia variabilis	157.92 ± 730.17	--	♀♂, broadcaster spawner
Solenosmilia variabilis	165	290	♀♂, broadcast spawner
Goniocorella dumosa	135	480	♀♂ sup., broadcast spawner
Caryophyllia ambrosia	700	200-2750	♀ broadcast spawner
Caryophyllia sequenzae	430	52-940	♀ broadcast spawner
Caryophyllia cornuformis	350	-	♀ broadcast spawner
Fungiacyathus marenzelleri	1400	2837 ± 121	♀♂, broadcast spawner
Flabellum alabastrum	1010	550	♀♂, broadcast spawner
Flabellum angulare	814	2800	♀♂, broadcast spawner
Flabellum thouarsii	4800	2412	♀♂, brooder
Flabellum curvatum	5120	1618	♀♂, brooder
Flabellum impensum	5167	1270	♀♂, brooder
Seriatopora hystrix		--	Larvae observed

(Brooke 2002, Waller et al. 2002, 2005, 2008, Flint 2003, Waller & Tyler 2005, Waller 2005, Burguess & Babcock 2005, NOAA 2007, Waller & Baco 2007, Mercier et al. 2011, Waller & Feehan 2013, Pires et al. 2014, Prasetia et al. 2017)

Octocorals

Species	Oocyte size (μm) (max)	Nr Oocyte/Polyp	Incubation mode (reproductive strategy)
Acanella arbuscula	600-700	--	♀♂, broadcaster brooder?
Primnoella chilensis	752.96	36	♀♂, broadcast spawner? No larvae observed
Swiftia simplex	695.77	42.53 ± 9.82 SE	♀♂, no brooded larvae observed
Swiftia pacifica	664.81	4.6 ± 2.06 SE	♀♂, no brooded larvae observed
Primnoa notialis	687.99	18	♀♂, no brooded larvae observed
Primnoa pacifica	802	86 ± 612	♀♂, broadcaster spawner, lecitotrophic larvae?
Swiftia beringi	726.63	13.6	♀♂, no brooded larvae observed
Swiftia kofoidi	561.81	3 ± 1.53 SE	♀♂, no brooded larvae observed
Swiftia torreyi	244	8 ±1.15 SE	
Funiculina quadrangularis	> 800	500–2000 per 1 cm rachial midsection	♀♂, probably broadcast spawner
Drifa glomerata	--	40–3,000 larvae/colony	♀♂, internal brooder
Primnoa resedaeformis	~ 1000	84.3 ± 3.1 (colonies < 500 m depth); 45.5 ± 1.7	♀♂, broadcaster spawner ? No larvae observed no male colonies observed
Keratoisis ornata	~ 700	0-10 (effective relative fecundity)	♀♂, broadcaster spawner ? No larvae observed no male colonies observed
Anthomastus grandiflorus	1,000–1,100 (largest vitellogenic oocytes and planula)	15.0 ± 1.0 larvae per 4 cm2	♀♂, broadcaster spawner ? larvae observed
Anthomastus riterii	376 ± 178.8	3.3 ± 1.0 (mm) larva	♀♂, brooder
Pennatula phosphorea	> 500	50 (40000 per colony!)	♀♂, broadcast spawner
Fannyella rossi	264.7 ± 32.2	1.5 ± 0.06	♀♂, brooder
Fannyella spinosa	183.1 ± 9.82	1.4 ± 0.08	♀♂, brooder
Dasysthenella acanthina	394.2 ± 26.6	1.2 ± 0.08	♀♂, no larvae observed
Thouarella sp.	261.3 ± 15.6	1.1 ± 0.1	♀♂, brooder
Ainigmaption antarcticum	900	12	♀♂, broadcaster , no larvae observed

(Lawson 1991, Cordes et al. 2001, Orejas et al. 2002, 2007, Edwards & Moore 2008, 2009, Sun et al. 2010, Kahng et al. 2011, Mercier & Hamel 2011, Waller et al. 2014, Feehan & Waller 2015, Rossin et al. 2017)

Antipatharians

Table 1. Summary of previously published information on the sexual reproduction of antipathari

Species	Authority	Family	Collection location	Collection depth (m)	Sex	Gonad location	Oocyte size (µm)	Spermato-cyst size (µm)	
Antipathes assimilis	(Brook 1889)	Antipathidae	Strait of Magellan	320	G*	PTM		224	Brook 1889
Antipathes contorta	(Brook 1889)	Antipathidae	Strait of Magellan	320	G*	–	340	–	Brook 1889
Antipathes dichotoma	Pallas 1766	Antipathidae	Mediterranean	201–256	G*	PTM	250	100	Brook 1889, Van Pesch 1914
Antipathes dubia	(Brook 1889)	Antipathidae	Japan	–	G*	PTM	80–120	–	Pax 1932
Antipathes ericoides	(Milne-Edwards 1857)	Antipathidae	Indonesia, East Timor	5–34	G*	PTM	65	–	Van Pesch 1914
Antipathes griggi	Opresko 2009	Antipathidae	Hawai'i	45–58	G*	PTM	≤100	–	Grigg 1976
Antipathes minor	(Brook 1889)	Antipathidae	Strait of Magellan	320	G*	PTM	–	–	Brook 1889
Antipathes plana	Cooper 1909	Antipathidae	Indonesia	113	G*	–	–	40–60	Van Pesch 1914
Antipathes spp.	N/A	Antipathidae	Indo-Pacific		G	PTM, T	–	–	Schmidt & Zissler 1979
Cirrhipathes anguina	(Dana 1846)	Antipathidae	Indonesia	36	G*	PTM	–	–	Van Pesch 1914
Cirrhipathes cf. *anguina*	(Dana 1846)	Antipathidae	Indonesia	25–35	G*	PTM	35–120	≤120	Gaino et al. 2008, Gaino & Scoccia 2008, Scoccia & Gaino 2010
Cirrhipathes contorta	(Van Pesch 1914)	Antipathidae	Indonesia	9–45	G*	PTM, APSM	–	–	Van Pesch 1914
Cirrhipathes propinqua	Brook 1889	Antipathidae	New Guinea	7	G*	PTM	–	–	Brook 1889
Cirrhipathes rumphii	(Van Pesch 1914)	Antipathidae	Indonesia, East Timor	30–113	G*	PTM	–	55	Van Pesch 1914
Cirrhipathes sp.	N/A	Antipathidae	Indonesia	40	Seq. H	PTM	40–200	–	Bo 2008
Cirrhipathes sp.	N/A	Antipathidae	Indo-Pacific	–	G	PTM, T	–	–	Schmidt & Zissler 1979
Cirrhipathes spiralis	(Blainville 1834)	Antipathidae	Arafura Sea, Indonesia	32–469	G*	PTM	–	–	Van Pesch 1914
Pseudocirrhipathes mapia	Bo et al. 2009	Antipathidae	Indonesia	17–32	G*	–	80–140	–	Bo et al. 2009b
Pteropathes fragilis	Brook 1889	Antipathidae	St. Paul's Rocks	18–146	G*	PTM	–	–	Brook 1889
Stichopathes ceylonensis	Thompson & Simpson 1905	Antipathidae	Arafura Sea	984	G*	PTM	–	–	Van Pesch 1914
Stichopathes gracilis	(Gray 1857)	Antipathidae	Indonesia, Morocco	73	G*	PTM	–	–	Van Pesch 1914, Schultze 1902
Stichopathes spp. ($N = 2$)	N/A	Antipathidae	Puerto Rico	15	G	PTM	≤150	–	Goenaga, 1977
Stichopathes paucispina	(Brook 1889)	Antipathidae	Eastern North Pacific	>1000	G*	–	–	–	Opresko & Genin 1990
Stichopathes pourtalesi	Brook 1889	Antipathidae	Caribbean	82–1606	G*	–	–	–	Brook 1889
Stichopathes richardi	Roule 1905	Antipathidae	NE Atlantic	540–1557	G*	PTM	–	–	Roule 1905
Stichopathes saccula	Van Pesch 1914	Antipathidae	Indonesia	560	G*, Sim. H	PTM	–	120	Van Pesch 1914, Pax et al. 1987
Stichopathes semiglabra	Van Pesch 1914	Antipathidae	Indonesia	55–94	G*	PTM	–	–	Van Pesch 1914
Stichopathes solorensis	Van Pesch 1914	Antipathidae	Indonesia	113	G*	PTM	250	–	Van Pesch 1914
Stichopathes sp.	N/A	Antipathidae	Indo-Pacific	–	G	PTM, T	–	–	Schmidt & Zissler 1979
Stichopathes spiessi	Opresko & Genin 1990	Antipathidae	Eastern North Pacific	450–990	G*	–	–	–	Opresko & Genin 1990
Stichopathes variabilis	(Van Pesch 1914)	Antipathidae	Indonesia, Borneo	15–567	G*	PTM, T	–	70	Van Pesch 1914
Heliopahtes americana	Opresko 2003	Cladopathidae	Jamaica	2200	G*	–	–	–	Opresko 2003
Heliopathes pacifica	Opresko 2005	Cladopathidae	North Pacific	3563–4511	G*	–	–		

Wagner et al. 2011

Antipatharians

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Antipathes ericoides	(Milne-Edwards 1857)	Antipathidae	Indonesia, East Timor	5–34	G*	PTM	65	–	Van Pesch 1914
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Stichopathes sp.	N/A	Antipathidae	Indo-Pacific	–	G	PTM, T	–	–	Schmidt & Zissler 1979

Species	Oocyte size (µm) (max)	Nr Oocyte/Polyp	Incubation mode (reproductive strategy)
Anthipatella wollastonii	122.197 ± 96.8	1 to 309	♀♂, broadcast spawner, no larvae observed

(Wagner et al. 2011 and references therein, Rakka et al. 2016)

Sexual reproduction of deep corals: summary on the "basics"

Scleractinians

- From 16 deep water Scleractinian species description of reproduction

  - 13 gonochoric (♂♀)

  - 3 observed hermaphroditic species: *Caryophyllia* **BUT** hermaphroditims also observed in *Madrepora* and *Lophelia* (Pires et al. 2014)

- Most species are broadcaster

- Three records of brooders (3 *Flabellum* sps.) from the Antarctic continental shelf

- Gametogenesis: continuous, periodic, seasonal → More related to phytodetrital fall or episodic events (cascading??)

(Waller 2003, 2005, NOAA 2007)

Sexual reproduction of deep corals: summary on the “basics”

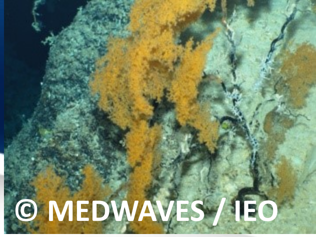
Octocorals

Some observed traits…..

- More brooders in cold and deep habitats than in tropical and temperates
- Lower polyp fecundity in cold and deep habitats than in tropical and temperates
- Short seasonal breeding periods in cold and deep habitats
- Continuous year round breeding in cold and deep habitats

(Review by Khang et al. 2011)

Sexual reproduction of deep corals: summary on the "basics"



Antipatharians

- Gonochoric or a sequentially hermaphroditic mode of reproduction
- No evidence of internal fertilization
- No developing embryos or larvae were observed. Fertilization and larval development likely occur externally in the water column and not internally within polyps

(Review by Wagner et al. 2011)

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Potential relevant aspects in reproductive traits to feed predictive dispersal models

Scleractinians

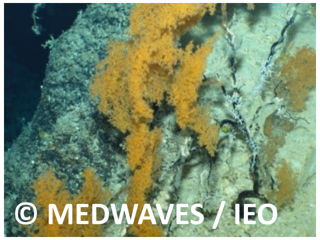
Broadcasting

Continuous, periodic, seasonal

Octocorals

Brooding-Broadcasting

Short seasonal breeding periods



Antipatharians

Broadcasting

Unknown for most deep-sea species

Lophelia pertusa

Waller and Tyler (2005) → NE Atlantic (785–980 m)

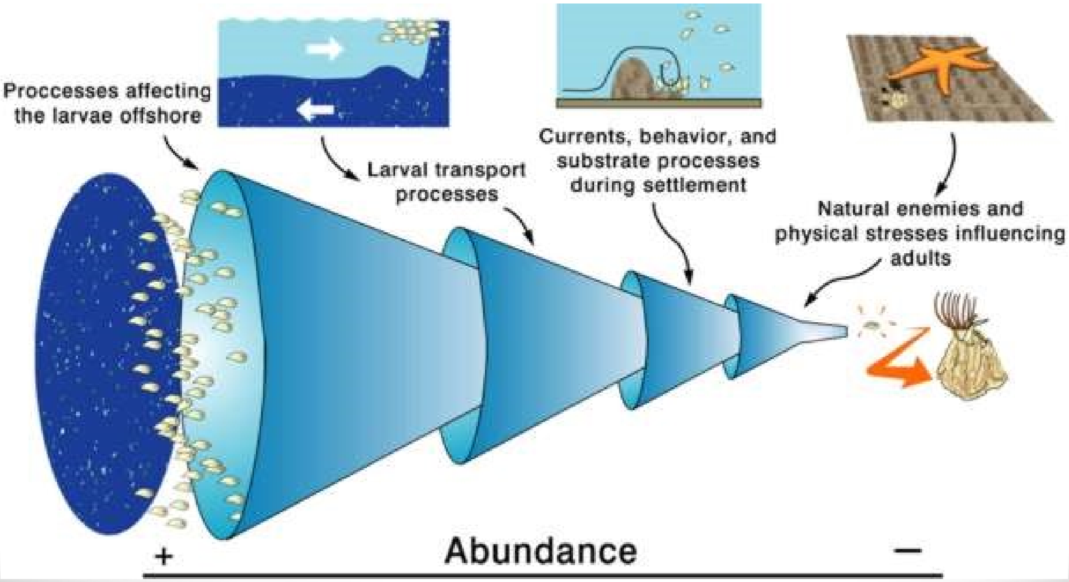
Brooke and Schroeder 2007→ Gulf of Mexico (300-500 m)

Brooke and Jarnegreen (2013) → Trondheim Fjord (40-250 m)

	NE Atlantic	Trondheim Fjord	Gulf of Mexico
Oogenesis	Starts June-August No overlapping	Starts January Cycles overlapping (1-2 months)	Starts October-November (?)
Oocyte size	August: 41.3 µm October: 88.7 µm	August: 57.8 µm October: 79.8 µm	

Potential relevant aspects in reproductive traits to feed predictive dispersal models

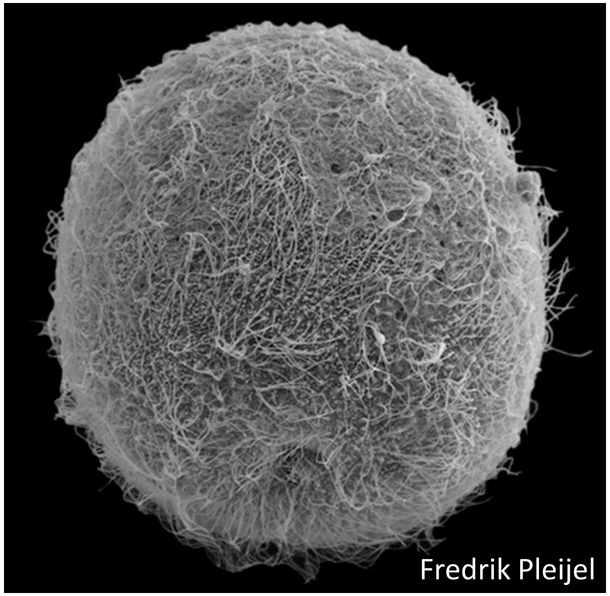
- Differences in reproductive mode: broadcaster / brooder
- Differences in reproductive timing among different regions → currents seasonality
- Reproductive output
- Propagules size an buoyancy



Pineda (1998)

Larval traits to feed predictive dispersal models

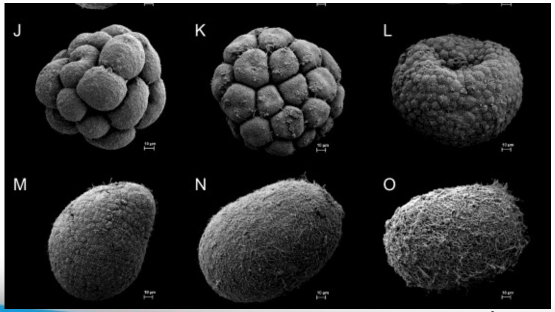
- Larval type
  - Crawling or swimming
- Larval precompetency period
- Pelagic larval duration (PLD)
  - Min, median, max
- Embryo and Larval behaviour
  - Buoyancy, vertical migration, feeding
- Mortality
  - Affects connectivity outcomes (but not max dispersal distance)



Larval precompetency period

- Time before competent to settle
- Determines the minimum period of time spent in the pelagic
- Usually shorter for brooded larvae
- A short pre-competency period will increase the proportion of larvae recruiting locally

- Brooding octocoral *Drifa sp* (4°C): Settling 1 day
- *Lophelia pertusa* (8°C): min 3 weeks (behaviour, cnidosysts)
- Facultative zooxanthellate *Oculina varicosa* (25°C): min 1 week (behaviour), settling 3 weeks
- Temperate cup coral *Caryophyllia smithii* (15°C): Settling 8 weeks



Susanna Strömberg

Sun et al. 2010
Larsson et al. 2014
Strömberg & Larsson 2017
Brooke & Young 2003
Tranter et al. 1982

Pelagic larval duration

- Min PLD = precompetency period
- Max PLD = Time after which larvae still have energy reserves to settle and metamorphose

- Brooding octocoral *Drifa sp* (4°C): up to 70 days (settling)
- Brooding octocoral *Corallium rubrum* (20°C): up to 42 days (settling)
- *Lophelia pertusa* (8°C): up to 1 year (longevity)
- Facultative zooxanthellate *Oculina varicosa* (20°C): min 42 days (longevity)
- Temperate cup coral *Caryophyllia smithii* (15°C): up to 20 weeks (settling, less food)

Sun et al. 2010, Martinez-Quintana et al. (2015), Strömberg & Larsson 2017, Brooke & Young 2005, Tranter et al. 1982

Embryo and larval behaviour

- Egg and embryo density
- Vertical migration
  - Ontogenetic, diurnal, tidal
- Feeding or not
- Onset of bottom probing

Will decide where in the water column larvae are transported during their different life phases

Lophelia pertusa

- Neutrally buoyant eggs
- Positively buoyant embryos

At 7-8°C:

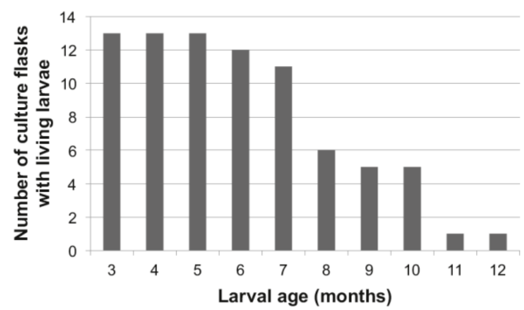
- 5 days swimming blastulae, slowly ascending
- 6-8 days, Gastrulation
- 9 days, swimming planulae
- 3 weeks, protractable mouth
- 3 weeks, cnidosysts for attachment
- 3-5 weeks: onset of bottom probing

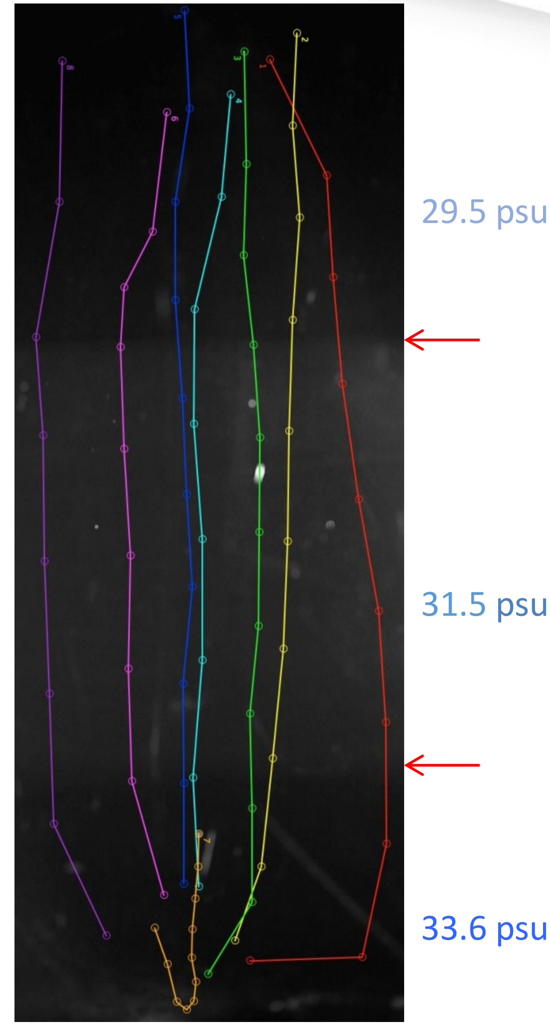
Development time is temperature dependent!

Larsson et al. 2014, Strömberg & Larsson 2017, Strömberg et al. in prep

Lophelia pertusa larval traits

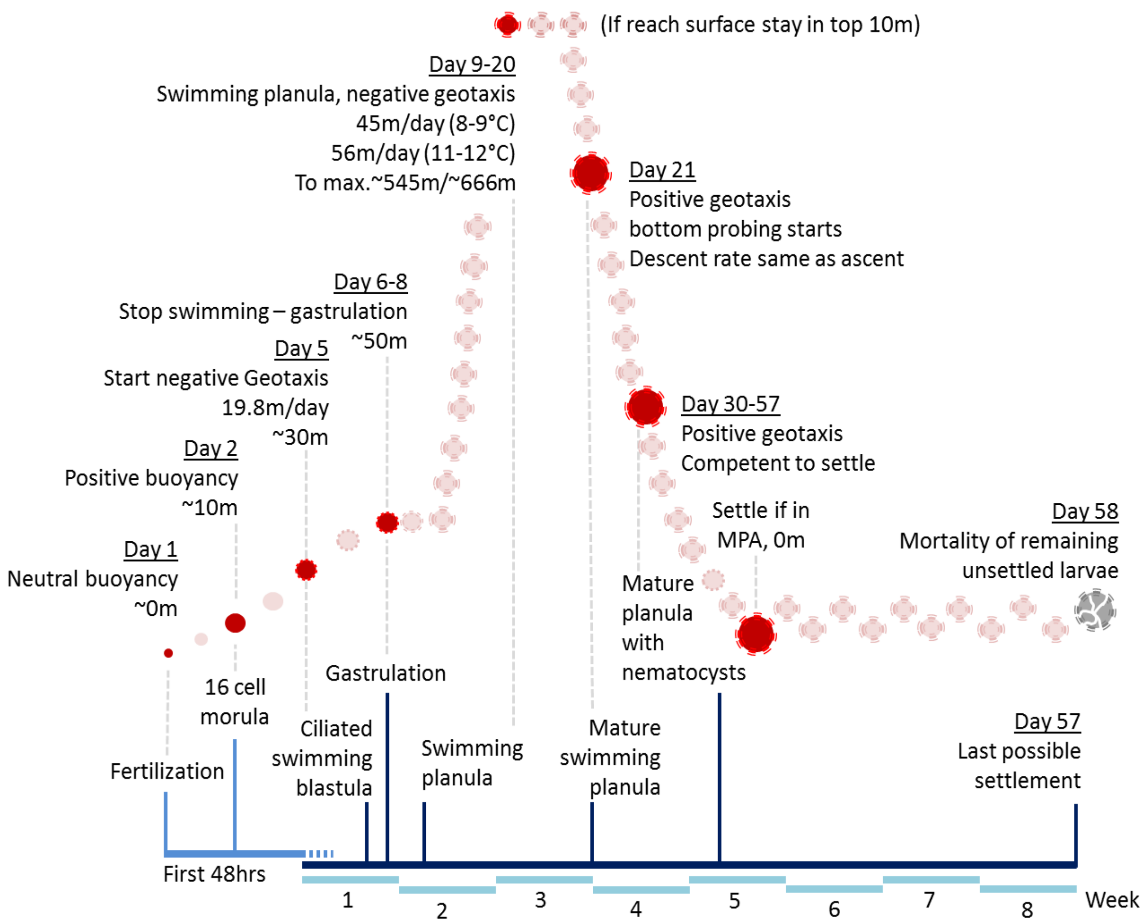
- Ontogenetic vertical migration
- Ascend 40-60 m/day for 3-5 weeks (possibly longer)
- Cross salinity gradients (max tested difference 5 psu)
- Survives for many months in 25 psu
- Feed
- 60 % of postembryonic larvae survived for 3 months
- Longevity in lab 1 year





Larsson et al. 2014, Strömberg & Larsson 2017, Strömberg et al. in prep

Vertical position “scheme”



Ross et al. 2017

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Thanks for your attention!

Image credit: DeepSeaLab, IMAR-UAz

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