Sediment impacts on coral communities: gametogenesis, spawning, recruitment and early post-recruitment survival

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Overview

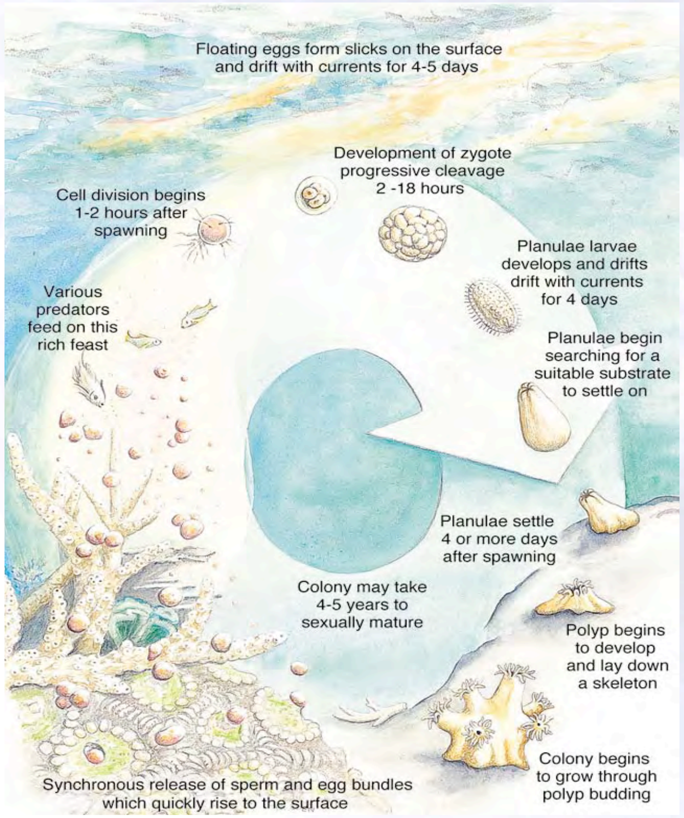
- Survival of the different early life-history stages of coral
- The impacts of sediment on each life-stage

What is the Life Cycle of a Coral (growth, survival & reproduction)?

Brooding
vs
spawning

larvae

eggs
(fecundity)



recruits

large adults

juveniles

small adults

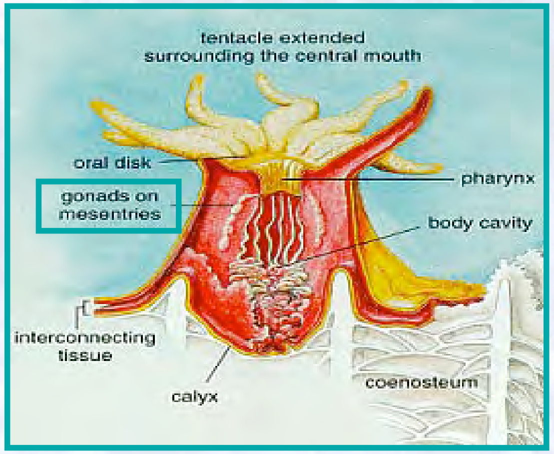
Impact of sediment on gametogenesis & fecundity

Theory: additional energy is being used for the removal of sediment (ie. mucous, polyp activity, tissue expansion) causing a reduction in fecundity

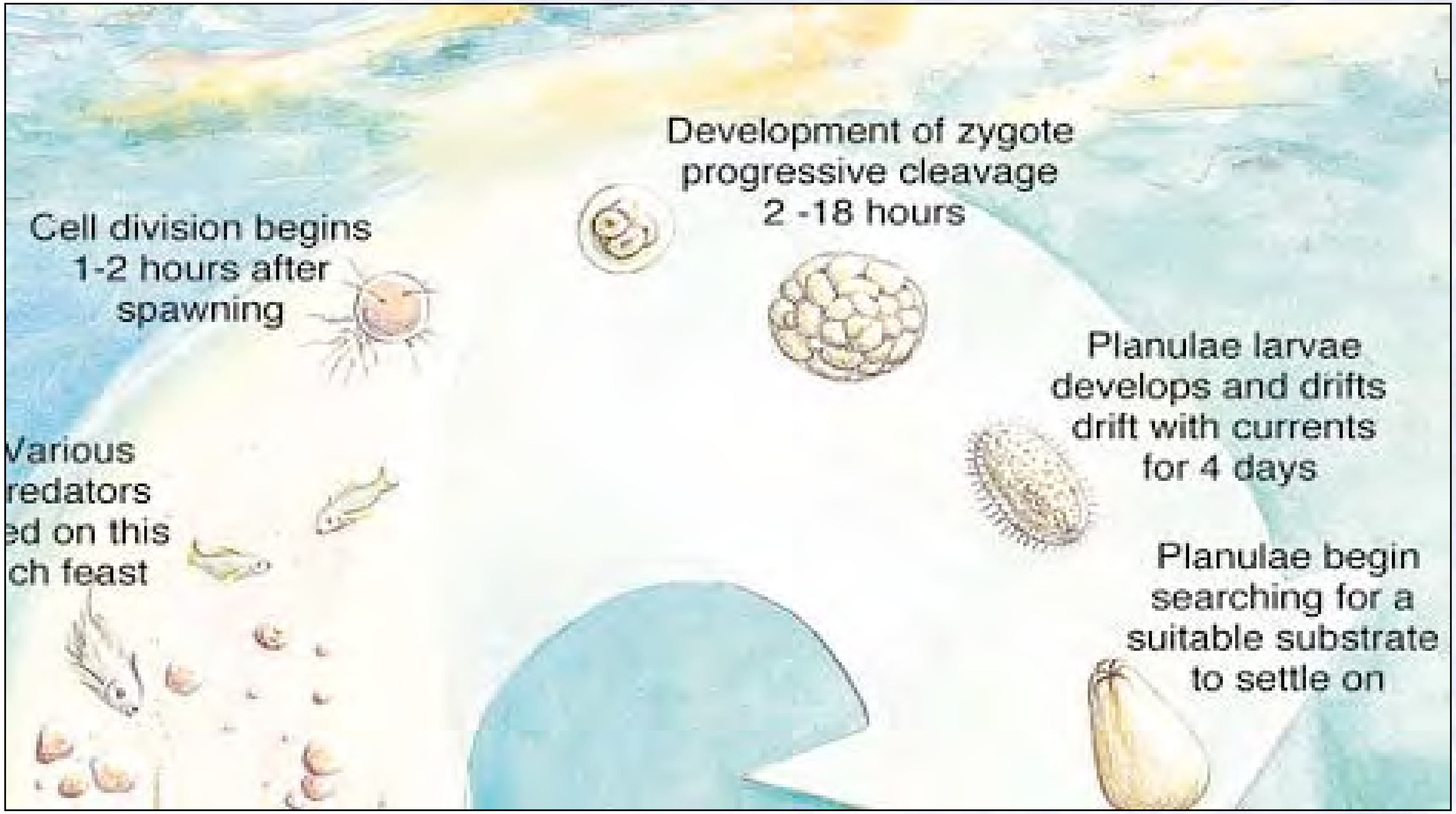
Evidence - A single study

e.g. fecundity and natural rates of sedimentation (Kojis and Quinn 1984)

High sedimentation (10 to 15 mg cm^{-2} d^{-1}), 50% decrease in fecundity
(Low sedimentation; 1 mg cm^{-2} d^{-1})

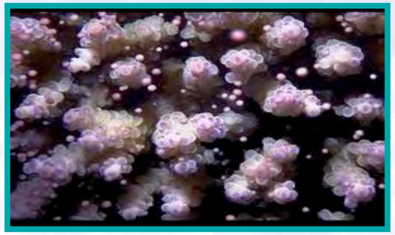


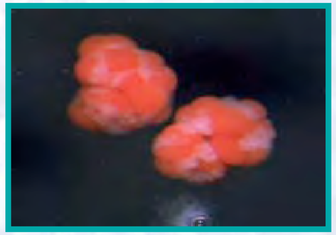
Spawning, Embryogenesis & Larval Development



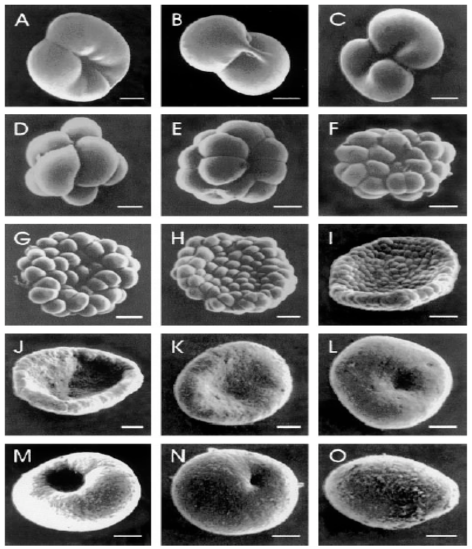
Spawning, Embryogenesis & Larval Development

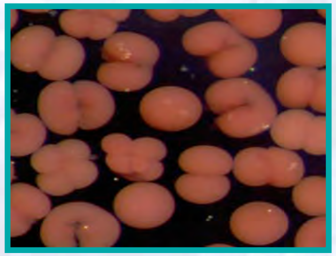
Release of gametes (spawning)





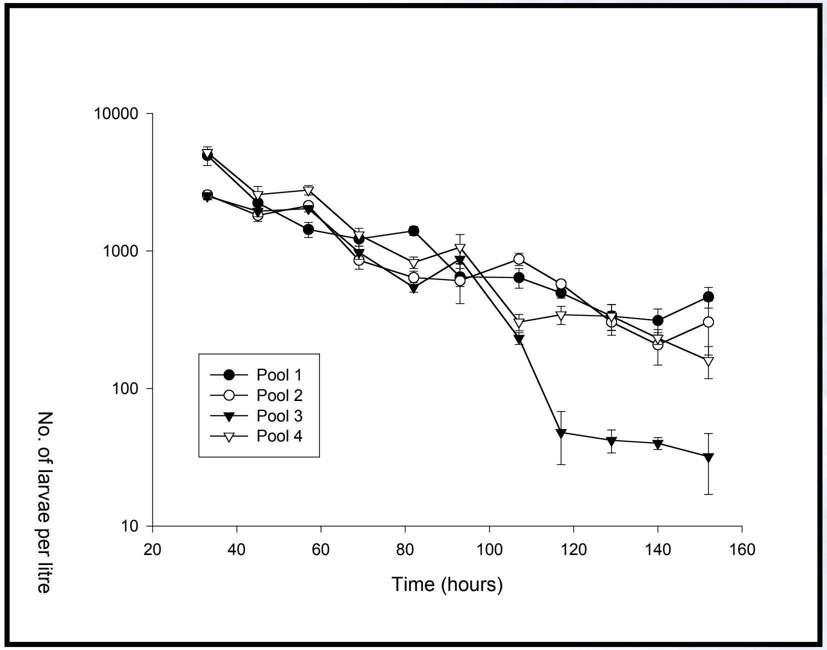
Fertilisation of eggs and gametogenesis





Larval development

Larval Survival – no turbidity



Naturally low???

6% survival after seven days in the water column

Impact of sediment on Larval Survival

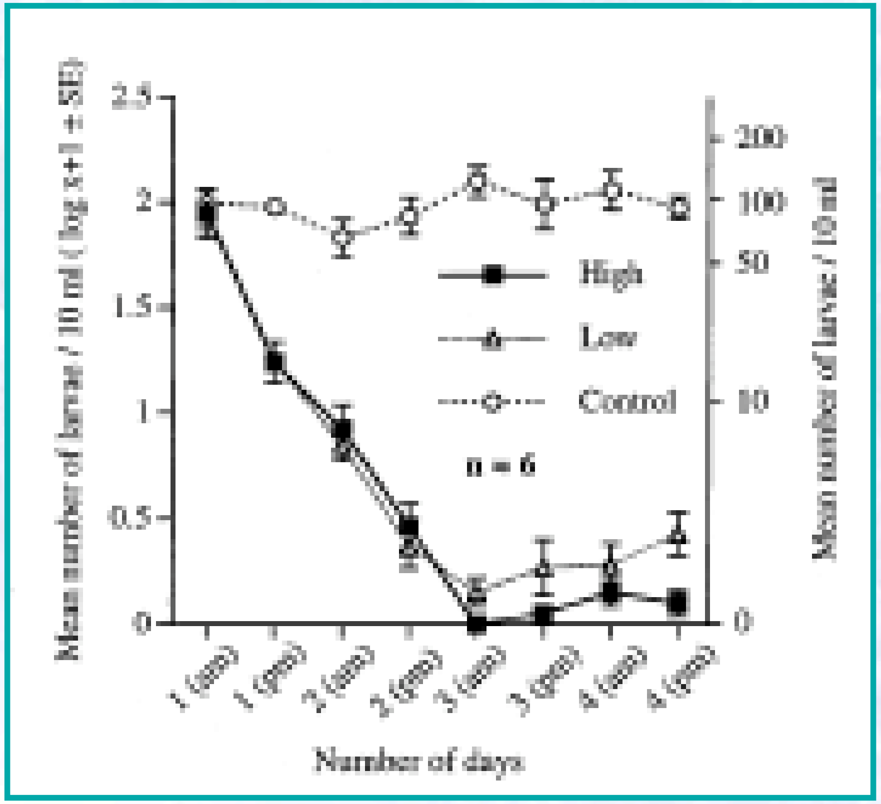
Gilmour (1999): Acropora digitifera Coral Bay, WA
(Control, 0; Low, 50; High, 100 – 150 mg cm^{-2} d^{-1} sediment loads)

Larval Survival

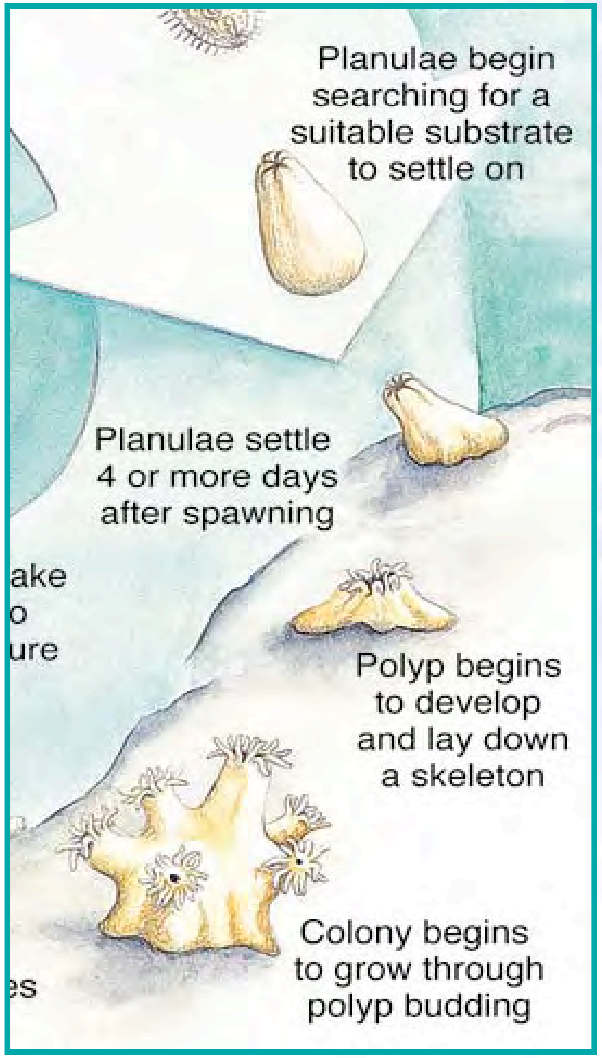
12 hr ↓ 10%

24 hr ↓ 80%

48 hr ↓ 98%



Settlement & early post-settlement survival



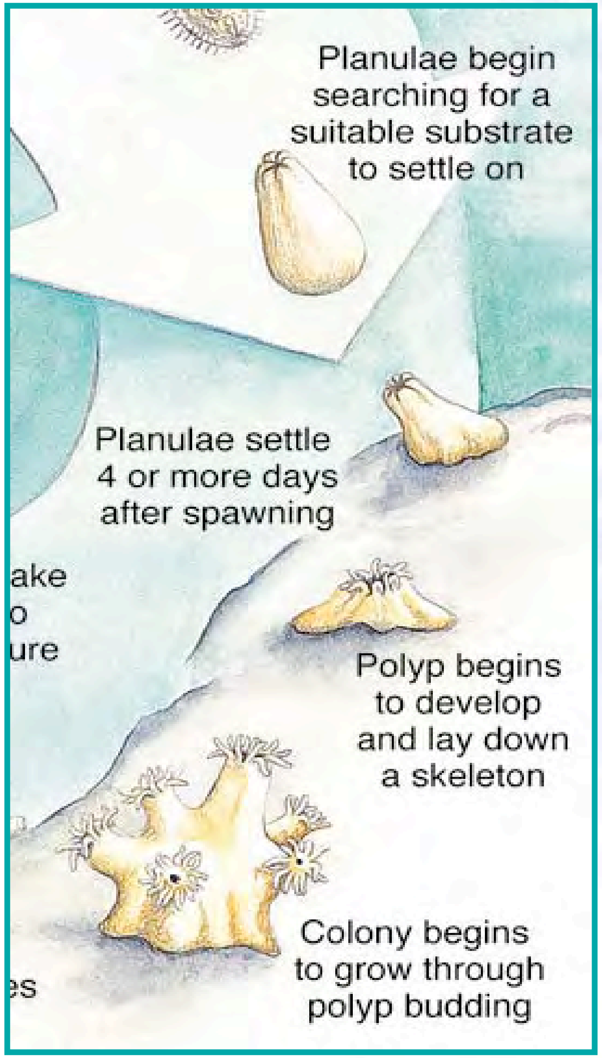
Trying to settle

Settlement & metamorphosis (< few millimetres)

Study	Sediment load	Coral	Effect
Te (1992)	0, 10, 100, 1000 mg L^{-1} (one dose, not all covered)	*P. damicornis* (brooder)	**No difference** in settlement, (reverse metamorphosis). But settlement occurred on edge of containers.
Hodgson (1990)	50% and 90% substrata covered	*P. damicornis* (brooder)	**80 – 95% reduction** in settlement, not on edge of containers.
Babcock and Smith (2000)	1 (cont), 5 mg cm^2 d^{-1} (max 15 $month^{-1}$)	*A. millepora*	**30% reduction** (most settlement on happen on undersides)
Babcock and Davies (1991)	1 (cont), 3, 6, 100-300 mg cm^2 d^{-1}	*A. millepora*	**No reduction** in settlement, **major shift** (> order of magnitude) to sides of plates with increased sedimentation*
Gilmour (1999)	0 (cont), 50, 100 mg cm^2 d^{-1}	*A. digitifera*	**> 80% reduction** in settlement (settlement on undersides)

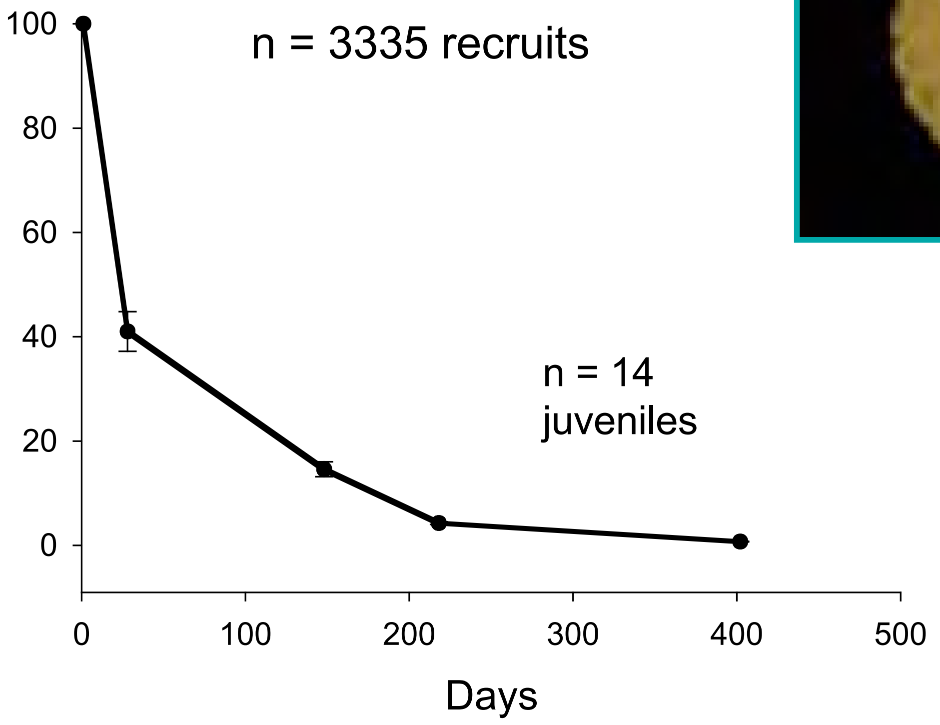
Overall: Shift in settlement preference and/or reduced settlement success

Settlement & early post-settlement survival



Trying to survive

Survival after settlement in the first 14 months (day 1 to 14 months)

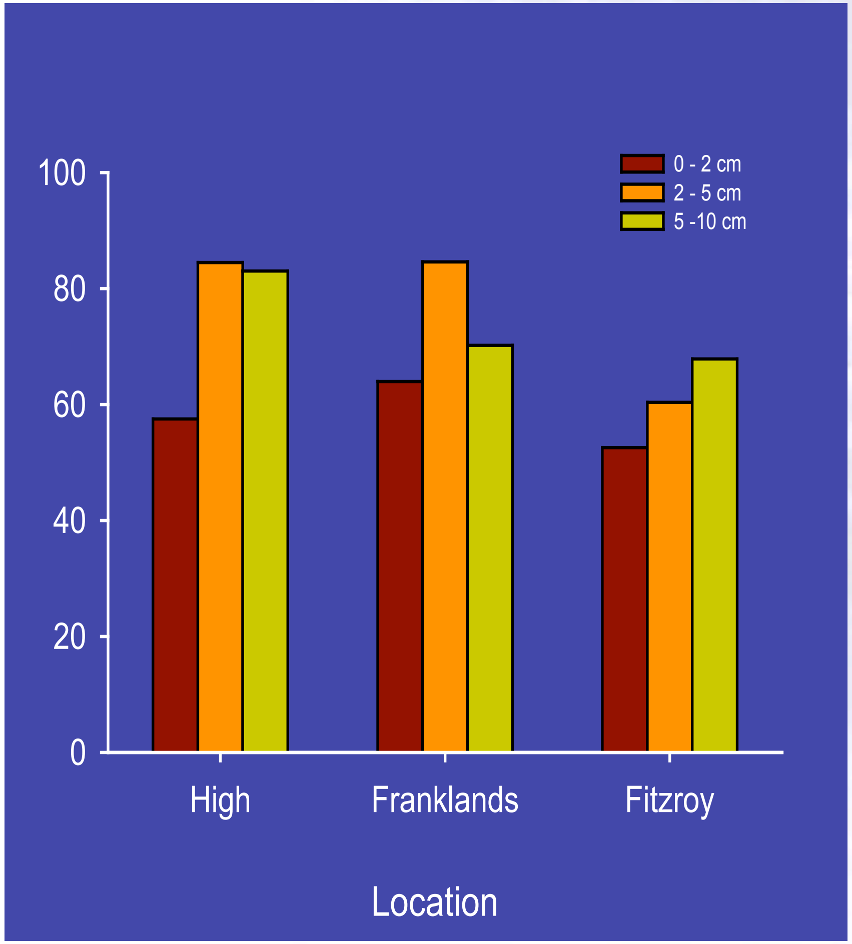


No sediment – Coral Bay

Smith (unpublished data)

→ Very Low Survival

Annual survival of juvenile acroporid corals (1-3 years old) in the Wet Tropics (North Queensland)



Smith *et al* (2005)

Impact of sedimentation on post-recruitment survival

Study	Sediment load	Age/Time	Coral	Effect (compared to controls)
Fabricius et al. (2003)	14 mg cm^2 43 hrs (7 mg cm^2 d^{-1})	1 mo	*A. willesae*	**No reduction** in survival
Babcock and Smith (2000)	1 (cont), 5 mg cm^2 d^{-1}	< 8 mo	*A. millepora*	**60% reduction**
Babcock and Mundy (1996)	few mm among turfing algae tops of plates	< 4 mo	*A. millepora*	**Order of magnitude**
Gilmour (2002)	Natural, +1, +2.5, +5 mm d^{-1} (20 d)	3 to 5 cm (3 – 5 yrs)	*F. Fungites* (sediment tolerant)	**40 – 100% reduction in survival**
Gilmour (2005)	12 versus 30 mg cm^2 d^{-1}	2 to 6 cm (2 - 6 yrs)	*F. fungites*	**18% reduction in survival** (77% versus 63%)

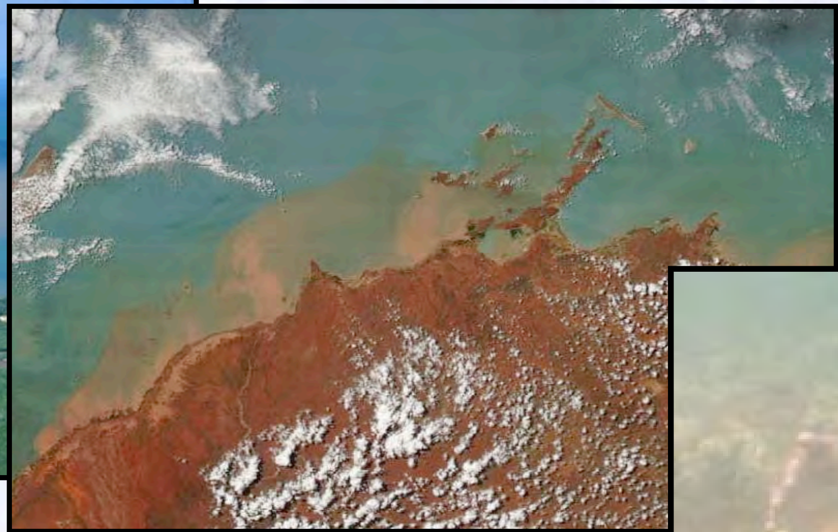
Highly variable likely to be species, size,- load and duration dependent

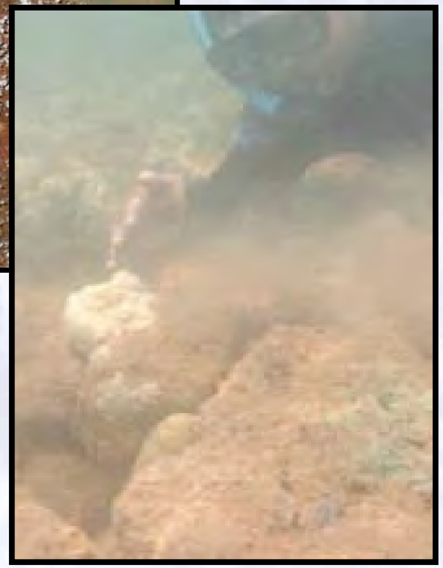
Conclusions:

Life-stage	Natural rates	Impact of Sediment	Comment
Fecundity		Single study on brooding coral indicating effect	Impact unknown?
Larval Survival	Very low (limited data)	Single study indicating dramatic effect	Likely to be an impact
Settlement and Metamorphosis	Unknown	Shift in settlement preference and/or overall reduction in settlement	Likely to be an impact
Post-settlement survival (first year)	Very Low	Minor to dramatic	Likely to be an impact
Juvenile (1-3 years)	Relatively high	Little data	Likely to be an impact

There is an energetic cost for all coral life-stages in dealing with sediment which likely leads to increased mortality rates at most stages

It can be argued that inshore coral reefs are regularly exposed to sediment deposition and turbidity from flood plumes and re-suspension





These events are an acute stress to the local coral communities causing impacts

But the stress is likely to be removed in weeks

Dredging and coral reefs

Dredging can dramatically increase turbidity and sediment deposition at local to regional (?) scales

Increasing concern about the impacts of dredging on coral communities in the Pilbara region

→ *Esp. since this stress can last months to years*

Effects of turbidity & sedimentation depend on load & duration

Heavy loads or long-term exposure can cause:

- *reduced larval survival and settlement*
- *potentially reduced growth and survival*
- *mortality*

↓

Major changes to coral communities (in the short-med term)

Conclusions:

- Lack of information on physical parameters of dredging activities vs background (ie. natural events)
  - see Stoddart & Stoddart 2004
- Need to collect data on biological impact of turbidity and sediment deposition on different life-stages (not just percent cover data)

Future directions:

- Need to learn from future dredging programs through the collection of physical and biological data

- These data can then be used to provide industry and regulators with better information to manage future dredging programs

- Need to start to collect quantitative data on impact of sediment on different life-history stages of corals

Question time

Simpson – Are WA coral reefs (esp Dampier) more at risk from stress imposed during the Autumn reproductive period because they have just completed the Summer where temperatures are high and winds stronger leading to increased sedimentation?	Smith – That's not clear. GBR inshore reefs are subject to substantially more runoff and fishing pressure than WA reefs – so it is not simple.
Oliver – There is a lot of data collected from historic studies at Dampier. Can't we use that?	Smith – I'm not sure whether the data available has been collected in a form that allows it to be used to answer today's questions.
Sim – In your work on cross-shelf comparisons, did you find consistent differences in vulnerability to sediment impacts – with respect to your relationship between sediment load-duration and stress?	Smith – It is likely that the main effect of sediment adapted corals would be to raise the level of sediment required to produce the same stress level by a constant factor.
Metaxis – It seems as if there are specific phases of the life cycle which may be bottlenecks, Management should target those bottlenecks to provide the best outcome for the shortest time.	Smith – We don't yet have enough information to determine whether a specific part of the life cycle is a bottleneck for all cases. Costen – Shutting down dredging immediately before some sensitive stage of the life cycle may not lower turbidity to natural levels during the event as plumes may remain in the area for some time post-shutdown.
Stoddart – The relationship between sediment load-by-duration and stress may be linear for energy cost but it is more likely to have a specific threshold effect for mortality.	Smith – That may be so.
Simpson – Can we pick up the issue of what triggers should be used for management and what criteria might be measured fro success in the Scenario discussions?	