Combining and projecting the consequences of sedimentation for coral communities

What we do know
What we don't know
What we need to know

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Reduced larval survival

Reduced recruitment

The Life Cycle
(growth, survival and reproduction)

↓

Vital Rates
(rates of movement through life cycle)

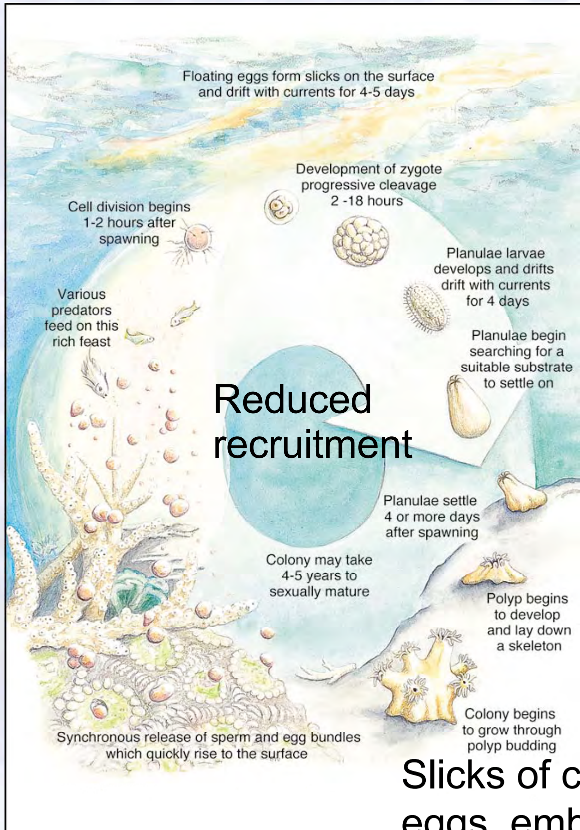
↓

Stage-Frequency Distributions
(numbers in size/stage classes)

↓

Percentage Cover

Sexual reproduction (spawning)



Reduced recruitment

larvae
< 1mm

recruits
< 10mm

eggs
(fecundity)

large adults
> 300mm

Slicks of coral spawn:
eggs, embryos, larvae

juveniles
< 80mm

small adults
80 to 300mm

Do anthropogenic increases in sedimentation affect coral communities?

YES...

How much do they affect coral communities
- now and in the future?

Do not know - well it all depends

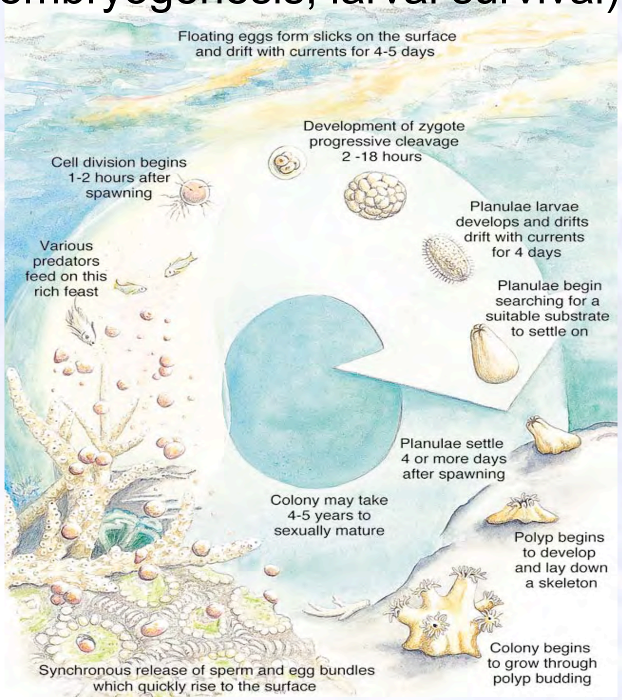
What is the evidence for the different life history stages?

LOAD and DURATION

Transitions among stages
(growth and survival)

Natural disturbances
Human disturbances
Natural and Human

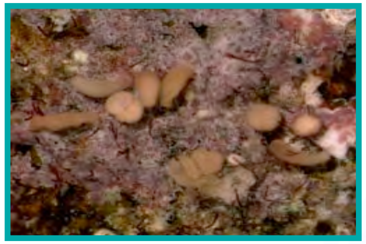
recruitment = fecundity x survival (fertilisation, embryogenesis, larval survival)

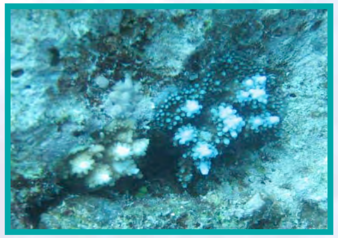


Adults
(small, med., large)

Recruitment

Juveniles (small, med., large)





VITAL RATES

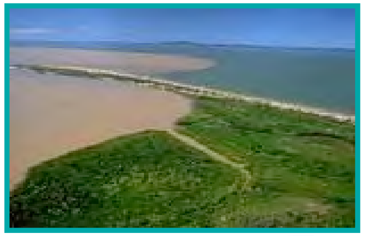
Transition among life history stages

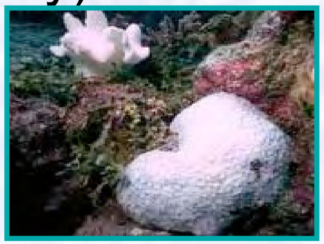
Before, during and after the impact

PHYSICAL PARAMETERS OF INTEREST

Natural (e.g. wind, waves, temperature)

Human (sedimentation, turbidity)

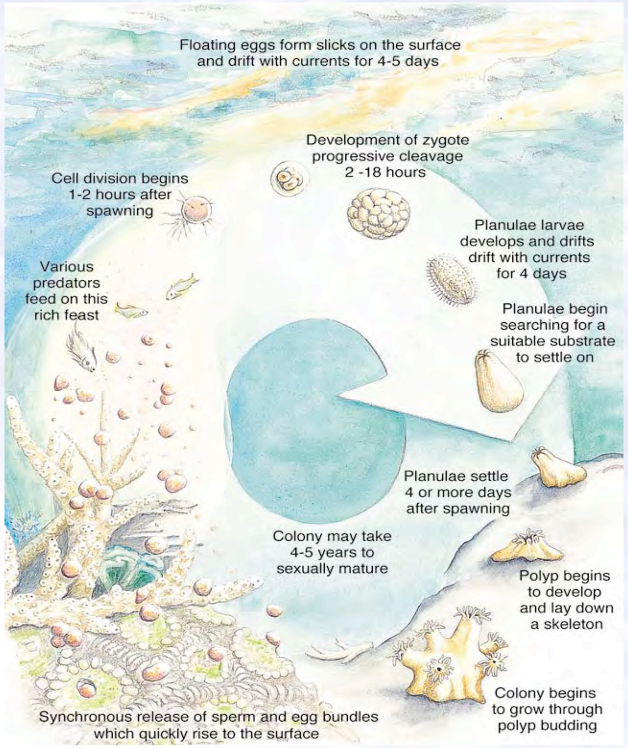




Transitions among stages (growth and survival)

Turbidity and sedimentation

recruitment = fecundity x survival (fertilisation, embryogenesis, larval survival)

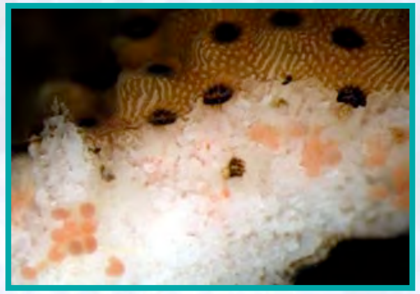


Adults
(small, med., large)

Recruitment

Juveniles (small, med., large)

RECRUITMENT:
A) Fecundity



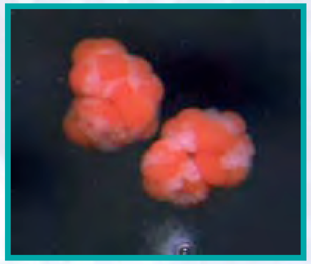
Sedimentation:
chronic exposure (10-15 mg cm^{-2} d^{-1}) 50% decrease (Kojis and Quinn 1984)

Variety of stressors reduce fecundity, and severe stress causes:
major reductions (50 – 100 %)
for more than one year (Michalek-Wagner and Willis 2001, Ward et al. 2001)

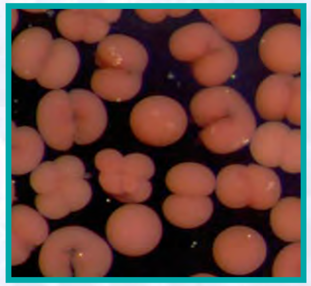
reduce size of maturity and adult size (injury)

Consider 20% and 40% reduction

RECRUITMENT: B) Fertilisation & embryogenesis



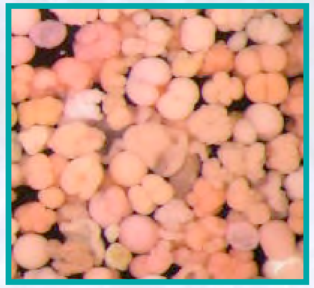
Sedimentation:
Experiment (50 and 100 mg l^{-1}; Gilmour 1999)



Fertilisation 50% reduction

Consider

25% & 50% reduction



RECRUITMENT: C) Larval survival

10% reduction 12 hr
80% reduction 24 hr
98% reduction 48 hr

25% & 50% reduction

RECRUITMENT: D) Settlement & metamorphosis

Te (1992), Hodgson (1990), Gilmour (1999), Babcock and Davies (1991), Babcock and Smith (2000)

0%, 0%, 30%, > 80%, >80% reduction in settlement

Sediment excludes larvae

Select alternate sites- provided alternates exist

Experiments- similar area horizontal (top), horizontal (underside), sides

Consider
15% and 30% reduction

Sedimentation and coral reproduction

consider: moderate and severe effects from 6 months dredging

Recruitment (f_x) = fecundity (m_x) survival (p_o)

Relative proportion (control)

Stage / transition	Moderate	Severe
Fecundity	0.80	0.60
Fertilisation	0.75	0.50
Larval survival	0.75	0.50
Settlement	0.85	0.70

Recruitment = 1.00 m^2 yr^{-1} (Connell 1973, Bothwell 1984, Gilmour 2005)
Moderate = 0.38 m^2 yr^{-1}
Severe = 0.11 m^2 yr^{-1}
(Babcock = 0.25 m^2 yr^{-1} for 5 mg cm^2 d^{-1})

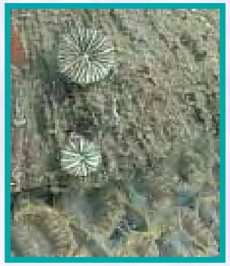
EARLY POST-RECRUITMENT SURVIVAL

(5 mg cm^2 d^{-1} for 8 months; Babcock and Smith 2000)
40% reduction (highly variable, all underside plates)

(30 mg cm^2 d^{-1} annual: Gilmour 2005)
Recruits (0.3 to 2cm) 80% reduction

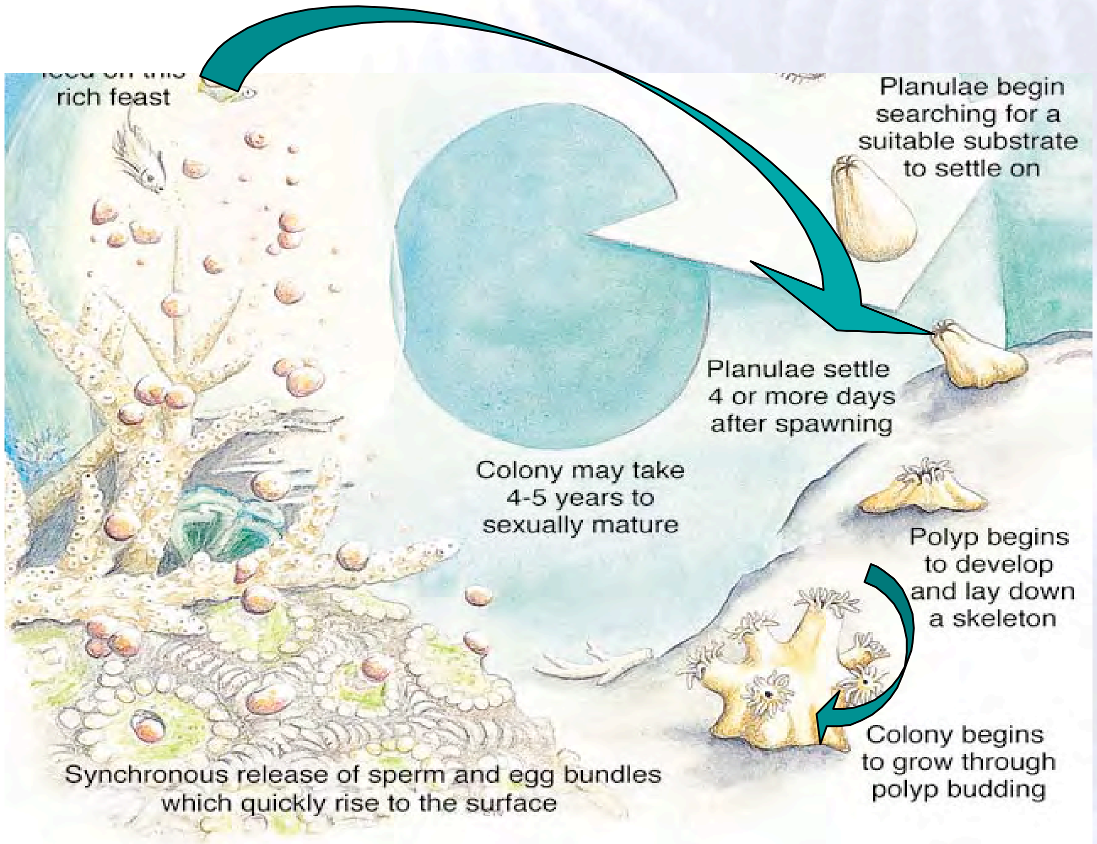
12 versus 30 mg cm^2 d^{-1} annual
Juveniles (2 to 6 cm) 28% reduction (70 versus 49% yr^{-1})

Much qualitative and anecdotal evidence of lower rates of survival of juveniles with increased sedimentation
(load – duration – size)



Consider
20% and 40% reduction year 1
15% and 25% reduction juveniles

Sedimentation and the life cycle



control, moderate, severe

recruitment

1.00, 0.38, 0.11 m^2 yr^{-1}

survival (yr 1)

0.010, 0.008, 0.006 yr^{-1}

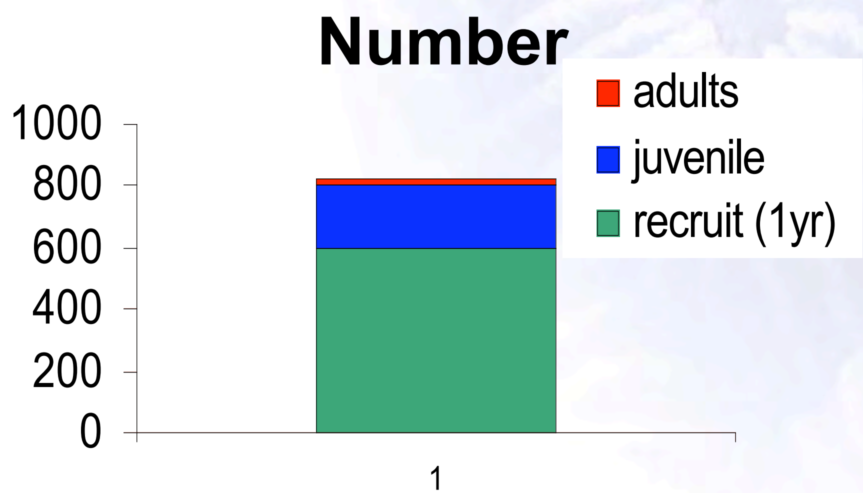
Survival (juvenile)

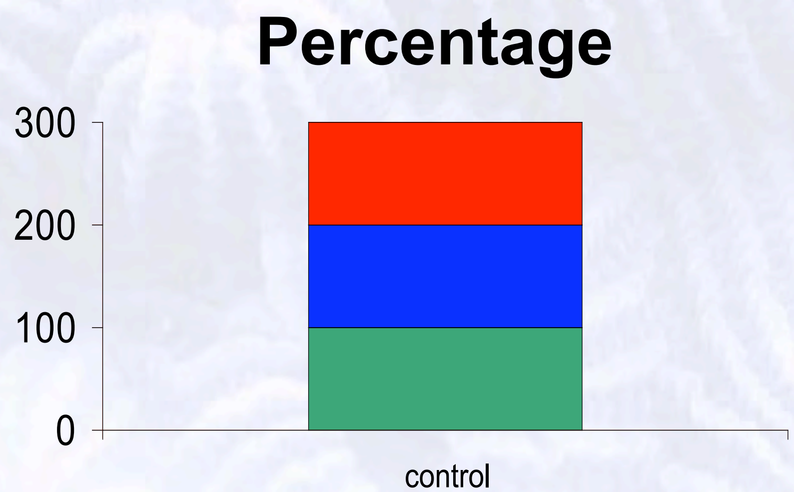
ADULTS ←

0.75 yr^{-1} (0.6 and 0.15) 0.63 yr^{-1} (0.50 and 0.13) 0.56 yr^{-1} (0.45 and 0.11)

Sedimentation & coral population growth rates

(NO adult impacts)
Population growth rates (1 = stable, 0.5 = half, 2 = double)
Control = 1 (stable population)
Moderate = 0.85 yr^{-1}
Severe = 0.75 yr^{-1}

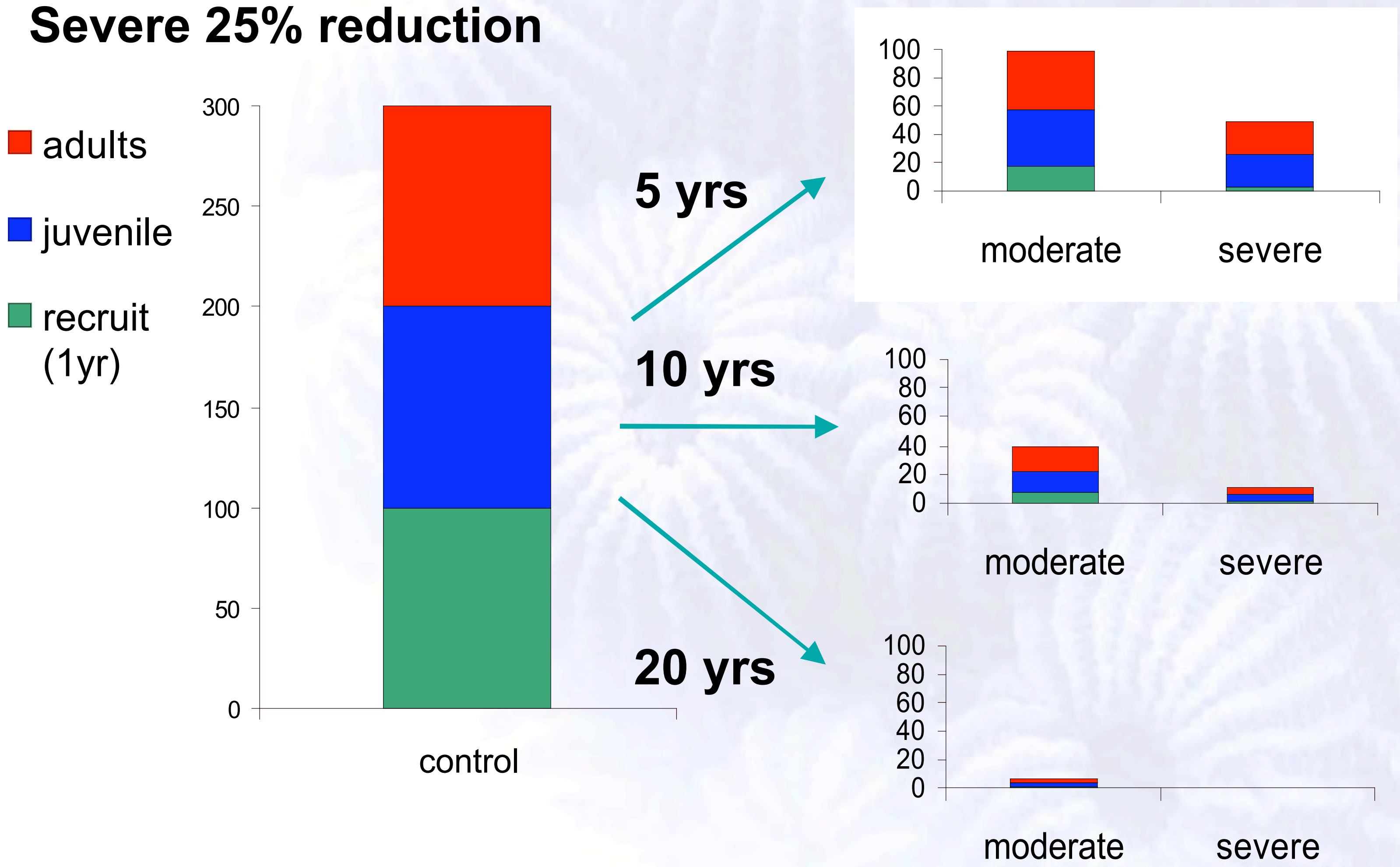




Control population ($10m^2$)

Moderate 15% reduction
Severe 25% reduction

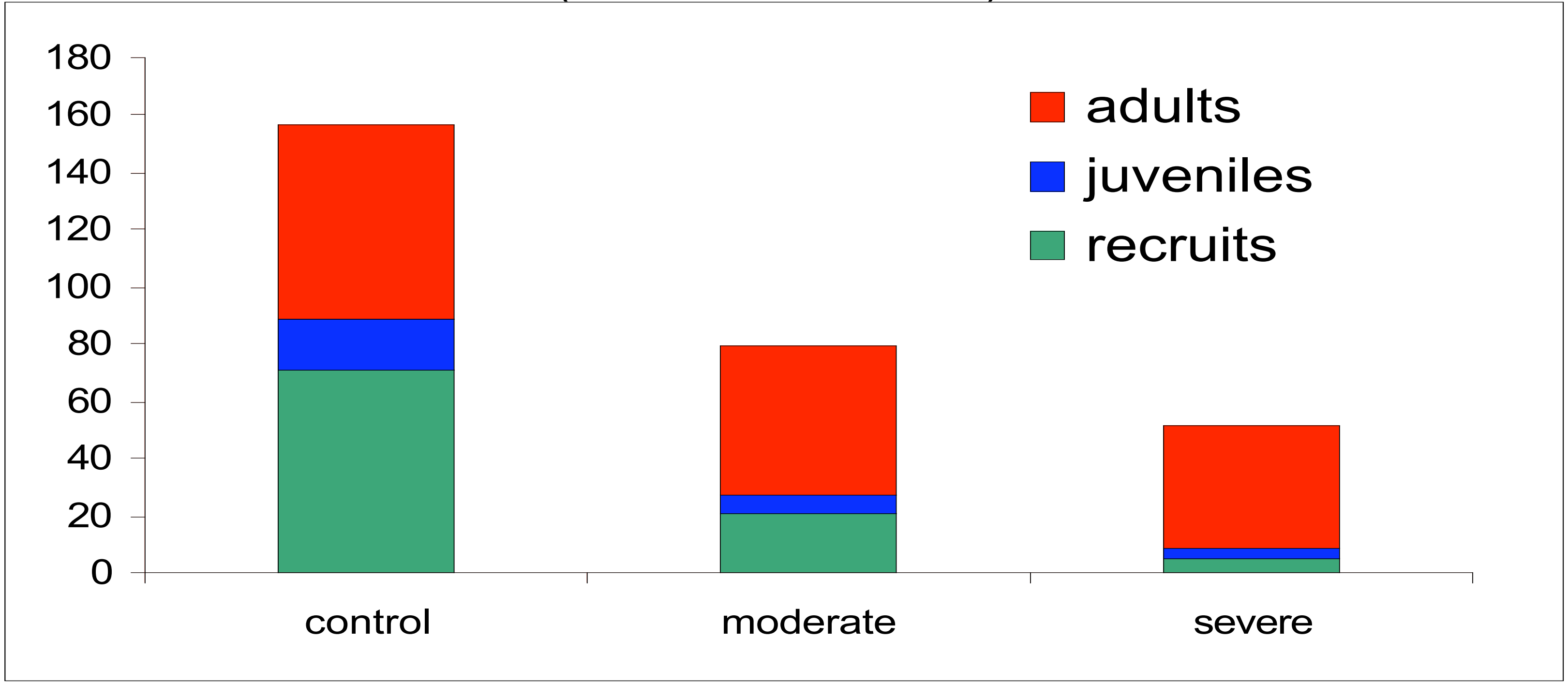
Percentage of control population size



LOAD – DURATION – SIZE – FREQUENCY

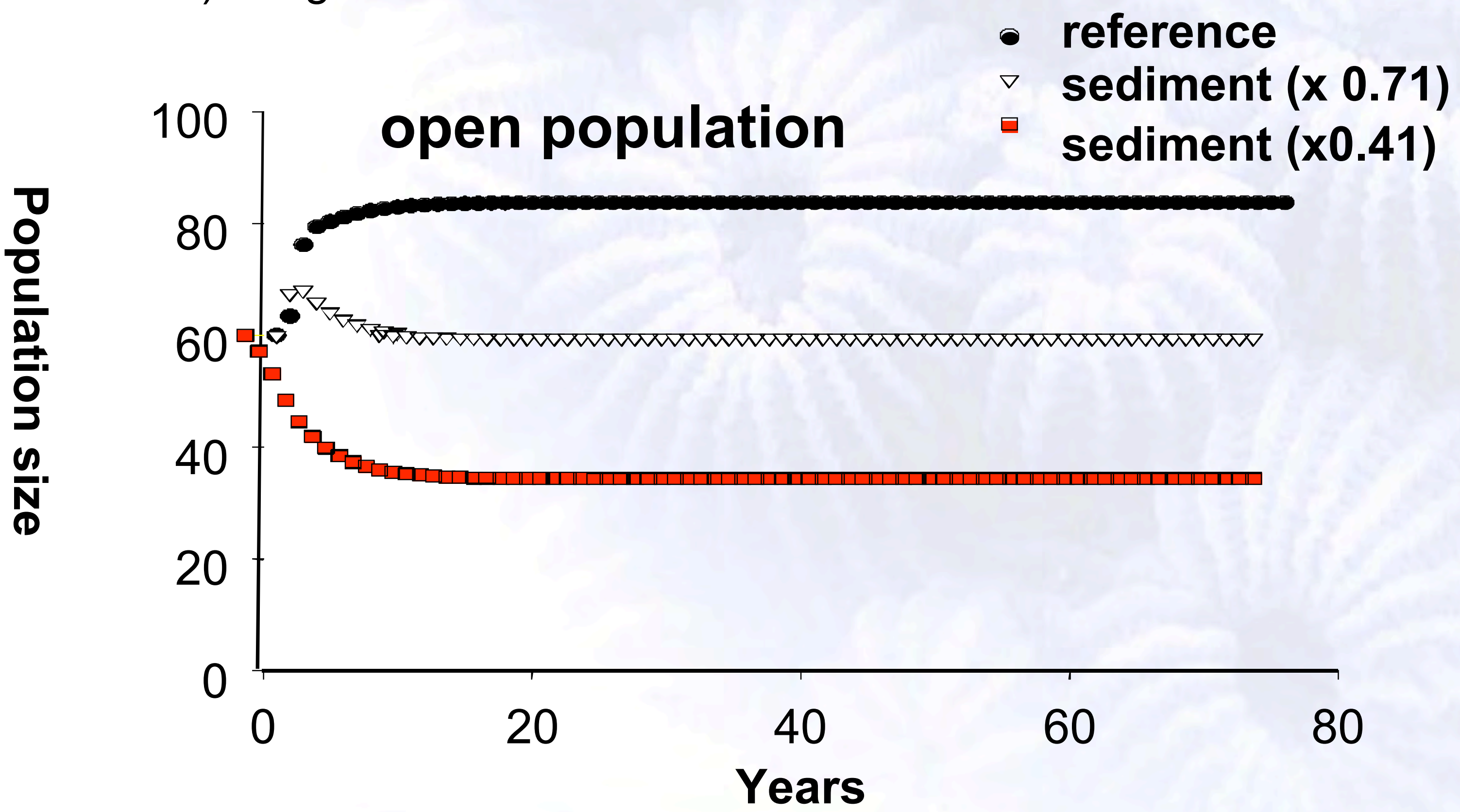
Size: effects on Adults are critical (large adults produce most sexual recruits, survive the longest-highest elasticities)

Changes in population size and structure following 5 years of exposure (NO effect on adults)



A.millepora (Babcock)

1) reduced settlement only (0.71 and 0.41)
2) open population
3) no effect on fecundity, post-settlement survival, or growth and survival of juveniles or adults
4) 5 mg cm^2 d^{-1}



LOAD – DURATION – SIZE – FREQUENCY

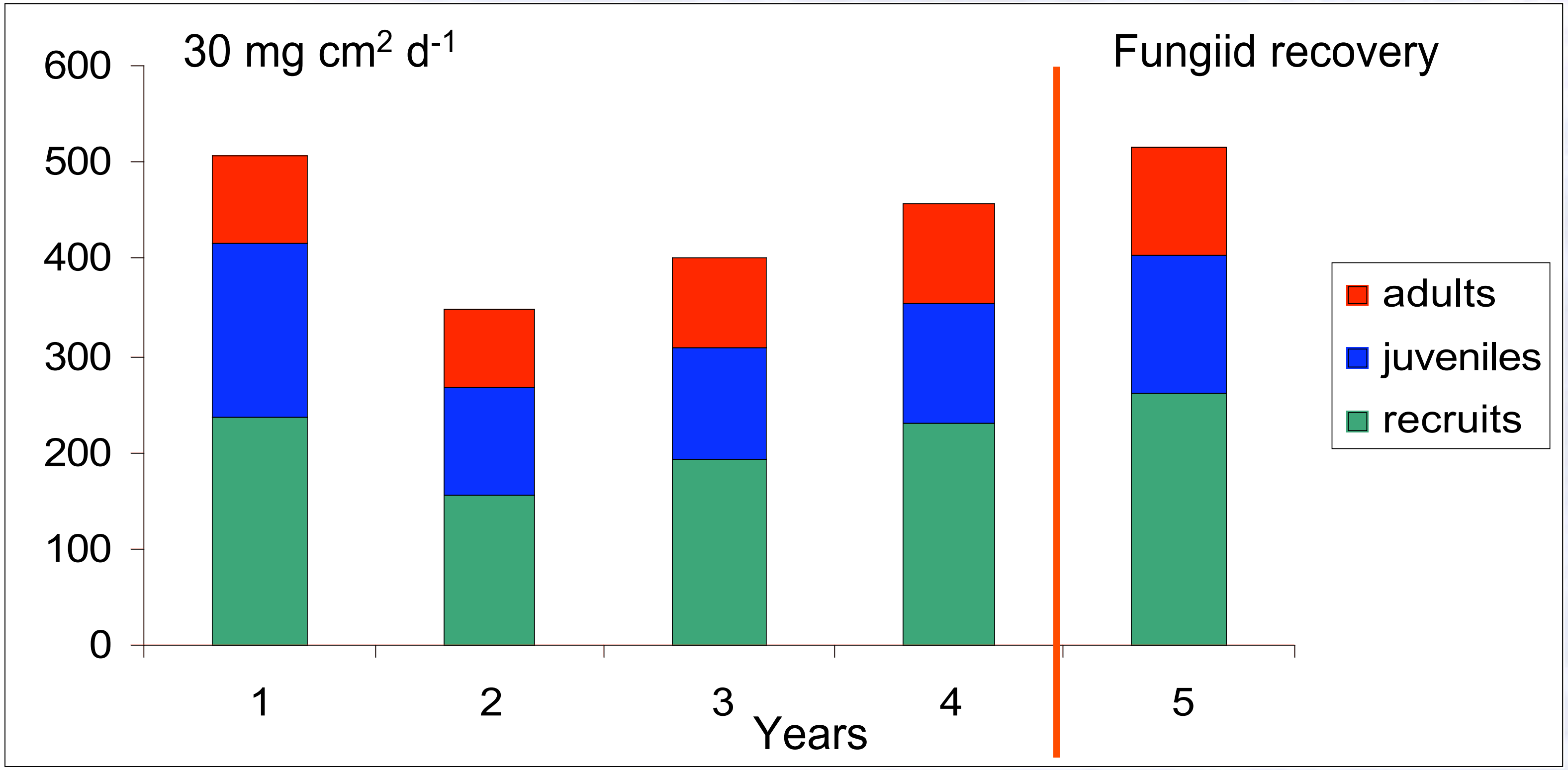
Size: effects on Adults are critical

Consider Fungiid populations: year with no major impacts other than differences in sedimentation rates (Gilmour et al. 2006)

12 mg cm^2 d^{-1}	30 mg cm^2 d^{-1}
1.12 growth rate	0.93 growth rate

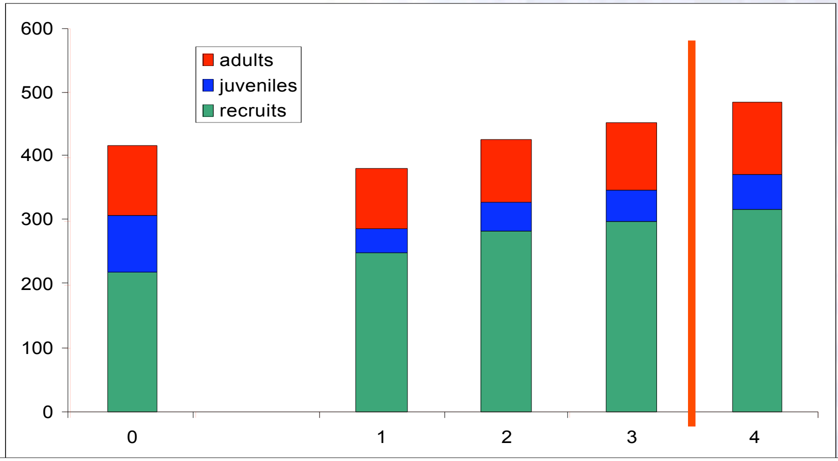
LOAD – DURATION – SIZE – FREQUENCY

Frequency: how often is the impact occurring and how long will the population take to recover?

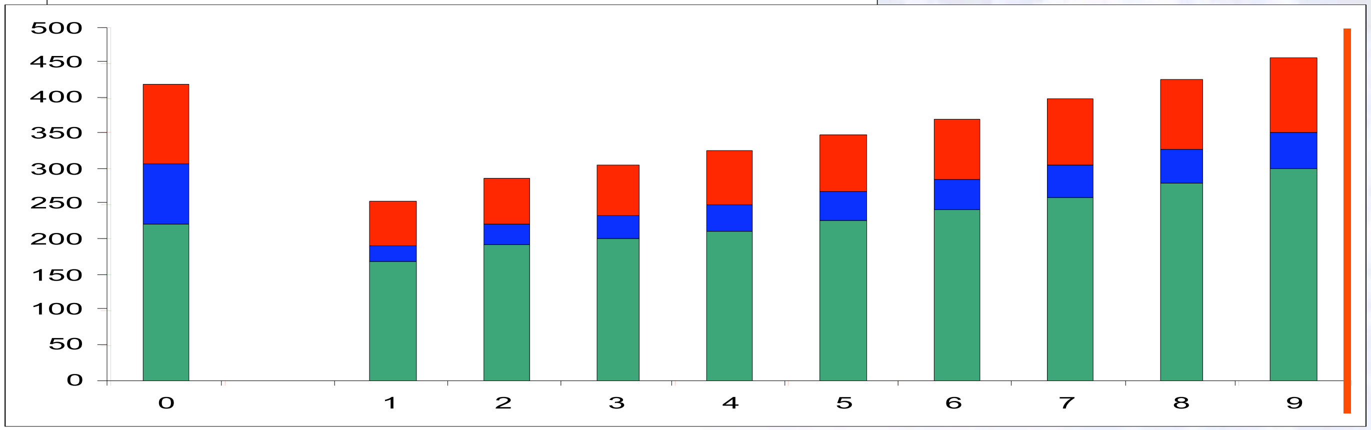


LOAD – DURATION – SIZE – FREQUENCY

Experimental decreases in recruitment and early post-recruitment survival (with relative adult effects from Gilmour 2005)



Moderate- 4yrs

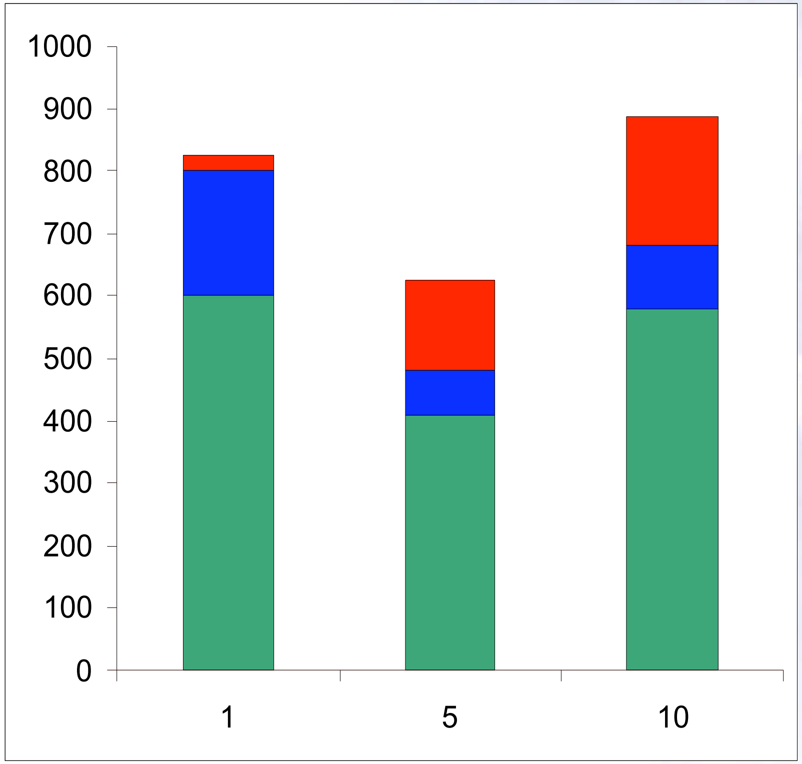


Severe- 9yrs

Years

LOAD – DURATION – SIZE – FREQUENCY

Experimental decreases in recruitment and early post-recruitment survival (with relative adult effects from Gilmour 2005)



Moderate- 4yrs
Severe- 9yrs

For population with growth rate of 1.07 yr^{-1}

Growth rates (yr) for fungiids in Pilbara

high sediment / disturbance: 0.77 to 0.98

low sediment / disturbance: 0.98 to 1.07

LOAD – DURATION – SIZE – FREQUENCY

Experimental decreases in recruitment and early post-recruitment survival (with relative adult effects from Gilmour 2005)

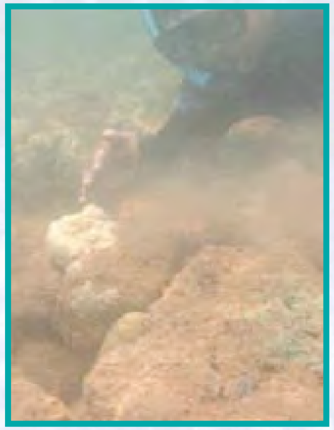
Annual population growth rate and frequency of sedimentation disturbance (relative decrease)

	$1yr^{-1}$	$3yr^{-1}$	$5yr^{-1}$	$10yr^{-1}$
	1.07			
Moderate	0.96 (10%)	1.02 (5%)	1.04 (3%)	1.06 (1%)
Severe	0.90 (15%)	0.97 (9%)	1.01 (6%)	1.40 (3%)

How much does elevated sedimentation affect coral communities- now and in the future?

Do not know - well it all depends

What we know (little) and what we need to know



VITAL RATES
Transition among life history stages

PHYSICAL PARAMETERS OF INTEREST
Natural (e.g. wind, waves, temperature)
Human (sedimentation, turbidity)

LOAD – DURATION – SIZE – FREQUENCY - TYPE

Question time

Oliver – Corals in the Dampier Harbour receive regular challenges from high sediments and waves during cyclone are these similar to short term dredging impacts?	Gilmour – The key factor is load x duration of sediment or other impact. Cyclones are generally of short duration so are not necessarily the same impact as dredging. If dredging occurs adjacent to a cyclone it may add to the load or duration of that. Simpson – cyclones generally cause effects for about 1 week duration. Dredging plumes can last much longer. Costen – Abnormal events like cyclones should not form part of the 'natural background' assessment.
Masini – The frequency of dredging needs to consider all projects in an area. Dampier has had a dredging program most years since 2002.	
Metaxis – The timing of a disturbance or control event can be critical. Would it be better to time dredging for periods of strong water motion or calms?	Gilmour – It may be best to dredge during winter to avoid any stress from high water temperatures or storms. However, the high energy conditions that suspend sediments may also act to clear sediments from corals so this needs some thought.