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Review

Effects of sediments on the reproductive cycle of corals

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ABSTRACT

Dredging, river plumes and natural resuspension events can release sediments into the water column where they exert a range of effects on underlying communities. In this review we examine possible cause–effect pathways whereby light reduction, elevated suspended sediments and sediment deposition could affect the reproductive cycle and early life histories of corals. The majority of reported or likely effects (30+) were negative, including a suite of previously unrecognized effects on gametes. The length of each phase of the life-cycle was also examined together with analysis of water quality conditions that can occur during a dredging project over equivalent durations, providing a range of environmentally relevant exposure scenarios for future testing. The review emphasizes the need to: (a) accurately quantify exposure conditions, (b) identify the mechanism of any effects in future studies, and (c) recognize the close interlinking of proximate factors which could confound interpretation of studies.

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1. Introduction

Natural resuspension events, terrestrial run-off and dredging-related activities can temporarily increase suspended sediment concentrations (SSCs) in the water column. The effects of suspended sediments on adult corals are well known (Erftemeijer et al., 2012a; Rogers, 1990) but nevertheless constitute only part of the demographic equation (Hughes et al., 2000, 2011). The sensitivity of the early life-history stages of corals has also been recognized for over a century (Stephenson, 1931; Wood-Jones, 1910), but even before fertilization, embryogenesis and the establishment of the sessile, and benthic juvenile form, sediments could exert a range of effects on the reproductive cycle including gametogenesis, spawning synchrony and on gametes in the water column.

This review examines the effects of turbidity on all aspects of the coral life cycle of corals from gamete development to the early post-settlement stage. The focus is on the effects of sediments on broadcast spawning species which usually dominate the tropical coral reef environment. Their life cycle is complex involving gametogenesis, reproductive synchronization, fertilization at the surface and larval development in the water column, leading finally to settlement and metamorphosis into a sessile polyp. Their life-cycle is stylized in Fig. 1 and based on *Acropora* spp.

Natural resuspension events regularly occur in the shallow, tropical marine environment (Anthony et al., 2004) and although resuspension and transport of suspended material may be strongly influenced by unidirectional currents, wind-driven waves are the primary mechanism of turbidity generation in the shallow reef environment (Jing and Ridd, 1996; Larcombe et al., 1995, 2001; Lawrence et al., 2004; Ogston et al., 2004; Verspecht and Pattiaratchi, 2010). In the shallow inshore turbid zone of the Great Barrier Reef, resuspension of bottom sediment by waves affects coral communities on an estimated 110 days year^{-1} (Orpin et al., 1999). During predicted coral spawning periods wind speeds have averaged 8–10 m s^{-1} (or 15–20 knots) on six out of eleven years from 2000–2010 (AIMS, 2011). At these wind speeds natural resuspension and wind-wave induced turbidity would occur in the inshore turbid zones (Larcombe et al., 1995; Orpin et al., 2004; Orpin and Ridd, 2012) with possible implications for spawning and recruitment success of local corals.

In addition to natural events, anthropogenic activities can also release sediment into the water column, and dredging and disposal of dredged material (spoil) are the most well-known sources and are also the most amenable to management. In recognition of the sensitivity of the early life-cycle stages of corals, and since reproduction and recruitment processes underpin the maintenance and resilience of communities to disturbance, policy makers have attempted to protect coral spawning periods from sediments generated by dredging-related activities. Since 1993 dredging projects in Western Australia that are close to reefs are required to temporarily stop when corals are spawning (Baird et al., 2011; EPA, 2011). This regulatory condition is currently set as 5 days before spawning to 7 days afterwards. This is referred to as the coral spawning environmental window (EW) and is associated with the well-known synchronous, multi-specific release of gametes by broadcasting spawning coral species that can occur in WA in single epidemic events of relatively short duration (EPA, 2011; Simpson, 1985; Styan and Rosser, 2012). Unfavorable conditions during a spawning period could result in loss of the entire reproductive output for the year (Harrison et al., 1984). This management approach has also been adopted

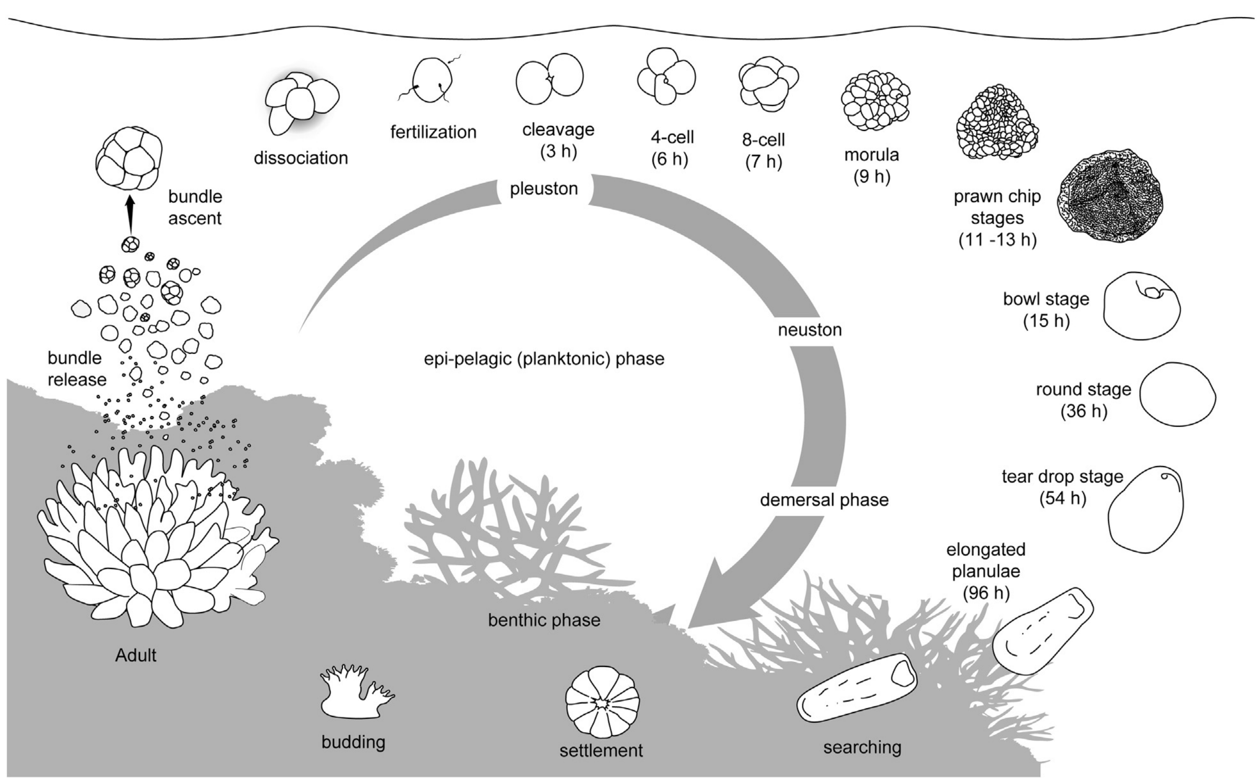

Fig. 1. A stylized depiction of the reproductive cycle of the broadcast spawning *Acropora* species with indicative timings based on the studies of Hayashibara et al. (1997), Okubo and Motokawa (2007), Okubo et al. (2008) and Ball et al. (2002). The cycle begins and ends with gametogenesis in the adult colonies on the reef, but in between there are a complex sequence of phases which are spatially and temporally separated. Spawning occurs through the release of positively buoyant membrane-less, mucous bound egg and sperm bundles which dissociate at the surface and upper water column releasing the eggs and sperm. Fertilization occurs at the surface and upper water column where the initial stages of embryogenesis occur. Cleavage takes place by progressive furrow formation and the embryos of most *Acropora* species undergo an relatively unordered, irregular division cycle after the 8-cell stage eventually and after the morula stage becomes a convex-concave cellular bi-layer stage (the prawn-chip stage sensu Hayashibara et al., 1997) then bowl stage. The embryos then fatten to become a roughly spherical shape and by 36 h develop cilia over the epidermis, which beat synchronously imparting mobility to the planulae larvae. The larvae then become progressively elongated and begin searching substrata and eventually settle and undergo metamorphosis into juvenile polyps.