BIOLOGICAL DYNAMICS OF CORAL REEFS

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Summary

Coral reefs are characterized with high biodiversity, rich biomass, and complex co-evolved relationships between organisms. Coral reefs are also a dynamic system under the influences of natural and anthropogenic disturbances on various spatial and temporal scales. Studies on the effects of biological processes, such as recruitment, competition, and predation, on the dynamics of coral communities provide an important approach toward a comprehensive understanding of reef ecosystems. This article summarizes our current understanding of the biological dynamics of coral reefs by reviewing representative examples in an attempt to demonstrate the synergetic effects of disturbance factors, such as typhoons, predation, disease, overfishing, and eutrophication, on coral communities. These cases include (1) the population dynamics and life history of branching pocilloporid and acroporid corals on shallow reef flats under frequent disturbances; (2) population dynamics and life istories of foliaceous corals on deep reef slopes and their characteristics under stable environments; (3) the predation effects of starfish and sea urchins on coral communities; and (4) the phase shift from a coral-dominated to an algal-dominated community in Jamaican reefs. The discussion emphasizes the roles of various biological factors, including sexual and asexual recruitment, competition, and predation, on the dynamics of coral populations and communities.

1. Introduction

(see also Effects of Climate Change on Coral Reefs, Coral Reef Ecosystems: An Overview of Their Structure and Function)

The biological communities of coral reefs are characterized by high biodiversity and high abundance of marine organisms. Many instances of co-evolved relationships and ingenious symbiotic relationships are the most fascinating phenomena of coral reefs. How do these organisms maintain dynamic equilibrium and high biodiversity? What kind of adaptations and life history strategies enable them to be abundant under the influence of various disturbances and intense competition? What is the interactive mechanism responsible for the formation of symbiotic relationships and the co-evolution of symbiotic organisms? All of these questions are of central interest to reef biologists. Studies on the effects of biological processes, such as recruitment, competition, and predation, on the biological dynamics of coral reefs are among the important approaches to answer these questions.

Coral reefs have been regarded as a stable environment, and reef species are highly specialized. Recently, it has been recognized that coral reef environments are not always benign, and that they are frequently interrupted by disturbances. In addition, population explosions and crashes of reef organisms and changes in community structure occur on contemporary coral reefs. Various disturbances can be classified as biotic or physical interferences. Physical interferences include strong waves induced by tropical storms, exposure to the air during low tide, sedimentation and dilution of seawater caused by heavy rain, and rising sea temperatures induced by global warming or thermal effluents from power plants. These disturbances mainly affect the coral communities on reef flats in shallow waters. On the other hand, the physical environments of reef slopes in deep waters are usually stable, and biotic disturbances, e.g., outbreaks of predators and interspecific competition, may play a more important role in structuring the community. Recently, it has been shown that the effects of global warming and anthropogenic disturbances, such as overfishing, eutrophication, and sedimentation have resulted in severe damage, or have totally changed communities.

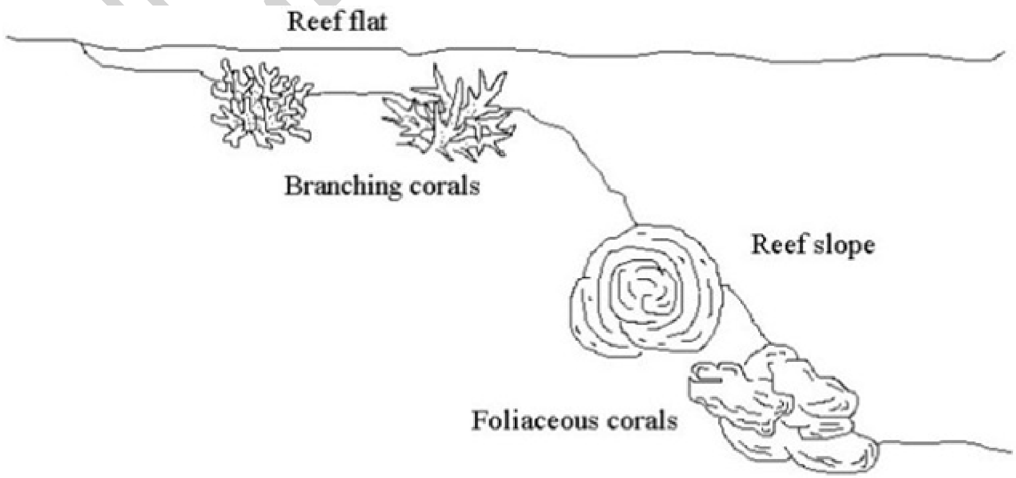

Figure 1. Cross section of a coral reef and the common growth forms of corals in shallow and deep waters.

Scleractinian corals are the major reef-builders and are widely distributed in tropical oceans. Other reef organisms may directly or indirectly interact with corals. Various coral species have evolved different patterns of growth and life history characteristics so that they can survive in and dominate different areas. In addition, distribution patterns of corals usually show marked zonation with depth. For example, the reef flat in shallow waters, characterized by frequent disturbances and unstable environments, is dominated by branching acroporid and pocilloporid corals (Figure 1), while, foliaceous corals often densely cover deep reef slopes where they may form a particular assemblage.

Corals and many reef organisms including algae, sponges, zoanthids, bryozoans, and ascidians are colonial organisms characterized by modular construction, asexual reproduction, and indeterminate growth. A coral polyp is the structural unit of a coral colony. The formation of a polyp involves a series of sexual reproductive processes such as the production of sperm and eggs by mature colonies, fertilization of gametes, and development and metamorphosis of larvae (Figure 2).

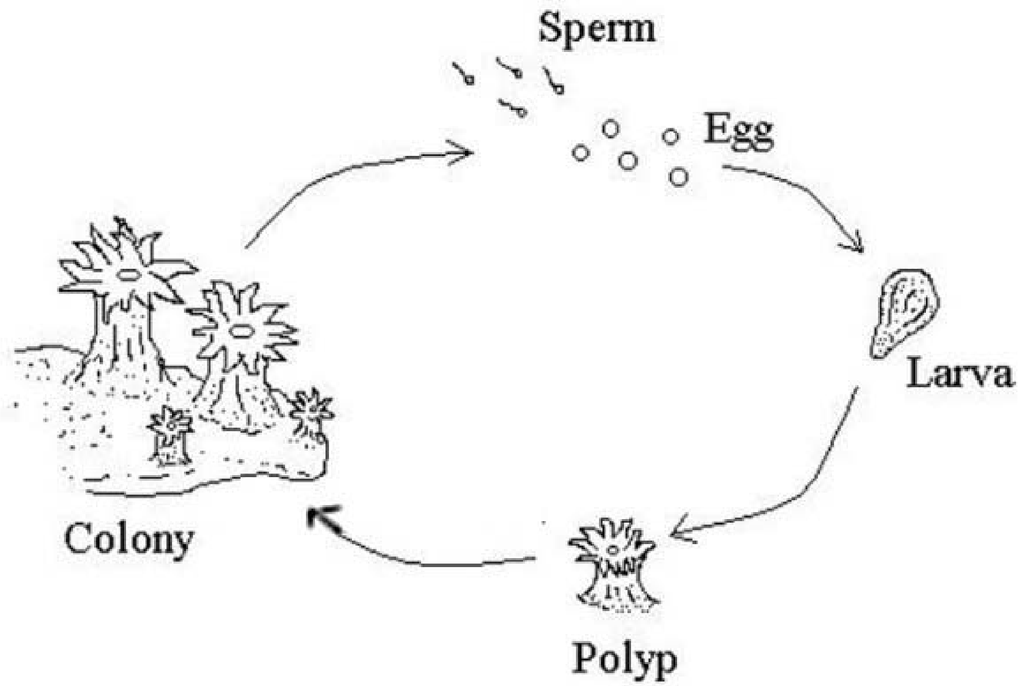

Figure 2. Life cycle of corals.

Polyps can duplicate themselves by budding and consequently form a colony. One large colony may be composed of thousands of polyps that have resulted from a series of asexual budding of a single polyp. Basically, each polyp is a functional unit and is able to carry out all living functions independently. The enlargement of a colony may result from budding or fusion of two colonies. Individual modules may die while others remain viable. Therefore, the balance between rates of module budding and death defines net colony growth, similar to the roles of birth and death in the dynamics of a population. This mode of growth of colonial organisms imposes on them a suite of demographic characteristics not usually found among other organisms such as fish and humans.

Besides producing planktonic larvae, the number of colonies will increase through dispersal, settlement, metamorphosis to juvenile colonies, and then becoming sexual recruits, fragmentation, or fission (Figure 3). However, total mortality and fusion of colonies will decrease the number of colonies. Therefore, the factors affecting colony number in a clonal population are greater than those in an aclonal one. On the other hand, colony size may increase through growth, regeneration, and fusion, but decrease through partial mortality and fission. Thus, colony sizes at the same age may be very different. Population structure of corals cannot be fully described by counting colonies, and a clear measure of a species' abundance is provided by measuring data on both the number of colonies and their areal extent.

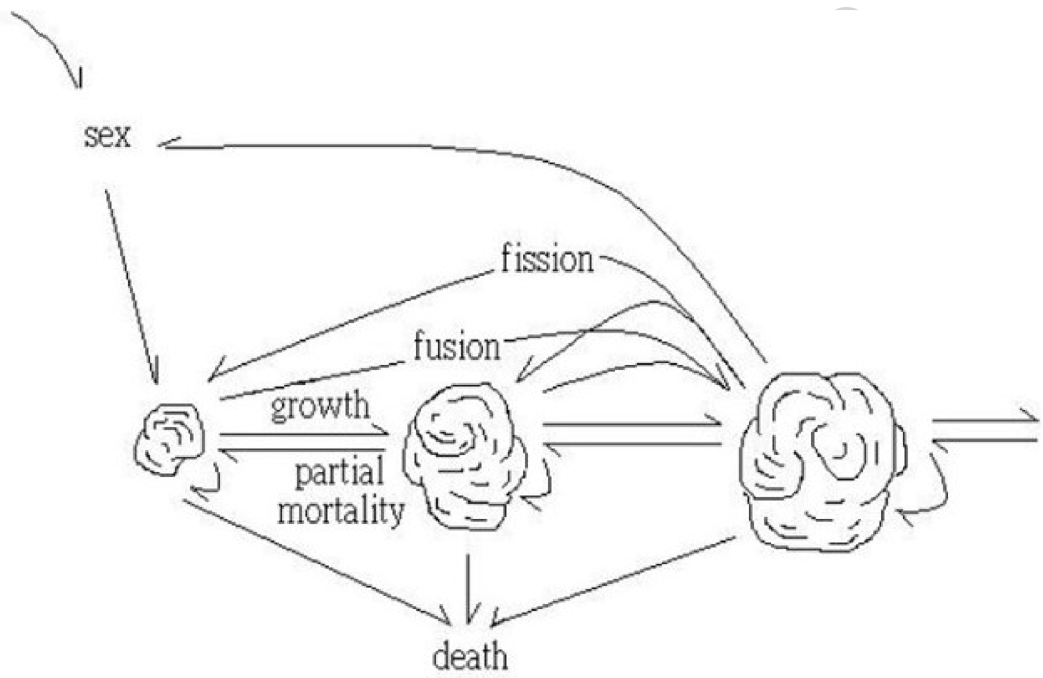

Figure 3. Life history of a coral colony.

This article summarizes our current understanding of biological dynamics of coral reefs by reviewing several representative examples: including (1) population dynamics and life history of branching pocilloporid and acroporid corals on shallow reef flats, (2) population dynamics and life histories of foliaceous corals on deep reef slopes, (3) the predation effects of starfish and sea urchins on coral communities, and (4) the phase shift from a coral-dominated to an algal-dominated community in Jamaican reefs. The discussion emphasizes the role of various biological factors, such as sexual and asexual recruitment, competition, and predation, on coral populations and communities.

2. Population Dynamics of Branching Corals

On shallow reef flats, environmental factors are variable and disturbances occur frequently. For example, water temperatures often vary with air temperatures, and the salinity changes with evaporation, rainfall, and river runoff. Animals on reef flats also suffer from strong wave forces due to the shallow depths. These factors may cause severe damage to corals and other benthic organisms. However, the death of benthic organisms also create new substrate for recruiters. Coral species abundant in this environment are branching corals such as pocilloporid and acroporid corals.

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Biographical Sketches

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