

Science

July 2012, Vol. 337 no. 6090 pp. 46-47

<http://dx.doi.org/10.1126/science.1223881>

© 2012 AAAS



The Seasonal Smorgasbord of the Seas

Adrian Martin*

National Oceanography Centre, Southampton SO14 3ZH, UK.

*: Corresponding author : A. Martin, email address : adrian.martin@noc.ac.uk

Abstract:

The spring bloom of phytoplankton—an annual population explosion that propagates poleward across much of the open ocean and spills across the continental shelves—is a seasonal bounty for the marine ecosystem. As it wanes, its annual legacy is a flux of carbon out of the atmosphere as the organic material, containing newly fixed carbon, sinks. On page 54 of this issue, Mahadevan *et al.* (1) suggest that the bloom can be triggered by instabilities in surface currents that trap phytoplankton near the sunlit surface. In another study, Teeling *et al.* (2) recently suggested that the bloom itself may help to explain the “paradox of the plankton” (3); how can a seemingly homogeneous ocean sustain thousands of species?

The long-standing theory for what triggers the spring bloom is the critical depth hypothesis (4). Only the top ~100 m of the ocean receives sufficient light for phytoplankton reproduction, but growth often strips this layer of nutrients. According to the critical depth hypothesis, stirring by winter cooling and winds brings deeper nutrient-rich waters up to the surface, but this benefit is often outweighed by phytoplankton being in turn stirred down into deeper waters, where there is too little light to prosper. In spring, the base of this mixed layer shallows. This shallowing was thought to be mainly caused by seasonally increased heating leading to stratification of the water. Simultaneously, day length and light levels increase. At a “critical depth” of the mixed layer, the growth allowed by the average light level experienced by phytoplankton is balanced by the losses due to processes such as consumption by zooplankton and respiration. When the mixed layer shallows beyond this critical depth, the phytoplankton population grows exponentially, creating the bloom (see the figure 1).

Traditionally, stratification at a given location has been attributed to the local surface heat input or wind-induced mixing. [Mahadevan et al.](#) (1) bring recent breakthroughs in understanding surface ocean physical processes at scales of 1 to 10 km to bear on the issue. Surface waters can stratify much earlier than by heating alone as a result of instabilities in surface currents that cause lighter water to slide over denser water (5). Focusing on the open North Atlantic southwest of Iceland, [Mahadevan et al.](#) argue that this process can advance bloom onset by 3 to 4 weeks. The exact conditions under which this phenomenon occurs remain uncertain, hindering estimates of global impact.

Previous observations showing blooms beginning before stratification have led others to revisit the critical depth hypothesis. [Behrenfeld](#) has suggested that the bloom is triggered not by an increase in the rate at which phytoplankton reproduce but by a decrease in the rate at which zooplankton consume, or “graze,” them (6). In contrast, [Taylor and Ferrari](#) have argued that mixing can decrease before the tell-tale signature of stratification appears, such that stratification is not a reliable proxy for bloom initiation (7). With a variety of explanations, the challenge is to determine the balance of drivers in dictating the start of the bloom. A globally dominant single influence is unlikely. Both biological controls, such as grazing (6), and physical ones, such as intensity of mixing (7) and susceptibility of surface currents to instabilities (1), vary markedly from place to place.

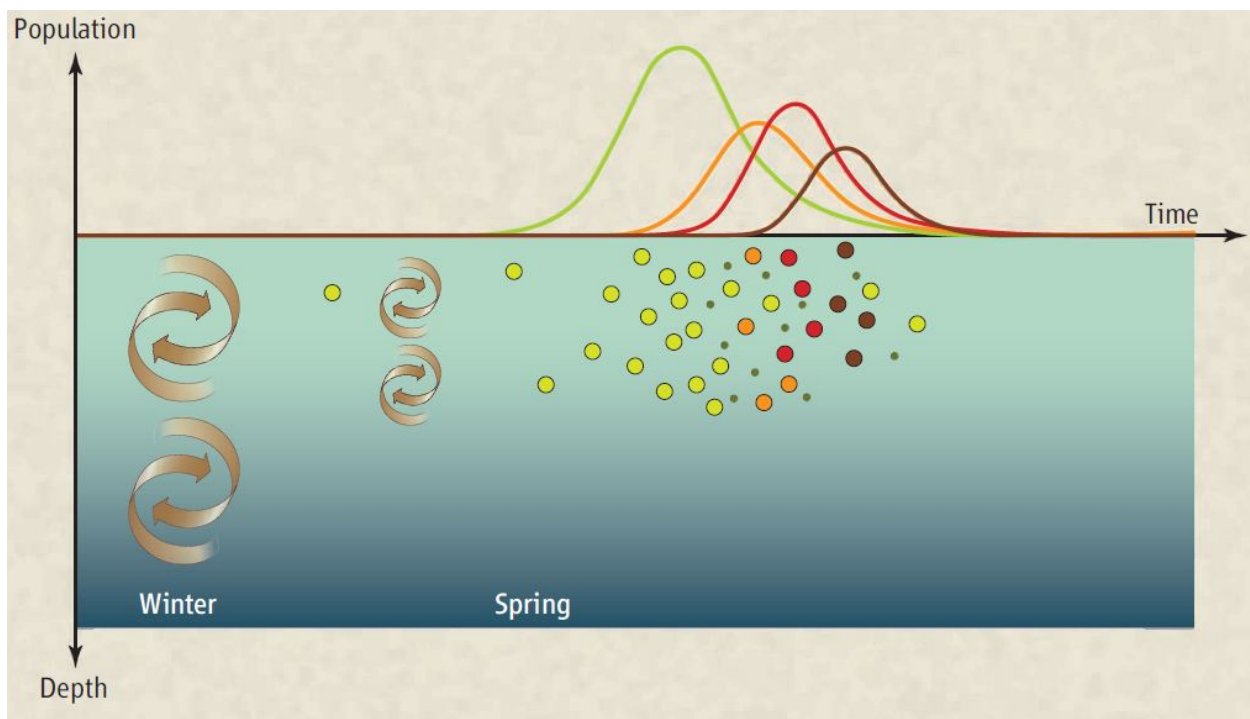


Figure 1. What happens in a bloom. In spring, a combination of less mixing, reduced “grazing” (the consumption of phytoplankton by zooplankton), and increased light allows phytoplankton (green) to grow exponentially in a bloom. Mahadevan *et al.* argue that instabilities in surface currents provide the necessary reduction in mixing. Teeling *et al.* demonstrate that as the bloom wanes, through mortality and grazing, the organic material released (green dots) provides a range of resources that can be exploited as ecological niches by a variety of bacteria (orange, red, brown).

Even if its drivers remain debated, the bloom itself may help to resolve one of marine ecology’s most enduring debates. The competitive exclusion principle (8) posits that the number of species should not exceed the number of resources: One species will inevitably have some advantage in acquiring a given resource and will ultimately outcompete the other species for it. If a species is excluded from all resources by competition, it will become extinct. For phytoplankton, it is difficult to see how species diversity is maintained if the only resources considered are light and the most abundant mineral nutrients, such as nitrate, phosphate, and silicate.

One possibility is that we are underestimating the number of resources. By shifting the focus to bacteria, another component of marine plankton for which the “paradox” should apply, Teeling *et al.* (2) show that the range of available resources and adaptations to exploit them provides sufficient ecological niches in the shallow southeastern North Sea to allow a diverse range of bacteria to prosper in the wake of a phytoplankton bloom when there is abundant organic material (see the Fig.1).

These considerations provide an interesting counterpoint to alternative explanations, which question whether a plankton ecosystem ever achieves equilibrium—an assumption underlying the competitive exclusion principle. The system may be kept out of equilibrium by fluctuations, either in the environment (9, 10) or arising from nonlinear interactions of its component species (11, 12). Either way, conditions may never be the same long enough to allow one species to outcompete others for the limited resources and to drive them to extinction.

These explanations harmonize with that of Teeling *et al.*, who argue that the rapidly changing environment associated with the bloom provides the niches exploited by the various bacteria. Spatial heterogeneity of the environment—evident in the strong spatial gradients in figure 1 of Teeling *et al.* - may provide further niches. Modeling (13) suggests that the dynamics of surface currents, such as those studied by Mahadevan *et al.*, can lead to adjacent but segregated patches of water with differing phytoplankton communities.

The growing debate over the causes and consequences of the spring bloom illustrates a deepening understanding of how the marine ecosystem operates. Substantial practical challenges lie ahead for furthering research. Multiyear time series are required to assess single-bloom studies (1, 2) more robustly and in a greater range of locations. Teeling *et al.* use an impressive portfolio of observational methods, but it is not clear how the study could be reproduced at locations farther from land, where sampling at the subweekly frequency necessary to resolve the rapid changes in populations during the short-lived bloom is technically extremely challenging. To test further the hypotheses for bloom initiation requires observations including turbulent mixing rates, zooplankton grazing rates, and detailed three-dimensional maps of surface circulations, at a time when weather conditions are most inhospitable to research ships.

Mahadevan *et al.* use modeling to augment their observations. Such a multidisciplinary multidisciplinary approach is promising, but additional focused observations are needed to configure localized process models, such as that in (1), frame hypotheses, and test model extrapolations to larger areas and different locations. Autonomous vehicles and sensors will play a key role, providing data throughout the year regardless of the weather. But for some time yet, scientists will continue to depend on and be constrained by short-period, ship-based sampling for many biological measurements, such as grazing rates.

References

Martin, A. 2012. *The Seasonal Smorgasbord of the Seas*, *SCIENCE*, Vol. 337 no. 6090 pp. 54-58, 10.1126/science.1218740

- (1). [A. Mahadevan, E. D'Asaro, C. Lee, M. J. Perry, *Science* 337, 54](#) (2012).
- (2). [H. Teeling *et al.*, *Science* 336, 608](#) (2012).
- (3). G. E. Hutchinson, *Am. Nat.* 95, 137 (1961).
- (4). H. Sverdrup, *J. Cons. Cons. Int. Explor. Mer.* 18, 287 (1953).
- (5). [G. Boccaletti, R. Ferrari, B. Fox-Kemper, *J. Phys. Oceanogr.* 37, 2228](#) (2007).
- (6). [M. J. Behrenfeld, *Ecology* 91, 977](#) (2010).
- (7). [J. Taylor, R. Ferrari, *Limnol. Oceanogr.* 56, 2293](#) (2011).
- (8). [G. Hardin, *Science* 131, 1292](#) (1960).
- (9). [U. Sommer, *Limnol. Oceanogr.* 30, 335](#) (1985).
- (10). [A. D. Barton, S. Dutkiewicz, G. Flierl, J. Bragg, M. J. Follows, *Science* 327, 1509](#) (2010).
- (11). [E. Benincà *et al.*, *Nature* 451, 822](#) (2008).
- (12). [J. Huisman, F. J. Weissing, *Nature* 402, 407](#) (1999).
- (13). C. Perruche, P. Rivière, G. Lapeyre, X. Carton, P. Pondaven, *J. Mar. Res.* 69, 105 (2011).