CONCLUSIONS AND RECOMMENDATIONS

Multiple nutrient sources are available to K. brevis blooms but these sources are dynamic and vary with bloom stage and location.

REDUCE controllable nutrient sources through the implementation of best management practices, with the understanding that, given the complexity of K. brevis bloom dynamics, no direct impact on K. brevis bloom frequency or magnitude may be evident as a result.

Current research and management are limited in their bloom predictive capabilities.

DEVELOP further short-term forecasting and now-casting capabilities. With increasing knowledge and understanding of red tide dynamics and ecology, the need for effective monitoring and predictive capability is also increasing. Continue to provide red tide-related monitoring products that allow for effective targeting of monitoring needs with reduced fiscal and manpower resources for state harmful algal bloom managers (e.g. particle tracking products).

A working hypothesis of bloom initiation has been developed but requires testing and confirmation.

Specific physical and chemical conditions on the west Florida shelf make it particularly vulnerable to annually reoccurring red tides.

CONTINUE research on the conditions promoting bloom initiation, with the addition of regular 3D surveys of water properties and bio-optics using gliders. Such data is essential for forecasting blooms and their impacts, and developing targeted management strategies.

ADAPT to blooms on the west Florida shelf, as they are a chronic, long-term problem. Support, update, and maintain red tide-related mapping, modeling, and monitoring products. Utilize new and existing educational outreach programs to disseminate information and resources.

Specific physical and chemical conditions on the west Florida shelf make it particularly vulnerable to annually reoccurring red tides.

REFERENCES

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FURTHER INFORMATION
http://myfwc.com/research/redtide/research/current/ecohab–karenia/591

FLORIDA RED TIDES ARE CAUSED BY THE TOXIC DINOFLAGELLATE KARENIA BREVIS

Karella brevis (Davis) G. Hansen & Moestrup, formerly Psychodiscus brevis and Gymnodinium breve, is an unarmed dinoflagellate ranging from 18–45 µm in size. Dinoflagellates are microscopic single-celled organisms. Cells have two flagella that allow for movement within the water column at speeds up to one meter hr−1. Like other dinoflagellates, K. brevis reproduces asexually by cell division but also has a sexual cycle that may include resting stages. K. brevis is a plant-like microalgae, capable of creating its own energy from the sun via photosynthesis but can also use a mix of biological and chemical sources of energy as food. The species is classified as a coastal bloom species; however blooms can occur over a wide range of coastal environments and nutrient conditions. Blooms typically occur in late summer and fall; however they have been documented in all months of the year.

KARENIA BREVIS BLOOMS ON THE WEST FLORIDA SHELF ARE NOT A NEW PHENOMENON

K. brevis is native to the Gulf of Mexico ecosystem, and reports suggesting bloom-related events (fish kills) date back to 1528. The organism responsible for red tide was identified and described in 1948 after the largest fish kill in Florida history occurred in 1947. The first nutrient-related K. brevis study was conducted in 1948 with the goal of examining the relationship of Calosohatchee River outflow with bloom events.

RED TIDES HAVE LARGE ECOLOGICAL AND ECONOMIC IMPACTS

Karenia brevis produces a suite of brevetoxins capable of killing fish, birds, and marine mammals. Toxins can accumulate in filter-feeding shellfish (oysters, clams) tissue and can, if ingested by humans, cause Neurotoxic Shellfish Poisoning (NSP). The State of Florida continuously monitors for K. brevis, and commercial shellfish harvesting areas are closed when 5,000 cells L−1 of K. brevis are detected in the vicinity. There have been no NSP cases from consumption of shellfish from these areas. In addition, when cells are disrupted by winds, breaking waves, or surf, toxins may become aerosolized. This can lead to respiratory irritation in people at beaches and up to three miles inland from the coast, depending on wind conditions. Beach clean-ups, tourism-related losses, medical expenses, and lost work days during red tide events can average over a million dollars lost annually during harmful algal bloom events.

Left: A fish kill caused by a K. brevis bloom.
**The West Florida Shelf is Prone to Red Tides**

Karenia brevis is native to the Gulf of Mexico and blooms have been recorded off of Mexico, Texas, Louisiana, Mississippi, Alabama, and Florida. On the west Florida shelf, blooms of K. brevis are common from the area off Clearwater to Fort Myers.

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### Karenia brevis is Opportunistic: Utilizing Multiple and Complex Nutrient Sources

Nutrient sources supporting K. brevis blooms are multiple, diverse, and complex. The ability of K. brevis to utilize a variety of inorganic and organic nitrogen (N) and phosphorus (P) sources allows the species a significant ecological advantage. Known nutrient sources were quantified and evaluated for their relative significance. The largest nutrient sources observed were the decay and recycling of *Trichodesmium* spp. bloom biomass, and nutrient release from zooplankton grazing, followed by the decay of red tide-related dead fish, *Trichodesmium* spp. N₂ fixation, and *Trichodesmium* spp. N₂ fixation. These were followed by estuarine inputs, including nitrification, photochemical nutrient production, microzooplankton grazing, pelagic N₂ fixation, and *Trichodesmium* biomass decay. Many of these sources alone were sufficient to support observed bloom biomass. Additionally, as K. brevis bloom concentrations increased, nutrient cycling by the microbial loop increased in importance.

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**Waters of the west Florida shelf are generally limited and therefore sources of newly available N could play a large role in relieving nutrient limitation.** Photochemically produced ammonium (NH₄⁺) is created during a chemical reaction involving light. Observed NH₄⁺ photoproduction rates were comparable within three K. brevis blooms during 2007, 2008, and 2009, but insufficient to support the measured NH₄⁺ uptake at all K. brevis sites. In addition, separate studies demonstrated that NH₄⁺ uptake by the phytoplankton community was dominated by the uptake of NH₄⁺, indicating the potential importance of newly available N as a source for K. brevis.

**Synechococcus spp.** is a single-celled cyanobacteria native to the Gulf of Mexico. The ability of K. brevis to graze on *Synechococcus* spp. cells has been observed in previous studies, and was investigated. Ingestion rates of K. brevis on *Synechococcus* spp. were highly dependent on experimental prey concentrations. Below a lower feeding threshold (1.86 x 10⁸ cells mL⁻¹) grazing did not occur and above a saturating prey concentration (~1.95 x 10⁸ cells mL⁻¹) grazing rates did not increase with increasing prey concentrations. Results suggest that grazing may play an important role in maintaining K. brevis populations at background, and/or bloom concentrations.

**A confocal laser scanning image showing a K. brevis cell (red indicates chlorophylls in periphery of cell) containing a Synechococcus spp. cell (green) (Leo Prazice, ODU).**

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**The West Florida Shelf is Characterized by Multiple, Overlapping Nutrient Sources**

- **Estuarine outflow**
- **Benthic flux**
- **Atmospheric inputs**
- **Trichodesmium N fixation, biomass decay, excretion**
- **Fish kills**
- **Other N sources** (picocyanobacteria, diatoms, tynhydras)

**THE WEST FLORIDA SHELF IS CHARACTERIZED BY MULTIPLE, OVERLAPPING NUTRIENT SOURCES**

**Red tide events, 1957–2012**

Karenia brevis growth is stimulated by urea, nitrate, and N₂ fixation from the co-occurring *Trichodesmium* spp. Points are the average value (± S.D.) of the difference from the initial sample. Positive indicates an increase in cell number, negative indicates decreased cell number (Siple et al., in press).

**K. brevis blooms** can be transported to the east coast of the US, model output showing the paths of surface drifters (which represent water parcels with K. brevis blooms present) demonstrate stationary bloom conditions in 2006 (top), and conditions promoting transport to the east Florida coast in 2007 (bottom) (Wesberg, 2011).

**K. brevis** blooms initiate in offshore, low-nutrient waters, where they are able to utilize ammonium produced by the micro- and macrozooplankton grazing and nutrient regeneration. Nitrification and up to 100% of N requirements of 5.0 x 10⁻² concentration of sedimentary ammonium (NH₄⁺) can play a large role in relieving nutrient limitation. Photochemically produced ammonium (NH₄⁺) is created during a chemical reaction involving light. Observed NH₄⁺ photoproduction rates were comparable within three K. brevis blooms during 2007, 2008, and 2009, but insufficient to support the measured NH₄⁺ uptake at all K. brevis sites. In addition, separate studies demonstrated that NH₄⁺ uptake by the phytoplankton community was dominated by the uptake of NH₄⁺, indicating the potential importance of newly available N as a source for K. brevis.

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**The surface aggregation layer, a narrow 5 cm surface band where cells collect during daylight hours, is not only an area of concentrated cells within a K. brevis bloom but also an area of increased biological activity and nutrient cycling.** Vertical migration of K. brevis to access deeper nutrient concentrations was not observed in blooms. However, based on observations of a daylight surface aggregation behavior of K. brevis, it is hypothesized that migration to a narrow sea surface layer during daylight hours serves as a nutrient acquisition strategy to access surface associated nutrients and microbial loop enhanced nutrient production.

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**Nutrient release rates from dead, decaying fish fall within the range required to support blooms of at least 10⁹ cells L⁻¹.** Additions of fish “goo” (a nutrient mixture produced by decaying fish) to natural microbial populations provided sufficient nutrients to alleviate P limitation in offshore populations. While both new and old phytoplankton communities utilized N from additions, a greater stimulation of chlorophyll a production was observed offshore. This suggests that decaying fish could provide an important enrichment source of N and P in both coastal and offshore habitats.

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**Karenia brevis cells L⁻¹ – 10⁵ – 5 x 10⁴ – 10³ – 5 x 10² – 10¹ – 5 x 10⁰.**

**In situ blooms** initiate in offshore, low-nutrient waters, where they are able to utilize ammonium produced by the micro- and macrozooplankton grazing and nutrient regeneration. Nitrification and up to 100% of N requirements of 5.0 x 10⁻² concentration of sedimentary ammonium (NH₄⁺) can play a large role in relieving nutrient limitation. Photochemically produced ammonium (NH₄⁺) is created during a chemical reaction involving light. Observed NH₄⁺ photoproduction rates were comparable within three K. brevis blooms during 2007, 2008, and 2009, but insufficient to support the measured NH₄⁺ uptake at all K. brevis sites. In addition, separate studies demonstrated that NH₄⁺ uptake by the phytoplankton community was dominated by the uptake of NH₄⁺, indicating the potential importance of newly available N as a source for K. brevis.

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Karenia brevis blooms are initiated in offshore, low-nutrient waters, where they are able to utilize ammonium produced by the mixed-layer phytoplankton community as an important source of N and P in both coastal and offshore habitats. Water of the west Florida shelf are generally characterized by multiple, overlapping nutrient sources.
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References


References


