EARTH'S ADVOCATE

COMMENTS ON PEBBLE BEACH EIR
for
A NEW GOLF COURSE

General Plan
Draft Environmental Plan
Environmental Policy Office
230 Church St. Bldg 3, Salinas, Calif. 93901

3/18/04

95
3/18/2004

I object to the building of a new golf course in Pebble Beach for the following reasons;

1). The Monterey Pine Forest is a rare and declining forest with its own unique forest system no human can mitigate no matter how well intentioned that mitigation might seem. Hundreds of trees are propposed to be cut. Huge old trees that carry the genetic blueprint of immune biology and fungus survival which nursery raised trees cannot possibly duplicate. As it is much of the Monterey Pine forest system is infected with disease, amoung them the unstoppable pitch canker. Some tress hold an immunity for this disease. We need as many trees as possible to offset the terrible death toll the Pitch Canker will take.

A mitigation measure for the Pebble Beach Golf Company would be to buy up an existing golf course such as Mr. Lombardos golf course now up for sale to introduce condos. 1

2). Golf course require fertilizers, weedkillers, funguicides and water. Already these fore mentioned chemicals are causing havoc with our oceans. (see article A on HABS -Harmful Algal Blooms).

The little known science is most distressing in pointing out the harmful effects of nitrogen, Urea, ammonium in killing off oxygen in the oceans and creating dead seas. As it is Pebble Beach uses unspecified amounts of these ferjilizers, weedkillers, funguicides that run off into the Carmel Point areas. I used to swin there thirty five years ago and the fish were abundant. Now it is almost void of sea life.* Harmful algal blooms are a recognized problem for Monterey Bay already and these golf courses have done nothing to lessen the problem. In the 'RED TIDE' report which I also submit it states that "red tides may also cause respitatory distress in birds and humans because individual cells can be aerosolized and swept along the ocean surface oceans." I have become increasingly breathless 2

Annie Griffin
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Monterey, CA 93942
831-

Comments on EIR for Pebble Beach Golf Course Proposal

Therefore I want to have the following questions and issues addressed by the Pebble Beach Company in ful in the completed Draft EIR.

A). If Pebble Beach Company insists on going forward with their pursuit of another golf course how will they determine what effect the added use of fertilizers, Round-up and other weed killers, fungicides will have on creating additional Red Tide in our area. How do they plan to mitigate it?

B). How will they mitigate the loss of marine life from increasing red tide phenomena?

C). Where will they get the additional water supply to water the golf course?

D). What kind of fertilizers does Pebble Beach Company plan to use and what will its impacts be on the sea life from run-off?
In submitted article 3 Toxic Fertilizers it points out that 'any material that has fertilizer qualities can be labeled and used as fertilizer even if it has dangerous levels of chemicals and heavy metals. Instead of storing these hazardous materials safely some companies are saving millions of dollars by repacking toxic wastes into fertilizers.'
Will these heavy metals and toxic substance be in the fertilzers used by Pebble Beach Company. How can they assure us that the fertilizers they use are not the kind mentioned above?

E). Round-up is a poisen and its effects are far more damaging than previously realized. Does the Pebble Beach Company use Round-up or its counter code names? I submitt article 4 on the harmful effects of Round-up and Rodeo. #4 Article 4 'Monsantos herbicide "Round-Up" linked to deadly fungus." How can this potential Fusarium fungas flare up from the use of Round-Up damage the existing forest system already weakened by Pitch Canker and other forms of diseases counter a further attck of Fusarium fungus. Will they be willing to forego the use of Round-up entirely as a mitigation?

F). How has the pesticide, fertilizer use and other chemicals needed to keep a golf course healthy affect the red legged frog, an endangered species A possible mitigation would be to provide a breeding program but what use would this be if their habitate was poisened to an unacceptable level and would an added golf course attain that level?
According to David Dillworth, Pebble Beach is using chemicals now banned due to high toxicityfle related this story to me. One day he was riding his bike through Pebble Beach, around Spanish Bay when he noticed someone using pesticiced. He got the name off the box and reasearched its name only to find out it was banned long

2 (cont.)

3

2 (cont.)

4

5

ago because of its high toxicity. We aslo stated that in trying to find out from the Pebble Beach Company what substances they were using on their grasses they wouldn't disclose them to him, a blatant breaking of OSHA law. So - another point to be addressed: If they are violating the law now what is to stop them in the future? **5 (cont.)**

In conclusion, all these points need to be addressed. I need all issues and facts to be thoroughly disclosed, explained simply and with an Index.

I will be submitting further science concerning the use of pesticides, fertilizers on the ocean as soon as it arrives but I wanted to get my comments in before the deadline. **6**

I also ask that hearings be held at the most appropriate times so people who work can attend. Will the Planning Commission hearings be held locally, in the evening when most people can attend?

Submitted by Lorna Moffat Lorna Moffat
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Mitigation measure for the delicate golf course grass now used. Crabgrass uses little water, is hardy enough it doesn't need fertilizers, weed-killers or fungicides. This grass should be substituted for existing golf course grasses **7**

Northwest Fisheries Science Center and Washington Sea Grant Program

RED TIDES

West Coast newsletter on marine biotoxins and harmful algal blooms

This second edition of the *Red Tides* newsletter is published jointly by the Northwest Fisheries Science Center and Washington Sea Grant Program to address the problem of harmful algal blooms (HABs) on the West Coast. The cost of HABs is highlighted in this issue, including economic impacts on human health, coastal fisheries, and environmental quality. As this issue goes to press, human illness and hospitalization in Washington state and Alaska, sea lion deaths in California, and widespread closures of shellfish areas in Puget Sound, Washington are being reported all because of HABs. Research can help find ways to mitigate these problems. However our work has just begun.

The cost of harmful algal blooms on the West Coast

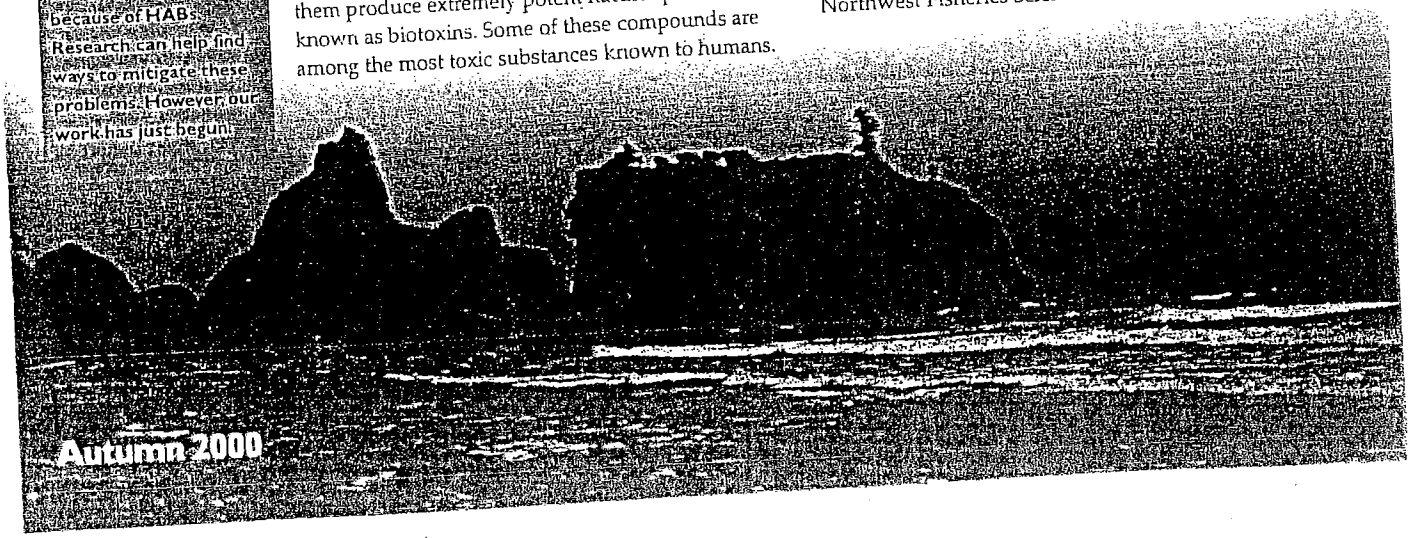
When you hear the words "harmful algal bloom," do you think of physical harm caused to people, such as illness or even death? These are the extreme harms, but there are many other, less visible harms caused by toxic algal blooms. In this issue of *Red Tides*, we examine one very important harm: the economic loss to the fisheries in coastal regions, including recreational, commercial and subsistence operations. The articles demonstrate how far-reaching and devastating West Coast toxic blooms can be.

What is a harmful algal bloom?

An algal bloom occurs when a single microscopic algal species multiplies until it dominates the microscopic plant (phytoplankton) community, reaching such high concentrations that the water becomes colored. These blooms often are referred to as "red tides" but can also appear green, yellow or brown. Most harmful algal blooms (HABs) are considered harmful because the algae constituting them produce extremely potent natural poisons known as biotoxins. Some of these compounds are among the most toxic substances known to humans.

How common are HABs?

Scientists believe the incidence of HABs and the marine biotoxins produced by them has increased over the past few decades. At least one study shows an increase in frequency, duration and geographical distribution that cannot be explained entirely by improved monitoring, greater attention from the scientific community, or consumer awareness related to increased seafood consumption. However, there is not enough information available to provide a clear answer to the question. We would need decades of comprehensive shellfish sampling data in order to reach conclusions about the frequency and possibility of increasing occurrences of HABs on the West Coast. Existing data are sketchy, focusing primarily on commercial and recreational shellfish harvesting areas. Further scientific research eventually will reveal the causes and mechanisms that trigger HABs. An example of collaborative research with a goal of determining the causes of HABs is the Olympic Region Harmful Algal Bloom (ORHAB) project (see West Coast Research, this issue), a program led by the Northwest Fisheries Science Center.



Autumn 2000

Toxins and toxic algae

Paralytic shellfish poisoning (PSP) is caused when humans eat shellfish or crabs that have accumulated toxins by filter feeding toxic algae. The toxins include saxitoxin and gonyautoxin derivatives, produced by single-celled plankton (algae) called dinoflagellates. The closure level (seafood cannot be harvested when toxin measurements are at or above this level) for PSP is 80 µg/100 g shellfish or crab meat.

Domoic acid poisoning, also called amnesic shellfish poisoning (ASP), is caused when humans eat shellfish, such as razor clams, or crabs, such as Dungeness crabs, that have ingested plankton that produce a toxin. The toxin, domoic acid, is produced by a species of single-celled plankton called a diatom. The closure level for domoic acid is 20 parts per million (ppm).

HABs and human health

Aside from the impact of HABs on local and regional economies, the significant health impacts of PSP are believed to be vastly under-reported. Since 1980, at least 183 cases of HAB-toxin-related illness and three deaths have been reported in the four West Coast states (primarily in Alaska, but also in Washington, Oregon and California). In August 2000, five people were hospitalized in Washington state after eating mussels tainted with PSP. Symptoms of PSP in humans include numbness and tingling of the lips, tongue, face and extremities, difficulty talking, breathing and swallowing, and lack of muscle coordination. There is no known antidote for the biotoxin that causes PSP and treatment is restricted to artificial respiration in life-threatening situations.

Economic consequences of red tides

HABs have adverse economic impacts on the aquaculture industry, human health, coastal economies and subsistence shellfish harvesters. For example:

- The threat of "red tide" has prompted routine closures of both commercial and recreational shellfish harvesting as well as finfish aquaculture operations in some coastal states. Past closures have resulted in large-scale financial losses for the industry and bankruptcies in some cases.
- HAB occurrences affect consumer perceptions of the safety of *uncontaminated* shellfish. This reduces the demand for shellfish in general and affects the fishing and aquaculture industries even where there is no algal contamination.
- HABs may have significant impacts on coastal economies. The uncertainty associated with toxic algal outbreaks adversely affects investment in coastal aquaculture.
- Bans on recreational harvests affect local economies by reducing the amount of money harvesters spend in local communities.
- HABs impede subsistence and ceremonial harvesting by native American coastal tribes. Some tribes and low-income coastal communities depend on shellfish as a source of nutrition, therefore they may experience a higher number of health effects associated with HABs.

The Need for Economic Analysis

Although some attempts have been made to estimate the economic impact of certain red tide events, these studies haven't gone far enough. Researchers have calculated direct costs to the aquaculture industry but these represent a low estimate of the true cost of HABs, which should include the health costs associated with toxic outbreaks, impacts on demand for uncontaminated shellfish and impacts on recreational shellfish harvesting and on the coastal economy. Estimating both the overall economic impact of HABs, and the costs of preventing and/or managing them calls for an integrated assessment approach that would

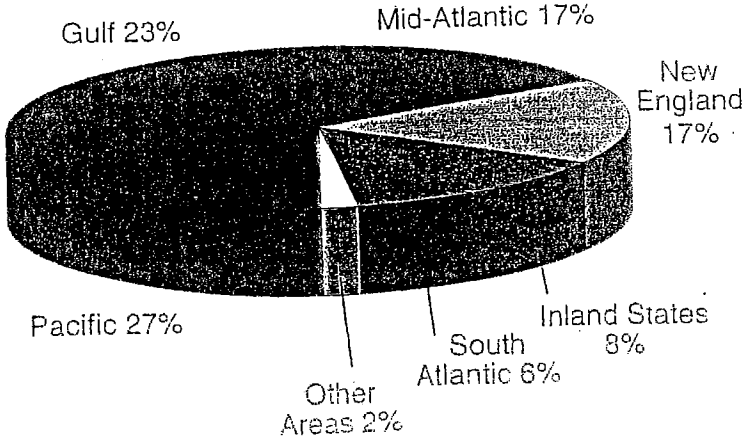
- examine the economic impact of HABs on consumers, the shellfish industry and both coastal and regional economies;
- evaluate of the costs and benefits of reducing coastal pollution and other human-related activities that may exacerbate the HAB problem; and
- weigh the costs and benefits of increased monitoring and surveillance that could potentially reduce the number of shellfish harvesting closures.

Pacific seafood is big business

The Pacific coastal region is home to perhaps the most important fishery in the United States, both in terms of the quantity of seafood harvested and the dollar value of that catch. The region leads in both the number of seafood processing plants (Figure 1) and also in the number of people employed (about 33% of all individuals employed in the seafood industry nationwide).

The Pacific region accounts for 63% of the total pounds of seafood landed in the U.S. and 41% of the total value of seafood products. The 1998 value of the region's salmon harvest was $257 million and the value of harvested crabs and clams was $608 million. In the United States, crustacean and molluscan shellfish account for about $1.4 billion per year or about 62% of the seafood market. All bivalve shellfish, and crabs such as Dungeness crab, are at risk of containing toxins from blooms of various harmful algae. Clearly, HABs can have a major impact on the economy of the Pacific region fishery and fisheries across the U.S.

Figure 1.
Distribution of seafood processing plants



Economic impact on commercial oyster farms

Washington's oyster industry is valued annually at more than $40 million

The 1997 PSP blooms in Washington state severely impacted the oyster harvest in Puget Sound and in the coastal estuaries of Willapa Bay and Grays Harbor. One unusual aspect of the blooms was that they occurred in November and December. The small farms in closed areas suffered great financial losses. A Puget Sound-area farmer of clams and oysters said that he was forced to close for eight weeks, causing him to miss Thanksgiving, Christmas, and New Year's sales, and estimated his losses to be $5,000 per week.

The PSP bloom in Willapa Bay and Grays Harbor was felt just before Thanksgiving Day, which is the oyster industry's busiest time of the year, accounting for 40% of the business. Although the coastal bays were reopened by mid-December, sales during the Christmas season were also lost because out-of-state competitors had moved into the market. About 34 coastal shellfish farms lost approximately 50% of their sales, reducing average sales by about $8 million. Over 100 workers were laid off and many more had hours reduced.

Not only did the small oyster farms suffer in 1997, the entire industry felt the impacts of PSP. Large companies had to scale back shellfish farming in the coastal estuaries and in Puget Sound. Oyster diggers and shuckers throughout the state lost their jobs during this PSP event.

HAB blooms are not yet predictable, so no one can tell you when and where a bloom will occur. But they are sure to occur again. Progress in HAB forecasting and rapid detection will help reduce economic impacts.

HABs in Alaska

In the "last frontier" state, the most damaging harmful algal species is the dinoflagellate *Alexandrium* that causes PSP. A persistent economic and human health problem for Alaska, PSP fatalities date back to 1799 when crew members of Alexander Baranof of the Russian American Trading Company ate tainted blue mussels at Poison Cove.

In 1997 and 1998, nine illnesses and one death were reported from Kodiak Island, the Aleutian Peninsula, and the panhandle near Juneau. Although most PSP illnesses happen during summer months, the season for toxin occurrence cannot be predicted. In the spring of 1999, another death occurred on Kodiak Island, and illnesses requiring emergency attention were reported in February and June 2000. Due to under-reporting of poisoning events, the actual number of illnesses may be 10 to 30 times greater than reports indicate.

Of all states in the Pacific region, Alaska has the largest, most productive fishery in the United States, contributing 54% of the nation's total landings. With an annual revenue of approximately $3 billion, commercial fishing is second only to oil as Alaska's most important industry. The fishing supplies more than 10% of Alaska's jobs, while seafood processing accounts for 63% of employment in the manufacturing sector. Although finfish and crab fisheries are enormous in the state, PSP hinders expansion of Alaska's shellfish industry because regulatory requirements for testing increase the costs and financial risks, and prevent existing shellfish operations from maximizing income.

The cost of PSP to the commercial fishery, recreational harvesters, and the aquaculture industry is believed to exceed $10 million annually. Research is underway to develop quick, inexpensive methods by which shellfish farmers and recreational/subsistence harvesters can determine safe shellfishing times. In addition, early warning systems that will allow more effective management of seafood resources are being tested on buoys (see West Coast Research, this issue).

Dungeness crab, an important West Coast resource

Alaskan Natives are subsistence users of marine resources, but no toxin monitoring program is required to assess the quality of their harvests in a timely manner. Alaskan Natives can be 10 times more likely to contract PSP than the average resident of Kodiak. Because Alaska does not have an agency charged with monitoring the recreational/subsistence harvests for marine toxins, sampling and testing costs must be paid by the harvester. Testing laboratories have a statutory responsibility to test commercially-harvested products first, so a subsistence harvester may wait several days for results of a sample test.

Alaska's aquaculture industry is greatly concerned that reductions in state funding will result in user fees for state toxin testing. The results to the aquaculture industry would be disastrous. A littleneck clam farmer who sells 800 lbs. of clams each week would be required to send six samples to a lab for testing, at a total cost of $750. With an estimated gross income of the harvest at $2000, the cost of testing would rise to over 37% of the income from the harvest.

Tribes and the value of early warning

Washington's coastal region is a unique area where treaty Indian tribes reside. For ceremonies, subsistence, and commercial sales, these tribes depend on the harvest of marine species such as razor clams, California mussels, littleneck clams, horse clams, butter clams, gooseneck barnacles and Dungeness crabs. Unfortunately, these species can accumulate toxins by filtering seawater. When toxins reach levels too dangerous for human consumption, tribes can face tremendous economic and quality-of-life losses.

Because of declining fish stocks in the Pacific Northwest, including rockfish and salmon, tribes are relying more heavily on shellfish than ever before. Shellfish and crustaceans are a primary source of income to many tribal members. The Quinault tribe, for example, depends on razor clams for both commercial and subsistence harvests. In September 1998, the tribe's entire harvest was lost because of record levels of domoic acid in the meats.

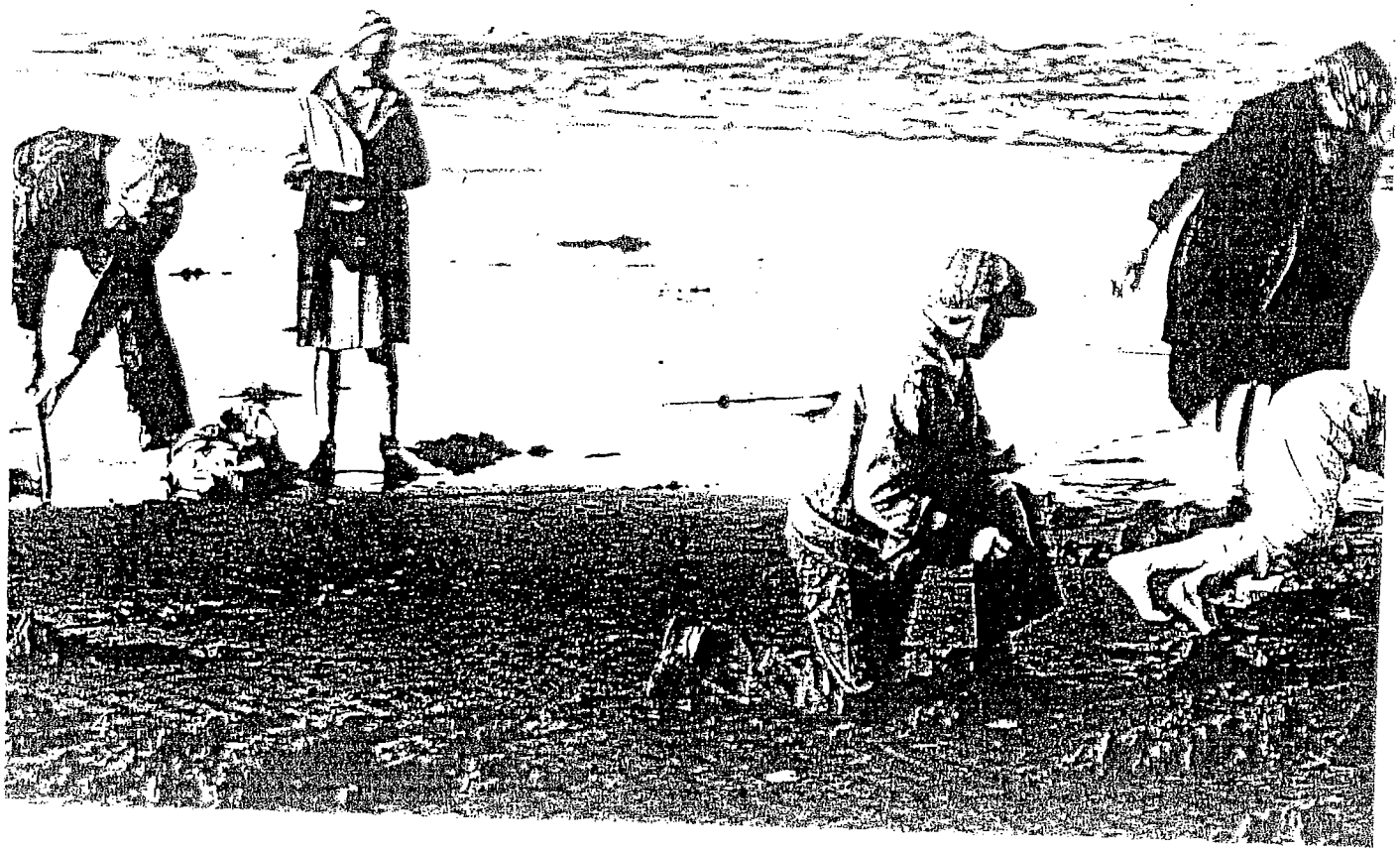
A resource survey that year by the tribes and Washington Department of Fish and Wildlife indicated that the large, adult clam population (over 3 inches shell length) greatly exceeded numbers calculated in previous years. On the four beaches that constitute the Quinault harvest areas, this survey indicated that approximately 250,000 of these clams should have been harvested for commercial sales. At about four clams per pound, that constituted a great economic loss to this tribe.

The situation did not improve in 1999. Because natural die-offs of clam populations occur about every five years, and possibly because of unfavorable 1998 El Niño conditions, the Quinault clam harvest was substantially reduced in 1999 for a second year in a row.

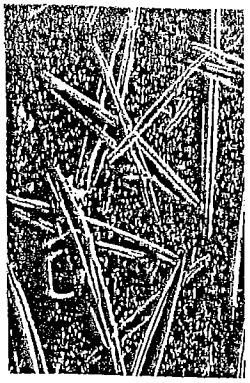
The Quileute Tribe in La Push, Washington also suffered great monetary losses during the 1998 domoic acid episode. Toxin levels in Dungeness crab were above the regulatory limit. Crabbers had a choice of eviscerating the crabs (removing the guts) or closing down the fishery entirely. They chose to eviscerate, which greatly decreased the market value of the crabs. This commercial industry lost 50% of the money typically earned. If this toxic episode had been predicted, tribal fishers could have sought an alternative buyer (for eviscerated product), and shellfish managers could have opened the razor clam harvest prior to the toxic event, saving money for a depressed tribal economy.

Shellfish managers need access to quick screening tools for the analysis of toxins and toxic species in both shellfish and seawater. Such screening assays would not only protect humans from exposure to toxins but also would make monitoring more cost effective. Screening assays are currently being developed and tested in the field as a collaboration between the Quileute tribe, the National Ocean Service, and the Northwest Fisheries Science Center.

Razor clam digging on a Washington state beach in 1932



Domoic acid impact on the recreational razor clam fishery



A scanning electron microscope image of *Pseudo-nitzschia*, the diatom that can produce domoic acid

Washington is known for its wide sandy beaches and large populations of the Pacific razor clam, *Siliqua patula*. This very tasty mollusk is one of the West Coast's most popular shellfish for recreational harvest.

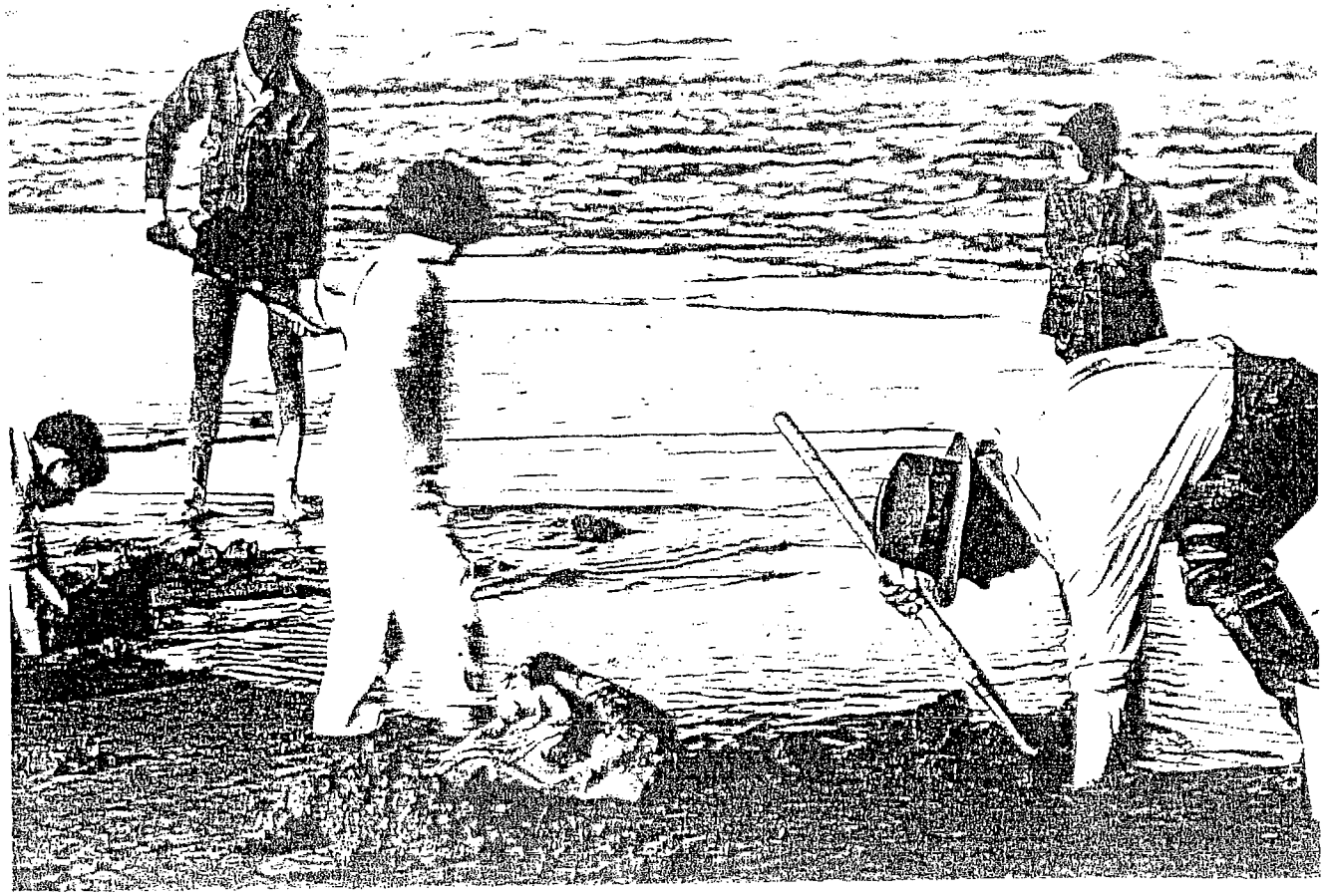
The razor clam industry started as a commercial fishery in the late 1800s and evolved into one of the state's largest recreational shellfisheries. During peak spring tides, up to 60,000 diggers have been counted on the 60 miles of sandy coastal beaches in central and southern Washington state. Over the years, disease and increased tribal harvest in off-reservation areas, within the tribes' usual and accustomed fishing areas, has reduced the number of clams available to the recreational fishery by up to 50%.

In the 1960s and 70s, up to a million digger trips were made each year to harvest razor clams on the open coastal beaches in Washington. This harvest provided business for restaurants, motels and RV parks where "clam cleaning sheds" attracted diggers to share stories of how they caught their limit of the "wily razor clam."

In 1991, domoic acid was discovered in razor clams during a routine test for PSP. Domoic acid is a natural toxin produced by a microscopic organism, *Pseudo-nitzschia*. The toxin can accumulate in digestive tissues of shellfish and in the meat of razor clams. While it does not hurt shellfish, people who eat domoic acid-laden meat can become sick, suffer short-term memory loss, and occasionally die. An emergency closure of the Long Beach peninsula in the fall of 1991 affected thousands of diggers and coastal businesses. Domoic acid levels continued to increase and spread to other beaches, resulting in the closure of all five major clamming beaches. The closures lasted into the following spring, causing an estimated revenue loss of $5 million to $8 million, based on estimates of $25 per day per digger.

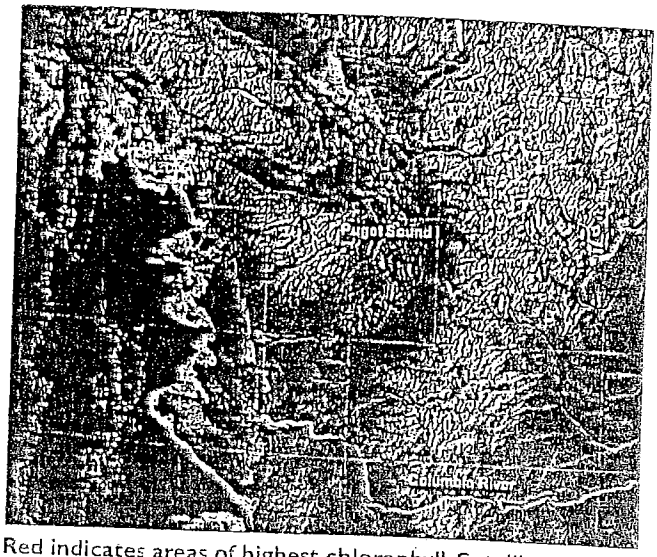
Less obvious economic impacts can be just as important to the overall picture.

- Short-notice emergency closures have sometimes left clam diggers disappointed and frustrated given the long-distances they travel, non-refunded lodging costs, and their disbelief of authority figures. In the 1999-2000 season alone, razor clam beaches were closed multiple times with only a couple of days' notice.
- Because few other recreational activities exist in Washington's coastal area, clam harvesting closures reduced income from tourist dollars.



Some of the problems discussed in this newsletter are the subjects of active West Coast research projects. Here is a brief overview of some of these projects.

- August 2000 launched the five-year Olympic Region Harmful Algal Bloom (ORHAB) monitoring project off the coast of Washington state. This is a multidisciplinary, multi-agency partnership to investigate the origins of open-coast blooms of domoic acid-producing algae, and assess the environmental conditions under which they occur and are transported to coastal shellfish. The major partners are: Battelle Marine Laboratory, Northwest Fisheries Science Center, Olympic Coast National Marine Sanctuary, Pacific Shellfish Institute, Quinault Indian Nation, Saigene Corporation, University of Washington, Washington Departments of Fish and Wildlife, Health, and Ecology. This project is sponsored by the Center for Coastal Monitoring and Assessment, NOAA.
- Also during August, field testing began on a prototype buoy monitoring system for the detection of toxic algal species. The instrument, called the Environmental Sample Processor, or ESP, will collect discrete water samples autonomously, concentrate microorganisms within those samples onto filter disks, and automate application of preservatives, DNA (or other molecular probes) to enable identification and quantification of species captured.
- A project on Kodiak Island, Alaska, will use molecular probe technology and advanced seawater toxin detection techniques to determine whether there is a correlation between the abundance of the toxic dinoflagellate, *Alexandrium*, and the toxicity of shellfish (*Mytilus edulus*). The plan is to develop the DNA probe method that can be used by shellfish farmers and recreational/subsistence harvesters to determine safe shellfish harvesting times. This project is funded by the Alaska Science and Technology Foundation.
- A three-year study funded by Washington Sea Grant Program is looking at whether unicellular or multicellular organisms have the ability to measure time. "Clocks" within the cell control fundamental biochemical and molecular events that dictate survival. For a unicellular alga, survival may mean replicating itself, swimming deeper to harvest more nutrients or, in the case of *Heterosigma carterae*, releasing a multiple-function toxin. *Heterosigma* causes severe problems to farmed fish globally in both temperate and sub-tropic regions.



Red indicates areas of highest chlorophyll. Satellite imagery is being tested as a forecasting tool in the ORHAB project.

Center for Environmental Visualization, University of Washington SeaWiFS Project, NASA/Goddard Space Flight Center and ORBIMAGE

How can you help researchers study HABs?

Evidence that marine biotoxins can have a dramatic impact on wildlife, including sea birds and marine mammals, has raised concern among scientists who research and monitor wildlife populations. Domoic acid was discovered on the U.S. West Coast in 1991 because of the death of hundreds of brown pelicans and cormorants. These birds had been feasting on anchovies in Monterey Bay, which had fed on a bloom of the diatom *Pseudo-nitzschia australis*, a phytoplankton species capable of producing domoic acid.

In 1998, and again in 2000, this scenario was repeated in Monterey Bay where a large number of dead or ill sea lions was linked to their consumption of anchovies tainted with domoic acid.

Although state monitoring programs and biotoxin researchers are always on the alert, they cannot be everywhere at once. People who frequent the shoreline and coastal waters for recreation can provide the first observational data of a potential biotoxin event.

To find out how you can help, call your state monitoring program. The following is a partial listing of contacts.

British Columbia
Canada Dept. of Fisheries and Oceans
**604.666.3169*
Marine Mammal Coordinator
250.756.7236 (Ed Lochbaum)

Alaska
Alaska Dept. of Health
**800.731.1312*
Marine Mammal Stranding Coordinator 907.586.7824 (Kaja Brix)

Washington
Washington Dept. of Health
**800.562.5632*
Marine Mammal Stranding Coordinator (Northwest Region)
206.526.6733 (Brent Norberg)

Oregon
Oregon Dept. of Agriculture
**503.986.4728*
Oregon State Police (Stranding Reports: 800.452.7888

California
California Dept. of Health Services
**800.553.4133*
Venura County: Dept. of Animal Regulation 805.388.4341
St. Luis Obispo to Monterey County: Marine Mammal Center 415.289.seal
Monterey to Santa Cruz County: Moss Landing Marine Lab 831.755.8650
Santa Cruz to San Mateo County: Long Marine Lab 831.459.2883
San Mateo to Medicino County: Calif. Academy Of Science 415.750.7176
Mendicino County: Calif. Dept. of Fish and Game 707.964.9078
Humboldt County to Del Norte: Humboldt State Univ. Vertebrate Museum 707.826.4872

Hawaii
**808.586.4725* (Food)
**808.586.4586* (Epidemiology)

**biotoxin hotlines*

lgae in the U.S., December 5-9, y in Woods Hole, Massachusetts

20-28, 2000, Hakodate,

ganization, PICES Ninth Annual Meeting. WG15) will convene. The goal of the cific, to identify the main gaps in the nent of collaborative investigations. ing, visit the Web site:

Orlova at *orlovat@chat.ru*

7th Canadian Workshop on Harmful Marine Algae, May 23-25, 2001, Pacific Biological Station, Nanaimo, BC, Canada

The 7th Canadian Workshop on Harmful Marine Algae will be held in Nanaimo, the central city of Vancouver Island on the west coast of British Columbia. Captain George Vancouver first recorded PSP on this coastline in 1793 when members of his expeditionary crew succumbed to the toxin after a meal of bivalves harvested at Poison Cove. The legacy of PSP occurrence on this coast remains with us today.

There is no registration fee for this workshop, so reserve your place on the distribution list by pre-registering as soon as possible. Participants are invited to submit provisional titles and subject categories (taxonomy, chemistry, ecology, toxicology, physiology, monitoring, mitigation, etc.) for oral and poster presentations.

Deadline for submission of titles, Dec. 15, 2000; abstracts, Feb. 2, 2001.

For further information:
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You can keep up to date on West Coast HAB issues through the NWFSC Web site (http://www.nwfsc.noaa.gov/hab) featuring recent HAB readings from a variety of West Coast researchers, state reports on sampling and HAB occurrences, and links to many other relevant sites.

We acknowledge the following colleagues for their contributions to this newsletter: Dan Ayres, Nancy Blanton, Deb Cannon, Andrea Copping, Frank Cox, Gregg Langlois, Ramanan Laxminarayan, Mitch Lesoing, Terry Nosho, Mike Ostaz, Ray Ralonde, Joe Rhodes, Robyn Ricks, Klaus Schallie, Chris Scholin, Joe Schumacker, Doug Simons, Barbara Stein

Produced by Washington Sea Grant Program, University of Washington

If you'd like to be on our mailing list or share your ideas for future newsletter articles, contact:

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Harmful Algal Blooms (HABs) in Western North America

Dr. William Cochlan
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cochlan@sfsu.edu
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HARMFUL ALGAL BLOOMS (HABs) – the definition of a HAB is not clear-cut, since it is a societal term, not a scientific term, that describes a diverse array of blooms (both macroscopic and macroscopic) that can cause detrimental effects to national economies, including:

- Toxic effects on humans and other organisms – biotoxins
- Physical impairment/death of fish/shellfish
- Nuisance conditions – odors and discolouration affecting recreation/tourism
- Overwhelming effects on ecosystems, including

    1) Severe anoxic conditions
    2) Overgrowth of bottom habitats
    3) Disruption of 'normal' food webs

However, the concentrations of algal cells which make HABs do not have to be so dense as to be visible – hence the confusion with the common term 'Red Tides'

RED TIDES – are blooms of single-celled microorganisms (phytoplankton) that attain such densities that they discolour the seawater; the most common 'red tides' are the motile phytoplankton cells, termed – dinoflagellates.
Red tide is a poor term since they have:

1) Nothing to do with tides (although always coastal), and are
2) Not necessarily red in colour (may be red/brown/green/orange)

Red tides are natural events and have been reported since Biblical times (Exodus, Chap.7, Vs. 20-21)
Most are commonly harmless and unreported.
Remember of the ~ 3400-4,100 extant marine phytoplankton species:

- only 300 species reach densities for water discolouration 'red-tides' (7%)
- 60-80 species of these 300 spp. are harmful (2%), and only half of these have the capacity to produce toxins (1%)

Three Basic Types of Harmful Algal Blooms
(all three found on West Coast of North America)

I. Indiscriminate Kill of Marine Fauna (Marine Fauna Mass Mortality)
II. Selective Fish (Marine Fauna) Killers (usually toxins produced)
III. Toxic Vectoring Through Food Chain (i.e., paralytic shellfish poisoning)

I. Indiscriminate Kill of Marine Fauna (Marine Fauna Mass Mortality)

This type of HAB is due to the creation of anoxic conditions resulting in the indiscriminate mortality of marine fauna, including fish and invertebrates. Any phytoplankton species could potentially cause such a HAB in a coastal environment thereby causing a change or disruption of normal food-web dynamics

Oxygen depletion is due to:

- High respiration at night, or in dim light during the daytime
- Bacterial respiration (decomposition reaction) during decay of bloom!

The most common series of events leading to such a HAB are as follows:

1 phytoplankton grow and multiply, increase in density
2 cells become concentrated physically – onshore winds, semi-enclosed bay
3 nutrients needed for their continued growth are eventually exhausted
4 phytoplankton cells die, and are decomposed (which requires oxygen) by bacteria
5 waters become low in oxygen or become oxygen depleted (anoxic)
6 indiscriminate death of marine fauna A CASCADING EFFECT

West Coast examples: dinoflagellates, *Lingulodinium polyedrum* (Kudela and Cochlan, 2000, *Aquatic Microbial Ecology* 22: 31-47) *Noctiluca scintillans* (Buskey, 1995, *Journal of Plankton Research* 17: 29-40) and the phototrophic ciliate, *Mesodinium rubrum* (Cloern et al., 1994, *Journal of Plankton Research* 16: 1269-1276) - a species which blooms frequently in San Francisco Bay, including last June, 2000.

I. Selective Fish (Marine Fauna) Killers (usually toxins are produced)

Phycotoxins, which are either ingested (endotoxins) or released into water (exotoxins), can harm or kill fish and shellfish. On the West Coast, HAB fish kills are most common in pen-reared Atlantic (*Salmo salar*) and Pacific (*Oncorhynchus* spp.) salmonids. Fish kills of wild fish have been reported, but are not as severe as the East Coast and Gulf of Mexico HABs.

- Raphidophyte, *Heterosigma akashiwo (= H. carterae)*: excessive mucous secretion by *H. akashiwo* results in fish mortality from the lodging of mucous in fish gills and the subsequent impairment of respiratory and osmoregulatory capabilities. An ichthyotoxic mechanism of killing by *H.* akashiwo has also been suggested involving superoxide hydroxyl radicals or hydrogen peroxide. No harm to humans. This species has also been found off the Los Angeles River. This is the main killer of farmed fish in Pacific Northwest, and also a major killer of penned fish world-wide (e.g., New Zealand, Scotland, Chile, Norway).

- Diatoms, *Chaetoceros convolutus* and *Ch. concavicorne* (both marine species) and *Ch. Concavicornis* (more euryhaline) are spiny phytoplankters which have long siliceous (glass)

setae armed with short secondary spines (barbed setae). Chains of these cells become lodged between gill tissue, and trigger massive amounts of mucus by the fish. Continuous irritation exhausts the supply of mucus and mucous cells, causing lamellar degradation and eventual death from reduced oxygen exchange.

- Dinoflagellates, e.g., *Gymnodinium breve* – problem areas include tropical seas, Gulf of Mexico, Florida, and Japan. Several different toxins either secreted or leaked out or released during cell lysis, causes red blood cells to burst in fin fish, eventual asphyxiation since they can't transport oxygen. Have been reported in Tampa Bay, Fl by Spanish explorers in the 16th century, not on the west coast.

- *Pfiesteria* spp - toxic ambush predators - no reports on the west coast as of 2000, strictly a east coast problem, mainly North Carolina, appears to be spreading northward into Chesapeake Bay and Virginia.

II. Toxic Vectoring Through the Food Chain

This HAB mechanism is an indirect poisoning via the food chain, where the filter-feeding organism is typically insensitive or marginally sensitive to the algal toxin, but the predator which feeds on this organism is sensitive to the toxin retained and accumulated in the tissue of the filter feeder. This type of HAB is the most dangerous to mammals (including humans) on the west coast, and can result in human illness, memory loss and mortality. Generally the toxin accumulates in the guts of crustaceans, crabs and sand crabs, and in the muscles of clams, scallops, geoducks, and oysters .

- Paralytic Shellfish Poisoning (PSP) – caused by a saxitoxin (there at least 18 different types of these PSP neurotoxins) released by species of the dinoflagellate genus, *Alexandrium*, particularly *A. tamarense* and *A. catenella*. There is no specific antidote to saxitoxin poisoning from PSP, only a treatment of the symptoms to prevent death by asphyxiation. First reported (and understood) on the West Coast by Native Americans, and later by Capt. George Vancouver (RN) in 1793 during explorations of the Pacific Northwest (Poison Cove, B.C). Note that toxin accumulates in the heavily pigmented siphon of butter clam (*Saxidomus giganteus*) for ~ 1 year. Possible cyclical periodicity in B.C. (every 6-8 years;El Nino years

- Diarrhetic Shellfish Poisoning (DSP) – caused by species of the dinoflagellate genus *Dinophysis*. Although DSP is not normally reported on the West Coast, the causative organism is commonly found here and recent unpublished research suggests that DSP is found in central California (i.e. Monterrey Bay). Species include *D. fortii, acuta, acuminata and norvegica*). Also the benthic dinoflagellate, *Prorocentrum lima* produces okadaic acid.

- Amnesic Shellfish Poisoning (ASP) also called Domoic Acid Poisoning (DAP) – first became a concern on the West Coast in 1991 with the death of >100 marine birds. Massive marine

mammal deaths (> 400 sea lions, northern fur seals, otters, marine birds) occurred in spring, 1998. Human deaths (3) and serious illness (> 100) reported on East Coast of Canada during one bloom event. The toxin, domoic acid (DA), is produced by species of the diatom genuus *Pseudo-nitzschia*. The toxin accumulates in filter-feeding shellfish (e.g., blue mussels, and razor clams), Dungeness crabs, zooplankton and planktivorous fish, northern anchovies sardines, (and zooplankton – unpublished results). Both non-toxic and toxic species of *Pseudo-nitzschia* species, including *P. multiseries, australis and pseudodelicatissima* have been identified on the West Coast, but individual toxic strains are not always toxic. A recent publication (Scholin *et al.* 2000, *Nature* 403: 80-84) describes the trophic transfer of DA to marine mammals off the central California coast (Monterey Bay region).

In humans, DA poisoning can cause disorientation and short-term memory loss that can become permanent. This disorientation was very apparent in affected sea lions in 1998, many which were apparently unable to find their way back to the sea in 1998. Recently, toxic blooms causing harm to marine mammals were reported in spring/summer, 2000 in upwelling zones off s central California coast (Trainer *et al.*, 2000, *Limnol.Oceanogr.* 45: 1818-1833), and blooms have been also reported (and shell fish affected) off Washington/Oregon in September-October, 2000.

Useful HAB Websites

http://www.redtide.whoi.edu/hab/	*Recommended*
http://www.bigelow.org/hab/	*Recommended*
http://www.cbr.nrc.ca/issha/	
http://www.ioc.unesco.org/hab/default.htm	
http://www.ioc.unesco.org/hab/news.htm	
http://www.nwfsc.noaa.gov/hab	
http://www.start1.com	

Good Review Literature

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Article A

Harmful Algal Blooms (HABs) Summary

Harmful algal blooms (HABs, which include the highly visible 'red tides', have become an increasing menace to our coasts over the last decade. Until recently, the most common type of HABs experienced in California were those caused by relatively harmless, non-toxic dinoflagellates (motile, single-celled phytoplankton). These microscopic, plant-like organisms accumulate in such great numbers that when they die from lack of nutrients and begin to decay, their decomposition uses up all the oxygen in the water and the region may become anoxic, resulting in an indiscriminate kill of marine fauna. Red tides may also cause respiratory distress in humans as well as in marine mammals and birds because the individual cells can be aerosolized and swept along the ocean surface by local winds. A dramatic red tide bloom of the dinoflagellate *Lingulodinium polyedrum* occurred in 1995, extending from the upper Baja peninsula in Mexico to Monterey Bay and as far offshore as San Clemente Island. Fortunately, a strong wind event dissipated this massive bloom prior to its decay, and no harm to the marine environment was reported. Although the economic impacts of such tides may be massive, scientists are still unsure of the factors that sustain such blooms, and little is known about their ecophysiology. In the AME paper (attached), Drs. Cochlan and Raphael Kudela, have demonstrated that *L. polyedrum* grows very well when provided with a broad range of nitrogen concentrations and light levels.

Most notably, these cells can be nourished (or fertilized) by an organic form of nitrogen that had been previously ignored in HAB studies – urea – which is a likely contaminant in heavily urbanized regions such as their study site off Newport Beach, CA. Urea and ammonium are found in high concentrations in both sewage, urban runoff and agricultural fertilizers.

Kudela and Cochlan are continuing their interests in HABs on another HAB phytoplankton, the potentially toxigenic diatom genus *Pseudo-nitzschia*, which is found locally along much of the west coast, including Monterey Bay. This diatom produces a toxin called domoic acid that enters the food chain through a number of vectors and accumulates in various zooplankton, crabs, shellfish and finfish. Marine birds and mammals feeding on these contaminated organisms become ill, and many eventually die, which unfortunately we have seen in abundance on the shores of Monterey Bay. Domoic acid poisoning was also the cause of a massive bird poisoning in 1961, which resulted in the birds acting as if they were intoxicated; this event was part of the inspiration for Alfred Hitchcock's movie "The Birds". In Prince Edward Island,

Canada, over 100 people became ill eating blue mussels contaminated with domoic acid and three elderly people died from this naturally occurring neurotoxic diatom bloom.

Currently we are attempting to better understand the causes of such blooms and develop an enhanced predictive and early warning capability to monitor these events. Using laboratory cultures and field experiments, we (myself and Dr. Raphael Kudela (UCSC) hope to determine the ecophysiological characteristics under which this potentially toxic *Pseudo-nitzschia* genus becomes dominant in local waters, and the specific factors which regulate domoic acid production. Funding for this effort is supplied as part of the ECOHAB initiative, which is a joint program administered by several federal agencies including the National Science Foundation (NSF), National Aeronautic and Space Administration (NASA), Sea Grant, and the National Oceanic and Atmospheric Administration (NOAA).

Annie / this is a tough read but... I hope it is of use to you

Regards, Bill Gu

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Nitrogen and carbon uptake kinetics and the influence of irradiance for a red tide bloom off southern California

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ABSTRACT: The kinetics of nitrogen (nitrate, ammonium, urea) and carbon uptake by a red tide bloom consisting almost exclusively of the dinoflageliate *Lingulodinium polyedrum* (Stein) Dodge were determined with ^{15}N- and ^{13}C-tracer techniques, as a function of substrate concentration (for nitrogen) and irradiance (for both carbon and nitrogen). Samples were collected from Newport Beach, California, in late March 1995, during a massive red tide bloom which occurred off the California coast. At the collection site, surface concentrations of *L. polyedrum* reached 1.1×10^6 cells l^{-1}, with chlorophyll *a* = 125 µg l^{-1}. Maximal uptake rates of urea-N were approximately twice the maximal rates for either ammonium or nitrate during both the uptake versus substrate and uptake versus irradiance experiments, and the affinity for nitrate was much greater than previously demonstrated: half-saturation constant (K_s) = 0.47 µg-at N l^{-1}. Carbon and nitrogen uptake rates as a function of irradiance were well described by a 3-parameter P versus E relationship (photosynthesis vs irradiance) proposed by Platt & Gallegos (1980), although dark-uptake of nitrogen compounds accounted for ca 50% of V_{max}. These results demonstrate that *L. polyedrum* is capable of utilizing a broad range of both nitrogen concentrations and light fluences, and that urea could potentially provide a large percentage of the nitrogen demand at ambient urea concentrations and across the entire spectrum of light fluences. These data represent a more complete quantification of the N uptake dynamics of this bloom-forming species and contrast markedly compared to previous studies of *L. polyedrum*.

KEY WORDS: *Lingulodinium polyedrum* · Carbon · Nitrogen · Urea · Irradiance · Uptake kinetics

INTRODUCTION

During the late winter and early spring of 1995, a massive red tide bloom composed primarily of the dinoflagellate *Lingulodinium polyedrum* (Stein) Dodge (basionym *Gonyaulax polyedra*) occurred off the coast of California. Although blooms of this organism are relatively common in these waters, this particular episode was unusual in both its spatial extent and its temporal occurrence. The 1995 bloom extended from the upper Baja peninsula in Mexico to Monterey Bay, California, and as far offshore as San Clemente Island. At Newport Beach, where our samples were collected, chlorophyll *a* (chl *a*) concentrations were 125 µg l^{-1} while cell counts were in excess of 1.1×10^6 cells l^{-1}; even greater values were reported at La Jolla, where chl *a* concentrations reached 519 µg l^{-1} and cell counts exceeded 2×10^6 l^{-1} (Hayward et al. 1995). This represents the largest and most widespread red tide off California since 1902 (Torrey 1902). Typically, red tide blooms occur in southern California during the late spring and early summer, and the 1995 bloom was also the earliest known occurrence of a red tide for this region. Fortunately, *L. polyedrum* has rarely been reported to have direct toxic effects on other marine organisms, although a toxin similar to that which causes paralytic shellfish poisoning was first isolated

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from this species by Schradie & Bliss (1962). Since that report, *L. polyedrum* has regularly been included in tables of algal toxicity and screened with variable results (see review by Lewis & Hallett 1997). It appears, however, that marine fauna mortality associated with bloom concentrations of *L. polyedrum* is likely the result of deoxygenation and not direct toxicity.

Although *Lingulodinium polyedrum* has been extensively studied in both field (e.g. Holmes et al. 1967, Walsh et al. 1974, Eppley & Harrison 1975, MacIsaac 1978) and laboratory (e.g. Harrison 1976, Prézelin & Sweeney 1979, Heaney & Eppley 1981, Prézelin & Matlick 1983, Balch 1985) conditions, relatively little is known about the nitrogenous nutrition of this species. These data represent the first study to simultaneously examine the utilization of nitrate, ammonium and urea as a function of concentration, and to determine the effects of irradiance on N uptake. Previous studies have suggested that *L. polyedrum* must vertically migrate through the nutricline to obtain sufficient nitrogen to support observed growth rates (MacIsaac 1978, Heaney & Eppley 1981). This was predicated on the elevated dark-uptake values and the abnormally high half-saturation (K_s) values for NO_3^- in this species. We demonstrate that at the time of our study, *L. polyedrum* was capable of meeting its nitrogen demands from regenerated nutrients exclusively, and that the K_s values for all N substrates are much lower than previously reported.

MATERIALS AND METHODS

Sampling. This opportunistic 2 d study was conducted with samples collected aboard the RV 'Marda' during a cruise off Newport Beach, California (33° 34.58' N, 117° 53.24' W), on March 30, 1995, at approximately 10:30 h Pacific Daylight Time (PDT). Whole water was collected from the near surface using a clean plastic bucket, and stored in 2 acid-cleaned polyethylene carboys (rinsed 3× with sample water). The carboys were transported in dim light to the laboratory where they were placed in a walk-in culture room at low light (25 µmol photons m^{-2} s^{-1}), constant temperature (14°C), and with a bubbling air source. Vertical profiles of pH, temperature, salinity, and dissolved oxygen were conducted using a Seabird SBE19-03 CTD profiler equipped with an O_2 sensor. Light was measured with a Biospherical Instruments profiling 4π PAR meter with a matching deck unit. Discrete nutrient and pigment samples were collected using 5 l Niskin bottles (equipped with silicon springs) deployed on a hydrowire. Nutrient and pigment samples were stored (frozen) on dry ice until analysis at the laboratory, and samples for the determination of species composition were collected and stored after preservation with acid Lugol's solution. Additional samples for nutrients, pigments, and species composition were collected again immediately before the initiation of laboratory experiments.

Tracer uptake experiments. Water was dispensed into 280 ml polycarbonate incubation bottles on March 31, 1995, ca 24 h after initial collection. Kinetic parameters of uptake for NO_3^-, NH_4^+, and $CO(NH_2)_2$ were measured by adding varying concentrations (10 substrate levels ranging from 0 to 36 µg-at ^{15}N l^{-1} (Cambridge Isotope Laboratories; all 99 atom% ^{15}N) to duplicate sample bottles. Uptake versus irradiance parameters were determined by adding saturating concentrations (final concentration = 8.92 µg-at ^{15}N l^{-1}) of the isotopes to duplicate sample bottles (except urea, for which no replicates were conducted). The $^{15}NH_4^+$-labeled bottles were also inoculated (final concentration = 178.6 µg-at ^{13}C l^{-1}) with $NaH^{13}CO_3$ (Cambridge Isotope Laboratories; 99.9 atom% ^{13}C) for determination of carbon uptake rates.

The uptake kinetics experiments were conducted from 11:15 to 12:30 h PDT, while the photosynthesis versus irradiance (P vs E) and N uptake velocity versus irradiance (V vs E) experiments were conducted from 14:30 to 15:35 h PDT. All incubations were conducted in clear Plexiglas® incubators on the roof of the Allen Hancock building at the University of Southern California (ambient sunlight, ca 2300 µmol photons m^{-2} s^{-1}). Ambient water temperature was maintained at 14 ± 1°C. The kinetics experiments were conducted at ca 50% of the average incident irradiance (E_o; µmol photons m^{-2} s^{-1}) while the P versus E and V versus E sample bottles were placed in clear Plexiglas® tubes wrapped with neutral-density film (Courtaulds Performance Films) to simulate the following light levels: 75, 43, 26, 18, 15, 11.5, 8.5, 5, 3, 1, and 0.27% E_o. The 100% (unscreened) and 0% (wrapped in aluminum foil) bottles were not placed in Plexiglas® tubes, but were in the same incubator as the tubes.

All incubations were terminated by filtration (pressure differential <150 mm Hg) onto pre-combusted (450°C, 4 h) Whatman GF/F filters, and the filters were immediately placed in a drying oven (<60°C, >24 h). The filters labeled with ^{13}C were acidified with 3 drops of H_2SO_3. Time-zero samples were taken to correct for cellular adsorption of the isotopes, and additional samples were taken to ensure that the addition of H_2SO_3 did not affect the ^{15}N analysis. No dark bottle correction was made (e.g. dark bottles were not subtracted from light bottles) in the calculation of uptake rates (e.g. Li et al. 1993). Samples were prepared and analyzed for POC, PN and isotopic enrichment using a Europa Tracermass mass spectrometer.

Absolute uptake rates were calculated for both nitrogen and carbon using Eq. (3) in Dugdale & Wilkerson (1986). For calculation of the carbon uptake rates, the

ambient TCO_2 concentration was assumed to be 2000 µg-at C (Slawyk 1979). This value is well within the error estimate of the TCO_2 value estimated from pH, salinity, and assumed total alkalinity (2008 µg-at C) using the calculations of Lewis & Wallace (1997). Uptake rates for ammonium and urea were not corrected for isotope dilution (Glibert et al. 1982), and therefore should be considered conservative estimates of uptake to the extent that isotope regeneration may have occurred at the relatively high ambient pre-inoculation nutrient concentrations during the short experimental periods utilized.

Analytical methods. Determinations of $NO_3^- + NO_2^-$ (hereafter referred to as NO_3^-) and $Si(OH)_4^{4-}$ were carried out using a Technicon AutoAnalyzer II following the procedures outlined in Wood et al. (1967) and Armstrong et al. (1967), respectively. Ammonium samples, collected directly into the polypropylene reaction containers and stored refrigerated after addition of the phenolic reagent, were manually analyzed (within 48 h) using a spectrophotometer equipped with a 10 cm cell according to Sólorzano (1969). Urea samples (stored frozen) were also manually analyzed according to Price & Harrison (1987) and modified to account for a longer (30 min) and lower (80 to 85°C) digestion temperature. Pigment samples (chls *a*, *b*, *c*, carotenoids and phaeopigments) were collected on combusted Whatman GF/F filters and stored frozen prior to extraction in 90% acetone for 24 h at −20°C. Analysis for pigments was conducted using a 1 or 10 cm cell following the spectrophotometric method described by Parsons et al. (1984) using the extinction coefficients provided therein. All nutrient and pigment samples were collected in duplicate; reported values are means of the replicates. Phytoplankton species samples were preserved in acid Lugol's solution (Parsons et al. 1984) and stored in the dark until enumeration following Utermöhl procedures (Utermöhl 1958).

Curve parameters. All curve fitting was completed using a computerized, iterative non-linear least-squares technique (Deltagraph, Deltapoint Inc.) which utilizes the Levenberg-Marquardt algorithm (Press et al. 1992). The nitrogen kinetics data were fitted to the Michaelis-Menten formulation, after removing 1 extraneous point (see below):

$$V = \frac{V_{max} \times S}{K_s + S} \quad (1)$$

where V is the specific uptake rate (pg-at S cell^{-1} h^{-1}), V_{max} is the maximal specific uptake rate, S is the substrate concentration (ug-at S l^{-1}), and K_s is the half-saturation constant for the substrate (µg-at S l^{-1}). Uptake versus irradiance data were fitted to the 3-parameter P versus E model proposed by Platt & Gallegos (1980; hereafter referred to as the Platt model) for both carbon and nitrogen substrates. The original equation was modified to account for dark uptake by the inclusion of a positive y-intercept (as described by Cochlan et al. 1991b):

$$V = V_s\left(1 - e^{\frac{-\alpha \times E}{V_s}}\right)\left(e^{\frac{-\beta \times E}{V_s}}\right) + V_D \quad (2)$$

where V_s is the maximal uptake rate in the absence of photo-inhibition, α and β are the respective light-limited and light-inhibited slopes of the uptake versus irradiance curve defined by the equation with units of (pg-at S cell^{-1} h^{-1}) (µmol photons m^{-2} s^{-1})$^{-1}$, and E represents irradiance between 400 and 700 nm (µmol photons m^{-2} s^{-1}). For convenience we have not standardized the units for α and β (i.e. converted to either h^{-1} or s^{-1}), but have left the units in the same form as was used for the V and E values. The V_D term represents the positive intercept in the presence of dark-uptake, and is excluded from the carbon curves. Note that V_{max} and V_s are functionally equivalent if no photo-inhibition occurs, where V_{max} represents the maximal uptake rate observed, and V_s represents the maximal uptake rate in the absence of inhibition. The conventional index of light adaptation (E_k) is determined as the initial slope of the V versus E curve (V_{max}/α), and has units of µmol photons m^{-2} s^{-1}. For clarity, we have utilized nitrogen symbols; the same equation can be parameterized for carbon by substituting the symbol P^B (biomass-specific carbon uptake) for V (biomass-specific nitrogen uptake). Curve fits were completed using all available points; for ease of interpretation, the graphical representations provide the mean and error bars (±1 SD) for points where replicates were conducted.

As demonstrated by Frenette et al. (1993), intercomparison of various curve-fitting methods may lead to markedly different fitted parameters. All of these data demonstrated some degree of photo-inhibition, which is not accounted for by the Michaelis-Menten formulation. Furthermore, the fitted parameters (V_{max}, E_k, α) were similar using either the Platt model or the Michaelis-Menten hyperbola (modified to allow for dark-uptake) when the photo-inhibited samples were removed from the analyses (data not shown). Therefore, although most of the (few) previous studies of nitrogen uptake versus irradiance have used the Michaelis-Menten formulation, we present these data using the Platt model (except where noted). All curve fits (uptake vs irradiance, and uptake kinetics) are normalized to cell number. Rates are given in units of pg-at S cell^{-1} h^{-1} which is calculated by dividing the absolute uptake rate (ρ; pg-at S h^{-1} l^{-1} where S is carbon or nitrogen) by the cell abundance (cell l^{-1}). This rate is proportional to the biomass or PN-specific rate (V; h^{-1}). Statistical analyses for goodness-of-fit were

determined using the variance approximation techniques described by Zimmerman et al. (1987).

RESULTS

General hydrographic characteristics

In the spring of 1995, a massive algal bloom composed of the dinoflagellate *Lingulodinium polyedrum* occurred off the west coast of North America, extending from the northern Baja peninsula to Monterey Bay, California. In Newport Beach, California, surface concentrations of *L. polyedrum* were 1.1×10^6 cells l^{-1} and chl *a* concentrations were in excess of 125 mg m^{-3}. Biomass maxima (as determined from photosynthetic pigments) were found at both the surface and subsurface (6 m). The deepest collection depth for this study (10 m) exhibited chl *a* concentrations in excess of 60 mg m^{-3}, suggesting that the total biomass was substantially higher than the 835 mg m^{-2} calculated from trapezoidal integration of the upper 10 m. The predominant pigment was chl *a*, although secondary pigments (primarily carotenoids) accounted for ca 40% of the total at all depths (Fig. 1). Phaeopigments were negligible at all depths, indicating that at the time of collection, the bloom was composed of active cells rather than degradation products. The diffuse attenuation coefficient (K_{PAR}) for these waters was 1.075 m^{-1}. Floristic analyses of the samples indicated that *L. polyedrum* accounted for ca 97% of the autotrophic biovolume; co-occurrence of high concentrations of the heterotrophic dinoflagellate *Noctiluca scintillans* resulted in ca 42 and 56% of the total biovolume being attributed to *L. polyedrum* and *N. scintillans*, respectively. The *N. scintillans* population was not accounted for in the present analysis due to previous results indicating this species to be an apochlorotic, obligate phagotrophic dinoflagellate (Buskey 1995). During the approximately 24 h that the samples were maintained in our culture facility, cell numbers of *L. polyedrum* approximately doubled while chl *a* declined from 125 to 61 µg l^{-1}. No changes in the phaeopigment or accessory pigment to chl *a* ratios were detected, suggesting a physiologically mediated decrease in chlorophyll per cell.

Although previous dinoflagellate blooms off the California coast have often been associated with upwelling events (e.g. Dugdale 1979), the first 4 mo of 1995 for the southern California coast were characterized by positive sea surface temperature anomalies and negative upwelling index anomalies when compared to the long-term harmonic mean, and were accompanied by unusually heavy rainfall with comparably heavy coastal runoff throughout California (Hayward et al. 1995). Previous red tide blooms for this area have been reported from May to September (Hayward et al. 1995), which also makes this bloom the earliest known occurrence for this location. Vertical profiles indicated a relatively warm (15.0°C) and fresh (32.95 PSS) strongly stratified upper water column with cooler (12.9°C, 20 m), more saline (33.45 PSS, 20 m) waters below the pycnocline located at approximately 12 m depth. Dissolved oxygen concentrations were supersaturated throughout the mixed layer.

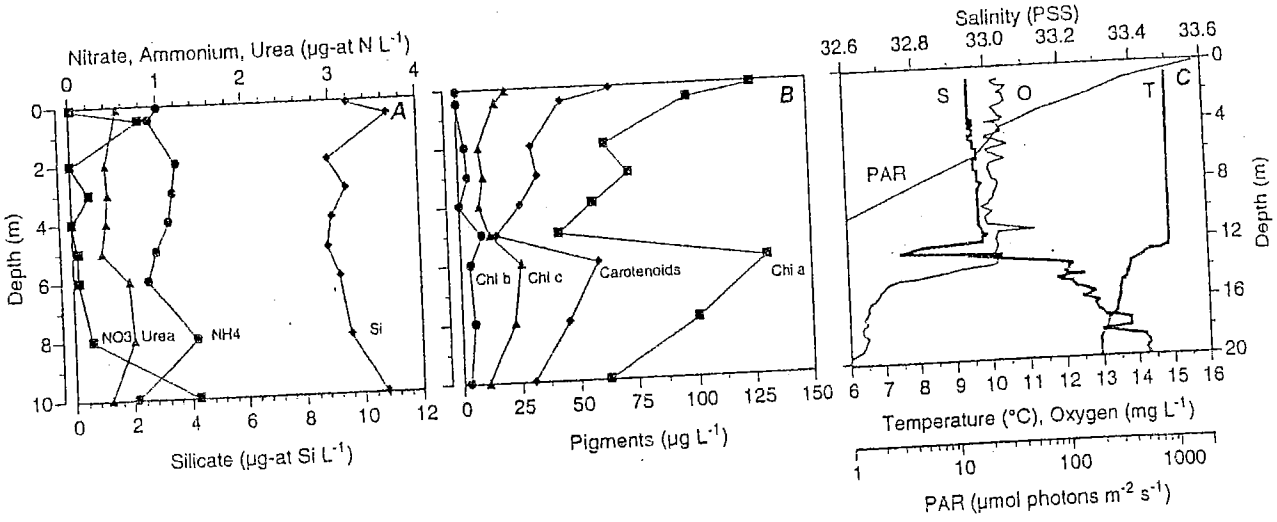

Fig. 1. Ambient conditions for the water column of Newport Beach, California, during sampling (March 30, 1995). (A) Depth profiles of $Si(OH)_4^{4-}$ (◆), NO_3^- (■), NH_4^+ (●), and urea (▲) concentration within the mixed layer (water column depth = 127 m). (B) Depth profile of plant pigment concentration (■: chl *a*; ●: chl *b*; ▲: chl *c*; and ◆: carotenoids) within the mixed layer. (C) Temperature (°C), salinity (PSS) oxygen (mg l^{-1}) and photosynthetically available radiation (PAR; µmol photons m^{-2} s^{-1}) at the study site. Note the change in depth (*y*-axis) scale from 10 to 20 m in (C)

Nutrient concentrations at the study site were typical of a red tide bloom (Eppley & Harrison 1975), with elevated $Si(OH)_4^{4-}$ concentrations and depleted N levels overlying a shallow thermocline and a deeper supply of NO_3^-. The anomalous near-surface peak at 0.5 m in NO_3^- and $Si(OH)_4^{4-}$ could be caused by freshwater runoff (Hayward et al. 1995; but note the lack of a corresponding salinity signal) aeolian deposition, or a mislabeled nutrient sample. Ammonium concentrations were elevated (ca 1 µg-at N l^{-1}) throughout the water column, with a maximum occurring at 8 m depth, below the subsurface chl *a* maximum (6 m). Approaching the thermocline, NO_3^- concentrations increased while NO_4^+ concentrations decreased. Measured urea concentrations (ca 0.5 µg-at N l^{-1}) were considerably lower than the NO_4^+ concentrations; urea exhibited a similar profile to NO_4^+, with a subsurface maximum at ca 6 to 8 m (Fig. 1).

Nitrogen kinetics

The estimated kinetic parameters for the uptake of nitrate and urea are presented in Table 1, and plotted in Fig. 2. It was not possible to determine the kinetics of ammonium using the iterative fitting procedure, due to elevated ambient concentrations present in the collected water (0.75 µg-at N l^{-1}). Fitting the data after linearizing with the Hanes-Woolf transformation (Dowd & Riggs 1965) provided values of 0.586 µg-at N l^{-1} and 1.01 pg-at cell^{-1} h^{-1} for the K_s and V_{max}, respectively (Fig. 2). However, these values rely on the assumed linearity of the data and should only be considered as approximations. At the highest nutrient inoculation (36 µg-at NO_3^- l^{-1}), NO_3^- uptake was depressed (0.231 ± 0.063 pg-at N cell^{-1} h^{-1}) to less than half of our reported V_{max}. We are not aware of any inhibitory or toxic effects in *Lingulodinium polyedrum* at these relatively low NO_3^- concentrations. It is unclear what the mechanism for this suppression was,

Table 1. Calculated kinetics parameters for uptake of NO_3^-, urea, and NH_4^+. Values for NO_3^- and urea were fitted using the Michaelis-Menten formulation; NH_4^+ values were derived from linearization (Hanes-Woolf) of the available data, and are presented for comparison only. The r^2 column provides the coefficient of determination and the sample size (n). Units for α_N are (pg-at N cell^{-1} h^{-1}) (µg-at N l^{-1})$^{-1}$. Cell abundance was 2.076 × 10^6 cells l^{-1}, PN was 44.5 µg-at N l^{-1} at the beginning of the experiment

	V_{max} (pg-at N cell^{-1} h^{-1})	K_s (µg-at N l^{-1})	α_N	r^2
NO_3^-	0.480	0.467	1.03	0.563
(SD)	(0.034)	(0.180)	(0.051)	(18)
Urea	1.321	0.989	1.34	0.729
(SD)	(0.119)	(0.316)	(0.114)	(16)
NH_4^+	1.01	0.586	1.72	0.922
(SD)	(0.069)	(0.627)	(0.397)	(20)

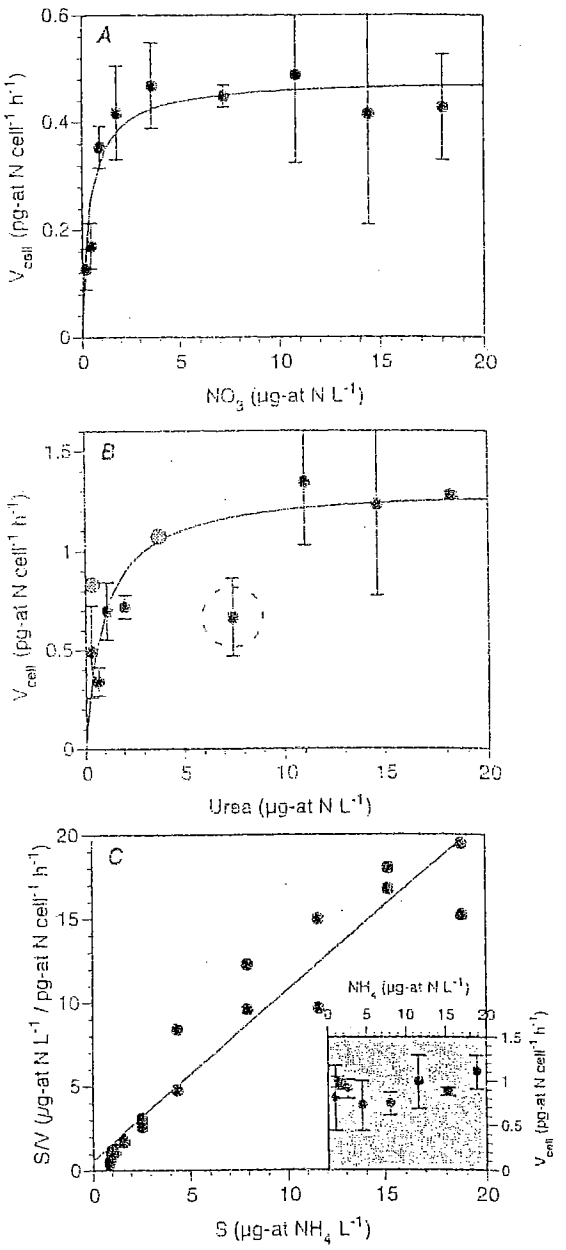

Fig. 2. Nitrogen uptake as a function of substrate concentration (A: NO_3^-; B: urea; C: NH_4^+) for a natural assemblage of *Lingulodinium polyedrum* off Newport Beach, California. The curved plots are fitted directly to the Michaelis-Menten formulation. Error bars indicate ±1 SD of duplicate samples. Data in dashed circle were not included in the curve fit or in the estimation of kinetic parameters. ⊛: non-replicate data. Note that for NH_4^+ (C), a Hanes-Woolf linearization of the data is plotted, with the non-linearized data presented as an inset graph

and these points were not used in our analyses. A comparison of maximal uptake rates (V_{max}, pg-at N cell^{-1} h^{-1}) indicated that uptake of urea was greatest, followed by uptake of NH_4^+ and NO_3^-, with values of 1.32, 1.01 and 0.480 pg-at N cell^{-1} h^{-1}, respectively. The K_s for urea was also greater than that for both NH_4^+ and NO_3^-, indicating that *L. polyedrum* could utilize lower concentrations of NH_4^+ and NO_3^- compared to urea. Because of the effects of V_{max} on K_s, these values are not necessarily a reliable indicator of preference at low nutrient concentrations (Healey 1980). The α parameter, referred to here as α_N ($\alpha_N = V_{max}/K_s$; [pg-at S cell^{-1} h^{-1}][μg-at S l^{-1}]$^{-1}$) to differentiate from the P versus E symbol, provides a more robust indicator for substrate affinity when substrate concentrations are low ($<K_s$), and substrate or inter-species competition is likely to occur (Healey 1980, Harrison et al. 1989, Cochlan & Harrison 1991). The α_N parameters (NO_3^-, NH_4^+, urea) were within a factor of 2.

Uptake versus irradiance

The estimated parameters for the uptake versus irradiance data are summarized in Table 2 for all substrates examined (NO_3^-, NH_4^+, urea and carbon) and plotted in Fig. 3. Lower maximal uptake rates (V_{max}) were obtained for the nitrogen substrates in the uptake versus irradiance experiments compared to the kinetics experiments (using V_{max} values from Michaelis-Menten curve fits for both data sets). There are several possibilities for this discrepancy, including the use of what we later determined to be less than saturating isotope enrichments (based on the kinetics experiments) or diurnal periodicity (e.g. MacIsaac 1978, Miyazaki et al. 1987, Pettersson & Sahlsten 1990, Cochlan et al. 1991a, Glibert & Garside 1992).

Although it was possible to fit the Platt model to all of these data, the N uptake data are not strictly light-dependent. Dark-uptake rates account for a significant proportion of the total uptake in these experiments, ranging from 37 to 52% of V_{max}. In contrast, dark carbon uptake was ca 1.1% of V_{max} for carbon. Both carbon and NO_3^- uptake versus irradiance data exhibited low E_k values and correspondingly high values for the initial slope of the uptake versus irradiance curves (α). The α value for carbon (after converting to chl-specific uptake rates) is proportional to 98% of the theoretical maximal value proposed by Platt & Jassby (1976) for coastal marine phytoplankton. All of the N substrates exhibited similar affinities for uptake at low light levels, with α values ranging from 2.04 to 2.41 × 10^{-3} (pg-at N cell^{-1} h^{-1}) (μmol photons m^{-2} s^{-1})$^{-1}$. Although the nitrogen substrate curves demonstrated pronounced uptake in the dark, the E_k value for carbon was 2 to 10 times lower than for the N substrates (25.8 μmol photons m^{-2} s^{-1} vs 64.1 to 253 μmol photons m^{-2} s^{-1} for carbon and nitrogen, respectively). These values, which represent the light intensity at the inflection point between light-limited and light-saturated uptake, translate into ca 1.2% of the average incident surface irradiance during the mid-afternoon incubations for carbon, and between 3 and 12% for nitrogen.

DISCUSSION

Lingulodinium polyedrum has been an oft-studied organism due to its frequent presence in red tide blooms off the southern California and Baja California coasts (review by Lewis & Hallett 1997), including examination of both nutrient (e.g. Eppley & Harrison 1975, Harrison 1976, MacIsaac 1978, Balch 1985) and light (e.g. Prézelin & Sweeney 1979, Heaney & Eppley

Table 2. Calculated uptake versus irradiance parameters for NO_3^-, NH_4^+, urea and carbon. All data were fitted to the Platt & Gallegos (1980) model modified for dark uptake, and error analyses were determined using the methods described by Zimmerman et al. (1987). *S*: various substrates being fitted; the Optimal % E_o column represents E_k as a percentage of near-surface irradiance (E_o). The r^2 column provides the coefficient of determination and the sample size (n). Units for α and β were omitted to conserve space; the units are (pg-at *S* cell^{-1} h^{-1})/(μmol photons m^{-2} s^{-1}) for both

	V_{max} (pg-at *S* cell^{-1} h^{-1})	V_{dark} (pg-at *S* cell^{-1} h^{-1})	E_k (μmol photons m^{-2} s^{-1})	α	β	Optimal % E_o	r^2 (n)
NO_3^-	0.321	0.166	64.1	2.41E^{-3}	2.05E^{-5}	3.0	0.769
(SD)	(0.026)	(0.002)		(1.04E^{-3})	(2.86E^{-5})		(26)
NH_4^+	0.488	0.182	149	2.05E^{-3}	7.41E^{-5}	7.0	0.801
(SD)	(0.126)	(0.018)		(9.48E^{-4})	(2.14E^{-5})		(23)
Urea	0.898	0.381	253	2.04E^{-3}	1.81E^{-4}	12.0	0.773
(SD)	(0.019)	(ND)		(6.67E^{-5})	(1.87E^{-5})		(12)
CO_2	5.25	0.059	25.7	2.04E^{-1}	2.15E^{-3}	1.2	0.838
(SD)	(0.404)	(1.31)		(1.39E^{-1})	(5.23E^{-4})		(23)

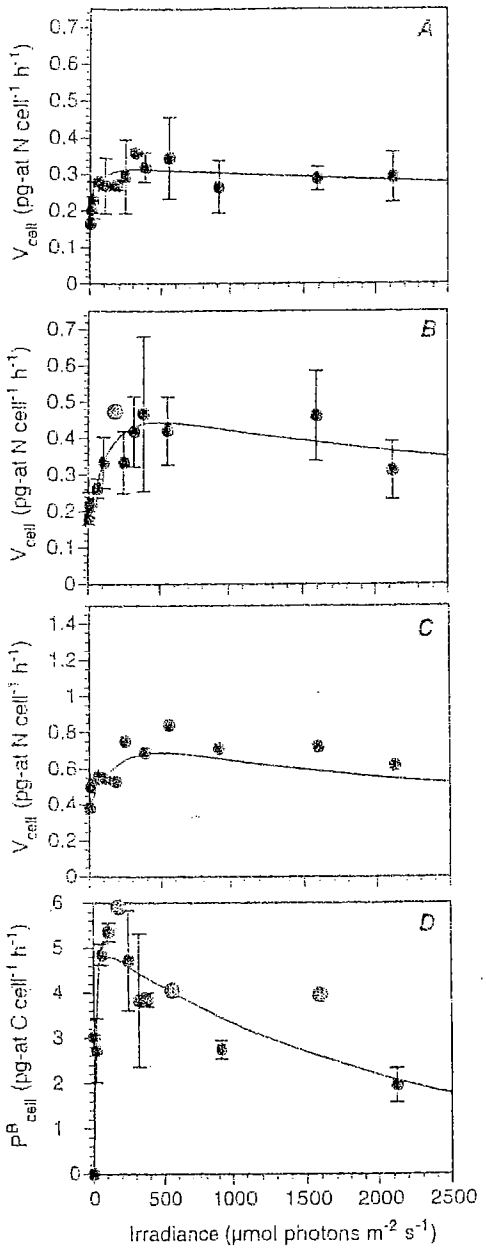

Fig. 3. Nitrogen (A: NO_3^-; B: NH_4^+; C: urea) and (D) carbon uptake as a function of irradiance for a natural assemblage of *Lingulodinium polyedrum* off Newport Beach, California. The curved plots are fitted directly to the 3-parameter P versus E curve (Platt & Gallegos, 1980) modified to account for dark uptake (Cochlan et al. 1991). Error bars indicate ±1 SD of replicate samples, except for urea (C) for which there were no replicates. ●: data were not included in the curve fit or in the estimation of kinetic parameters ◍: non-replicate data

1981, Meeson & Sweeney 1982, Prézelin & Matlick 1983) physiological responses in this species. To date, however, no study has examined the nitrogen kinetics and photosynthetic response of this species simultaneously. Our reported values also represent one of the few descriptions of the dynamics of urea uptake for a dinoflagellate under natural bloom conditions.

Previous field observations coupled with studies in the laboratory have led to the speculation that *Lingulodinium polyedrum* achieves maximal biomass concentrations in nutrient-depleted waters by vertically migrating through the nutricline at night (MacIsaac 1978, Heaney & Eppley 1981). By doing so, *L. polyedrum* could maximize its ability to utilize NO_3^- in the dark, which could account for 50 to 100% of its nitrogenous nutrition (Harrison 1976), while photosynthesizing during the daylight hours. Our results confirm that *L. polyedrum* is capable of maintaining significant uptake in the dark. It is important to note, however, that the culture room lighting (25 µmol photons m^{-2} s^{-1}) was equal to the E_k value for carbon uptake by this species (25.7 µmol photons m^{-2} s^{-1}), suggesting that significant amounts of stored photosynthate may have been present before the initiation of the experiment. Although elevated dark-uptake values are often associated with N deficiency (e.g. Harrison 1976, Paasche et al. 1984), this interpretation is confounded by the often high rates of dark-N uptake found in *L. polyedrum*, even under N-sufficient conditions (Eppley & Harrison 1975, Harrison 1976, MacIsaac 1978, Heaney & Eppley 1981). Harrison (1976) showed that in culture, dark NO_3^- uptake was enhanced from ca 20 to 40% of the light assimilation value when the culture was nitrogen starved, and that dark-uptake was more affected by starvation than was light uptake. Heaney & Eppley (1981) also showed that *L. polyedrum* exhibits complex behavior when nutrient limited, including avoidance of high light levels and cessation of vertical migration. In their data, this was accompanied by a rapid (ca 1 d) drop in the atomic C:N ratio from 8.5 to 6.5 with the addition of nitrogen. For our experiments, dark uptake accounted for ca 45% of total N uptake and the mean C:N ratio from the ^{13}C samples was 9.1 ± 0.20 (±SE). Based on the references cited above, this suggests that the assemblage was approaching nitrogen limitation. This remains speculative, however, given the wide range of dark-uptake capacities and C:N ratios in this and other algal species.

Heterotrophic uptake (especially by bacteria) of dissolved N compounds could also contribute to our measured dark-uptake rates. However, the elevated concentrations of *Lingulodinium polyedrum* would make the contribution of other potential competitors negligible in the measured uptake rates. Bacteria are known to preferentially utilize ammonium before nitrate or urea (e.g. Kirchman 1994, Kirchman et al. 1994, Kirchman & Wheeler 1998), and may gain most of their nitrogen requirement from dissolved free amino acids in coastal environments (Billen & Fontigny 1987, Kirchman 1994, but see Kirchman & Wheeler 1998). Auto-

trophic organisms have also been shown to outcompete heterotrophs at elevated substrate concentrations (Suttle et al. 1990) such as were measured at our study site. We are therefore confident that our dark uptake rates are not representative of heterotrophic uptake given the elevated ambient concentrations of ammonium and the use of near-saturating additions of N in our uptake versus irradiance experiments.

Based on V_{max} values, apparent N utilization followed the order: urea, NH_4^+, NO_3^-. Calculation of the *f*-ratio [$f = V_{NO_3}/(V_{NO_3} + V_{NH_4} + V_{urea})$] at ambient nutrient concentrations also demonstrates a reliance on regenerated forms of nitrogen, with an estimated value of 0.01. This value was calculated using the Michaelis-Menten equation and the kinetics parameters from Table 1. Even if saturating concentrations of NO_3^- were present (for example if the population were to vertically migrate below the nutricline), simple calculations demonstrate that the *f*-ratio would only rise to 0.29. This value is based on the measured uptake rates and kinetics parameters (Table 1) when the ambient NH_4^+ and urea concentrations are held constant and the NO_3^- concentration is increased to 12 µg-at N l^{-1}, stoichiometrically equal to the ambient $Si(OH)_4^{4-}$ concentration. Calculation of the percent urea uptake (% $Uptake_{urea} = [V_{urea}/(V_{urea} + V_{NH_4} + V_{NO_3}) \times 100]$, determined using kinetics parameters from Table 1 and average nutrient concentrations (in the upper 10 m), provides a relative urea utilization of 33.8%. This value falls well within previously reported literature values for other natural assemblages in oceanic, coastal, polar, upwelling, and freshwater systems (Table 3).

It is possible that the NO_3^- uptake rates, but apparently not the urea uptake rates, were inhibited by the relatively high ambient NH_4^+ concentrations (e.g. McCarthy 1981) or were diurnally fluctuating. However, Harrison (1976) reported that *Lingulodinium polyedrum* exhibited no NH_4^+ inhibition at 50 µg-at NH_4^+ l^{-1} for short periods. He also reported maximal NO_3^- uptake and nitrate reductase (NR) activity at midday in both N-saturated and N-deficient cultures. Similarly, Packard & Blasco (1974) reported high NR activity in low-NO_3^- waters. Regardless, the instantaneous nitrogen demand for this assemblage could easily be met by a combination of NH_4^+ and urea assimilation (assuming 7:1 C:N assimilation ratio, a sustained V_{max} for C uptake, and saturating irradiances). It is important to note, however, that sustained uptake at V_{max} could deplete the ambient nutrient pools in about 4 h, requiring an equally rapid regeneration rate to maintain this growth rate.

MacIsaac (1978) in a study of a naturally occurring bloom off the Baja peninsula argued that *Lingulodinium polyedrum* required both sufficient (and simultaneous) surface light and NO_3^- to achieve red tide concentrations, and that there was no evidence for the vertical migration and dark uptake of NO_3^-. Although our E_k values (3 to 12% of near-surface light) are similar to the values MacIsaac (1978) reported (ca 4 and 10% for NO_3^- and NH_4^+ respectively), MacIsaac also reported insignificant dark-uptake of NO_3^-. Prézelin & Matlick (1983) demonstrated that under nutrient-limiting conditions, *L. polyedrum* is more susceptible to photo-damage, while Heaney & Eppley (1981) reported that under nutrient-limiting conditions, *L. polyedrum* will delay or even cease vertical migration into higher light. These behavioral adaptations likely provide both prolonged exposure to higher subsurface NO_3^- levels, and avoid photodamage associated with the near surface.

In this study, uptake rates for all of the tested substrates demonstrated at least some photoinhibition (β values; Table 2). The carbon data were more pronounced in this inhibition, which is not unexpected given the extremely low E_k value and the direct dependence on light for carbon assimilation. Nitrogen uptake is potentially buffered by the ability to utilize indirect sources of reducing energy, and so would not be expected to demonstrate the same degree of dependency on irradiance. Notably, however, uptake rates at even the highest irradiance (>2100 µmol photons m^{-2} s^{-1}) were not appreciably depressed, with N uptake rates at 63 to 90% of V_{max}. Given the elevated dark-uptake of N, this lack of suppression may be partly explained by the lack of dependence on photon fluences for N uptake. However, examination of the dark-corrected V_{max} values (V'_{max}; calculated as $V'_{max} = V_{max} - V_{dark}$) indicates that N uptake for the highest light levels remained at >50% of V'_{max} while the light-inhibited carbon uptake rates were ca 37% of V_{max}.

Despite the low E_k values, this assemblage was capable of maintaining uptake rates of all N substrates at 50% of V_{max} or better, even at the highest irradiance (2119 µmol photons m^{-2} s^{-1}). This irradiance is unlikely to be encountered for any length of time in ecologically relevant conditions, given that it was achieved at noon in a Plexiglas® incubator. These data, together with the dark-uptake values which demonstrated that *Lingulodinium polyedrum* could maintain 37 to 52% of V_{max} in darkness, indicate that this dinoflagellate is capable of maintaining high uptake rates of nitrogenous substrates at all light levels. Similarly, photosynthetic carbon assimilation reached 50% of V_{max} at the extremely low level of 1.2% of surface irradiance, and was still at 37% of V_{max} at the highest light levels (Fig. 3D). It is possible to calculate the apparent demand for nitrogen at varying light levels and ambient nutrient concentrations based on our reported uptake versus irradiance and uptake versus substrate concentration kinetic

Table 3. Summary of literature values of urea uptake relative to total uptake, % $Uptake_{urea}$ = [$Uptake_{urea}$/($Uptake_{NO_3^-}$ + $Uptake_{NH_4^+}$ + $Uptake_{urea}$)] × 100 determined in natural assemblages from absolute[a] or specific[b] uptake rates conducted under natural conditions. Values reported are means with ranges given in parentheses. Depths sampled are reported in meters or percentage of surface irradiance (I_0)

Area	% Urea	Depth (m or % I_0)	Incubation period (h)	Isotope dilution correction	Comments	Source
Oceanic						
NE Subarctic Pacific Ocean						
Winter	12.2[a] (8.2–19.3)	100–1%	24	No	Stns P20, OSP	Varela & Harrison (1999)
Spring	30.0[a] (7.0–56.0)	100–1%	24	No	(integrated rates and	
Late summer	19.2[a] (22.5–30.1)	100–1%	24	No	high [NO_3^-])	
Central North Pacific Gyre	42[a] (27–57)	81–1%	24	No	Integrated rates	Eppley et al. (1973)
Subtropical (low [NO_3^-])					November	
Central North Pacific Gyre						Eppley et al. (1977)
Winter (subtropical)	30[a,d] (20–45)	0–85 m	24	No	Integrated rates	
Summer (subtropical)	25[a,d] (13–39)	0–80 m	24	No	Low [NO_3^-]	
Central North Pacific Gyre	32[a]	100–1%	3–4	Yes	Integrated rates	Sahlsten (1987)
Subtropical (low [NO_3^-])					August–September	
North Pacific						
Northern (J1–J7)	12[a,f] (8–22)	Surface	3	No	Maximum rates	Kanda et al. (1985)
Tropical/Subtropical (J9–J23)	31[a,f] (26–36)	Surface	3	No	(V vs S expt)	
Eastern Equatorial Pacific	5.6[a,d] (3.8–7.3)	15 m	6–8	No	Iron Ex II (controls and pre-fertilization)	Cochlan & Kudela (unpubl.)
Gulf Stream warm core rings	12[a]	100–3%	4	Yes	Integrated rates	McCarthy & Nevins (1986)
South Atlantic (off Brazil)	13.1[a]	50 and 1%	~1	Yes		Metzler et al. (1997)
South Atlantic (off S. Africa)	13.1[a] (0–17)[c]	Surface	4–6	No	Low [NO_3^-]	Probyn (1985)
NW Indian Ocean	28[a] (0–64)	100–1%	24	No	Integrated rates (inter-monsoon)	Watts & Owens (1999)
Coastal						
Baltic Sea (low [NO_3^-])	31[a] (24–44)	0–15 m	4–6	No	Drogue study of cyanobacteria bloom *Nodularia spumigena*	Sörensson & Sahlsten (1987)
Oslofjord (Norway)	19 (0–53)	0–2 m	3–5	No	April–October	Kristiansen (1983)
Eastern Skagerrak (Sweden)	Daytime %				Nighttime %	Pettersson (1991)
Autumn	13[a] (10–20)	0.5–4.0 m (50%)	~3	Yes	10[a] (8–12)	
Spring	7[a] (1–13)	0.5–4.0 m (50%)	~3	Yes	17[a] (6–22)	
Summer	14[a] (10–17)	0.5–4.0 m (50%)	~3	Yes	17[a] (14–20)	
Open Skagerrak (Sweden)					High [NO_3] during May diel study	Pettersson & Sahlsten (1990),
North	37[a] (22–53)	4–13 m	3–5	–		Rosenberg et al. (1990)
South	28[a] (19–61)	4–15 m	3–5	–		
Western English Channel						L'Helguen et al. (1996)
Winter	17[a,c] (8–29)	1.5–6 m (50%)	4	Yes		
Spring	10[a,c] (4–12)	1.5–6 m (50%)	4	Yes		
Summer	13[a,c] (12–14)	1.5–6 m (50%)	4	Yes		
Autumn	29[a,c] (10–47)	1.5–6 m (50%)	4	Yes		
Western Irish Sea	48[a]	Surface (4 m)	4.5	No	Daily rates used (night and daytime)	Turley (1985)
Lower Narragansett Bay, RI (USA)					Furnas (1983)	
Winter/spring	15[b] (0–44)	Surface	3.5–9	No	Generally substrate	
Summer	23[b] (3–64)	Surface	3.5–9	No	depletion (>80% used)	

(Table 3 continued on next page)

Table 3 (continued)

Area	% Urea	Depth (m or % I_0)	Incubation period (h)	Isotope dilution correction	Comments	Source
Strait of Georgia (Canada)						
Frontal	23[a] (14–34)	2 m (50%)	6	No	4, serial 6 h incubations	Price et al. (1985)
Stratified	32[a] (26–38)	3 m (50%)	6	No		
British Columbia coast (Canada)						
Winter	25.9[a] (8.4–45.7)	100–1%	24	No	Stns P4, P12, P16 (integrated rates)	Varela & Harrison (1999)
Spring	28.6[a] (12.9–45.7)	100–1%	24	No		
Late summer	14.0[a] (3.4–22.7)	100–1%	24	No		
Washington coast (USA)						
Shelf (fall-winter/spring/summer)	13.9/26.3/34[a]	100–1%	4–28	No	Possible [urea] errors; seasonal averages, using integrated rates	Dortch & Postel (1989)
Shelf break	15/26.8/30[a]	100–1%	4–28	No		
Offshore	20/23/21.9[a]	100–1%	4–28	No		
Oregon & Washington (USA)	20.6[a] (7.5–36.9)	15 m	2–4	No	Low nitrate stns (serial 0.5–1.0 h incubations)	Kokkinakis & Wheeler (1987)
Southern California (La Jolla, USA)	25[b] (6–47)	87–1%	24	No	Integrated rates	McCarthy et al. (1977)
Southern California (Newport Beach, USA)	33.8[b]	surface	~1	No	*Lingulodinium polyedrum* bloom	This study
Brazilian coast	18.0[a]	50 and 1 %	~1	Yes		Metzler et al. (1997)
Tasman Sea (Westland, NZ)						
Summer inshore	34.1[a] (5.1–79.4)	10 m	4–6	Yes	Artificial light	Chang et al. (1995)
Summer offshore	24.2[a] (15.9–31.4)	10 m	4–6	Yes	Artificial light	
Winter inshore	24.5[a] (10.9–38.7)	10 m	4	No	Potential (max) rates	Chang et al. (1989)
Winter offshore	25.4[a] (18.4–33.3)	10 m	4	No	Potential (max) rates	
Kaneohe Bay, HI (USA)	53.5[b] (7.2–100.0)	3 m	3–4	No	Time-series expt (every 0.5–0.75 h)	Harvey & Caperon (1976)
Upwelling						
Oregon & Washington coast (USA)	3.8[a] (2.0–7.2)	15 m	2–4	No	High nitrate stns (serial 0.5–1.0 h incubations)	Kokkinakis & Wheeler (1987)
Southern Benguela (S. Africa)						
Inshore	13.5[a] (0–19)[c]	Surface	4–6	No	High [NO_3^-]	Probyn (1985)
Shelf	13.7[a] (0–24)[c]	Surface	4–6	No	Low [NO_3^-]	
Namibian Coast	20[a] (8–44)	100–1%	4–6	Yes	Integrated rates	Probyn (1988)
Tasman Sea (New Zealand)						
Inshore	6.6[a] (1.8–12.0)	5–15 m	4–6	No	Mid-winter (after upwelling)	Chang et al. (1992)
Offshore	104[a] (4.1–22.3)	5–15 m	4–6	No		
Estuarine						
Carmans River, NY (USA)	11.3[a] (8.4–13.7)	Surface	~2	No		Carpenter & Dunham (1985)
Great South Bay, NY (USA)						
Spring	53[a]	0–1 m	2–3	No	Shallow lagoon	Kaufman et al. (1983)
Summer	53[a]	0–1 m	2–3	No		
York River, VA (USA)						
Summer	14–45[b]	1 and 4 m	2	No	Serial, daytime incubations every 2 h using ^{14}C-urea	Webb & Haas (1976)
Autumn	~5[b]	0.5 and 2 m	2	No		

Table 3 (continued)

Chesapeake Bay (USA)						
Spring	37.2[a,e]	Near-surface	0.5	Yes		Bronk et al. (1998)
Summer	28.2[a,e]	Near-surface	0.5	Yes		
Autumn	11.8[a,e]	Near-surface	0.5	Yes	11.1% including nitrite	
Chesapeake Bay (USA)					Drogue study	Glibert et al. (1991)
Winter	34[a,c] (22–57)	Near-surface	1	Yes	February	
Spring	12[a,c] (6–19)	Near-surface	1	Yes	April	
Summer	33[a,c] (11–62)	Near-surface	1	Yes	June and August	
Chesapeake Bay (USA)	20.3[a,e]	75 and 50%	2–4	No	Annual mid-day rates	McCarthy et al. (1977)
Gulf of Bothnia (Sweden)						Cochlan & Wikner (1993)
Northern basin (high $[NO_3^-]$)	29.0[a] (24.9–33.1)	100–1%	6	No	Summer, daytime	
Southern basin (low $[NO_3^-]$)	62.8[a] (50.5–84.3)	100–1%	6	No	integrated rates	
Polar						
Northeast Water Polynya	21[a,g]	100–0.1%	24	No	Spring/summer integrated rates	Smith et al. (1997)
Northern Baffin Bay (Canada)	32[a] (7–53)	100–1%	24	No	Summer integrated rates	Harrison et al. (1985)
Barents Sea					Autumn/winter rates	Kristiansen & Lund (1989)
Large biomass layer	11[a] (SD = 9)	5–60 m	6–8	No	Fluorescent light used	
Small biomass layer	27[a] (SD = 25)	5–60 m	6–8	No	Fluorescent light used	
Barents Sea						Kristiansen & Farbrot (1991)
Ice algae	2–3[a]	–	6–8	No	Spring/summer rates	
Marginal Ice Zone (MIZ)	3[a] (SE = 1)	Subsurface chl max.	6–8	No	Fluorescent light used	
South of MIZ	7[a] (0–20)	26–30 m	6–8	No	Fluorescent light used	
Barents Sea	2–13[a]	0.25–15 m	6–12	No	Average rates from 1984–1988	Kristiansen et al. (1994)
Barrow Strait (NWT, Canada)	26.7[a] (13.3–43.8)	Sea-ice; (bottom 3–5 cm)	1	No	Spring (blue-light incubations)	Harrison et al. (1990)
Bellingshausen Sea					Marginal Ice Zone	Bury et al. (1995)
Brown ice	58[a] (39–76)	–	24	No	Spring/summer	
Clear ice	7[a]	–	24	No	Spring/summer	
Water under ice	91[a]	–	24	No	Spring/summer	
Open water	14[a] (5–24)	2 m	24	No	Spring/summer	
Drake Passage	52[a]	100–0.1%	24	Yes	Spring/summer	Waldron et al. (1995)
Bellingshausen Sea MIZ	21[a]	100–0.1%	24	Yes	Regions 2 and 3	
Western Bellingshausen	16[a] (5–38)	100–0.1%	24	Yes	Region 4	
Gerlache Strait, Antarctica	3.5[a,d] (1.2–5.9)	0–50 m	24	No	Austral winter integrated rates	Cochlan et al. (1993)
Between Cape Ann & Mawson	27[a] (11–54)	1 m	5–9	Yes	Austral autumn	Probyn & Painting (1985)
Freshwater						
Lake Kinneret (Israel)	10[a] (3–37)	0–5 m	2–4	No	2 yr period *Peridinium* bloom	McCarthy et al. (1982)
Lake Biwa (Japan)	31.0[a] (21.2–43.5)	Surface	–	No	Artificial light	Mitamura (1986)
Lake Kasumigaura (Japan)	~20[b,f]	Surface	0.7–1	No	V vs S and V vs I experiments	Takamura et al. (1987)

[a]Absolute uptake rates
[b]Specific uptake rates
[c]Estimated from figures
[d]Conservative rates utilized in calculations of percentage of urea uptake
[e]Nitrite and/or DFAA uptake included in calculations
[f]Maximal uptake rates used in calculations
[g]Average values for study used in calculations
[h]Urea contribution based on Redfield C:N ratio of 6.6:1

parameters, and the reported atomic C:N ratio of 9:1 (Fig. 4). Fig. 4A provides the potential uptake of nitrogen at ambient concentrations of substrate (using the average concentration in the upper 10 m of the water column) versus irradiance. To determine these rates, we used Eq. (1) to calculate an ambient V value based on the kinetics parameters reported in Table 1 and the average nutrient concentration. We then used the calculated ambient V in Eq. (2) as V_s to determine ambient uptake versus irradiance (Fig. 4A). In Fig. 4B, the same data are presented as C:N assimilation ratios individually and for varying combinations of nutrient uptake, again as a function of irradiance.

Interpretation of these plots is somewhat difficult since the measurements were conducted at a single time point and we are assuming that the nutrient kinetics and uptake versus irradiance responses are both independent and representative of the population as a whole. However, several important points can be made. First, the low ambient concentrations of NO_3^- make this substrate the least utilizable form of nitrogen for this assemblage, while the ability to efficiently utilize urea and NH_4^+ at ambient concentrations and all light levels suggests a greater reliance on these reduced forms of nitrogen for growth. Second, if the assemblage were to maintain its atomic C:N ratio at 9:1, all of the nitrogen requirement could be met by urea assimilation alone. If the desired C:N ratio is closer to Redfield proportions (6.6:1), nitrogen demand could be met by utilizing urea subsidized with either NH_4^+ or NO_3^-. Third, exclusive reliance on NO_3^- assimilation could only meet the N demand at either extremely low or extremely high irradiance levels, while NH_4^+ utilization capacity falls between NO_3^- and urea. Reliance on urea or NH_4^+ of course requires a continuous supply of these nutrients, since at the cell abundance and nutrient concentrations measured the population could strip the water column of all the N in less than a day.

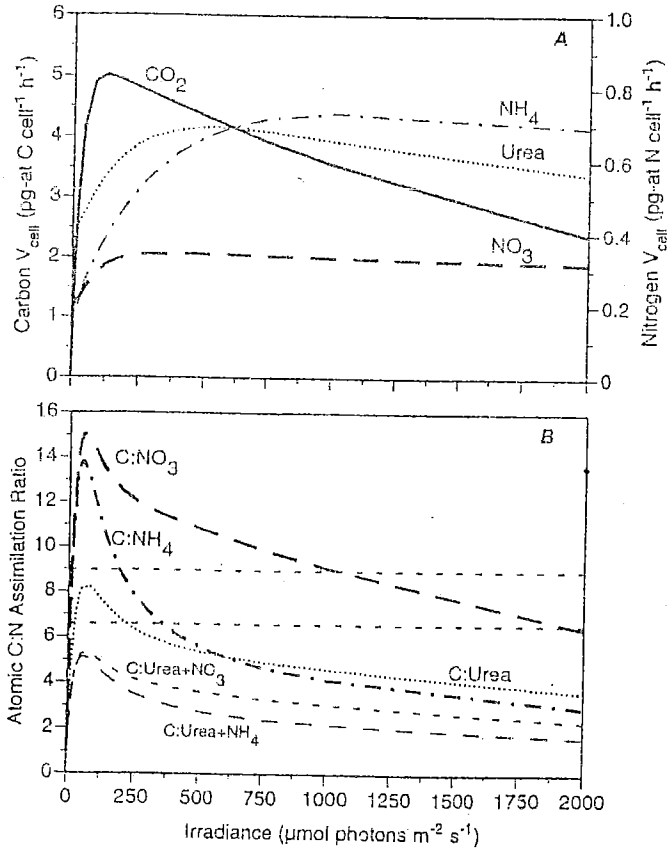

Fig. 4. (A) Uptake versus irradiance plots for all substrates are plotted using the calculated uptake values at ambient nutrient concentrations as described in the text. Note that N uptake parameters are on a separate y-axis. (B) Provides the same data plotted as C:N assimilation ratios versus irradiance for differing combinations of nitrogen. The dashed horizontal lines represent the measured atomic C:N ratio for the assemblage (9:1) and the Redfield ratio (6.6:1)

We observed an approximate doubling of cell number during the ca 24 h in which the samples were held in the laboratory, with an approximately 4-fold decrease in chlorophyll per cell (from 125 to 61 µg l^{-1} cell^{-1}; the relative proportion of phaeopigments did not change). Conditions in the culture room (25 µmol photons m^{-2} s^{-1}) were equivalent to considerably less than 5 m depth at noon for our collection site, using a zenith solar irradiance of 2300 µmol photons m^{-2} s^{-1}, 15% loss at the air/water interface (Kirk 1994), and the measured K_{PAR} value of 1.075 m^{-1}. Before and after the solar zenith, this depth would be proportionately shallower. Possible mechanisms for the decrease in cell pigmentation include photo-adaptation (since mean light levels in the culture room were constant and possibly higher than the average mixed-layer depth) and/or catabolization of the pigments as a nitrogen source to support growth. Final cell chl *a* levels (ca 35 pg chl *a* cell^{-1}) are consistent with the results reported by Prézelin & Sweeney (1979) for high- and low-light cultures (44 and 77 pg chl *a* cell^{-1}, respectively) and Prézelin & Matlick (1983) for N-limited (35 to 54 pg chl *a* cell^{-1}) and N-saturated (increase to ca 72 pg-at chl *a* cell^{-1}) cultures. In southern California, reported values for natural assemblages range from 22 to 38 pg chl *a* cell^{-1} (Holmes et al. 1967), 114 pg cell^{-1} at our study site, and with the presumed pigment concentrations of 260 pg chl *a* cell^{-1} (>2 × 10^6 cells l^{-1}, 519 µg chl *a* l^{-1}; Hayward et al. 1995). The growth rate suggests that the phytoplankton assemblage was not yet severely nutrient limited (typical growth rates range from 0.4 to 1.0 doublings d^{-1} in natural samples, ca 0.2 doublings d^{-1} in culture; Walsh et al. 1974, Eppley & Harrison 1975, Harrison 1976, Prézelin & Sweeney 1979). Unfortunately we do not have a direct estimate of the regeneration rates during this experiment. The presence of >50% of the plank-

tonic biomass as *Noctiluca scintillans*, and the extremely high total biomass combined with the potential for the catabolization of the chl *a* pool and the lack of inorganic nitrogen in the carboys suggest that all of the N demand *in vitro* was met by recycled nitrogen and/or a decrease in N per cell. Whether a similar mechanism occurred *in situ* is impossible to determine from these data, and we have no evidence for or against the *Lingulodinium polyedrum* population in this study augmenting their N nutrition by vertically migrating. However, based on the measured *f*-ratio and the ability of *L. polyedrum* to meet essentially all of its nitrogen requirements from regenerated sources, we believe that it is not necessary to invoke vertical migration from a nutritional standpoint.

Another trend reported in the literature that we could not corroborate in our study were the high K_s values for NO_3^- and NH_4^+ (Table 4), which are about 1 order of magnitude higher than the values reported here (Table 1). Harrison (1976) reported a K_s value for NO_3^- uptake in cultures that was similar to ours (ca 1 µg-at N), but went on to conclude that this 'low value' was likely due to poor growth rates in culture (0.2 d^{-1}). Because K_s values themselves are often misleading, we have also presented α_N values. Comparisons of our measured α_N values are similar to the historical estimates for NO_3^-, but are at the upper range of previously reported values. Since our α_N value for NO_3^- is the lowest of the 3 substrates tested, we again conclude that natural assemblages of *Lingulodinium polyedrum* can exhibit higher than expected (from literature values) affinities for reduced nitrogen. It is apparent that under stratified conditions where diatoms fare poorly (e.g. Margalef 1978), *L. polyedrum* is extremely competitive for both light and nitrogen.

Our K_s values for NO_3^-, NH_4^+ and urea suggest that *Lingulodinium polyedrum* is capable of competing with typical coastal phytoplankton such as diatoms. Those studies which have simultaneously examined uptake kinetics for urea, NO_3^- and NH_4^+ (Table 5) demonstrate that urea utilization is consistently in the same range as for NO_3^- and NH_4^+ in natural assemblages. Our study is no exception, and it is clear that there is no *a priori* reason for believing that *L. polyedrum* cannot compete (from a physiological perspective) with other coastal assemblages. The reported values are more in range with previously reported values for neritic diatoms and flagellates, with K_s (SD) = 1.66 (±0.07) and 1.82 (±0.09) µg-at N l^{-1} for NO_3^- and NH_4^+ respectively (Eppley et al. 1969). Our estimated half-saturation constants for urea are the first reported for *L. polyedrum* and are similar to the few values reported for cultures of marine neritic diatoms (0.4 to 2.0 µg-at N l^{-1}; McCarthy 1972, Rees & Syrett 1979), freshwater chlorophytes (generally 0.2 to 1.8 µg-at N l^{-1}; Healey 1977, Kirk & Kirk 1978), the freshwater cyanobacterium *Pseudoanabaena catenata* (0.8 µg-at N l^{-1}; Healey 1977), the picoflagellate *Micromonas pusilla* (0.4 µg-at N l^{-1}; Cochlan & Harrison 1991), and the neritic marine bacterium *Deleya venusta* (2.8 µg-at N l^{-1}; Jahns 1992). In contrast, much higher half-saturation constants have also been reported for cultures of the inshore diatom *Skeletonema costatum* (8.5 µg-at N l^{-1}; Carpenter et al. 1972), some freshwater chlorophytes (5 to 30 µg-at N l^{-1}; Syrett & Bekheet 1977, Williams & Hodson 1977, Kirk & Kirk 1978, Bekheet & Syrett 1979) and the lacustrine diatom *Melosira italica* (0.13 to 22 µg-at N l^{-1}; Cimbleris & Cáceres 1991).

Hayward et al. (1995) reported that the *Lingulodinium polyedrum* population was present in southern California coastal waters prior to the beginning of the heavy rainfall and associated runoff beginning in January 1995. They speculated that the peak biomass associated with our sampling period in March was likely triggered by the heavy rains just prior to this time, which, combined with the intense solar heating, caused strong stratification and isolation of the anthropogenic nutrients in the surface waters. Urea is a likely contaminant in heavily urbanized regions such as our study site (e.g. Antia et al. 1991) and was found at elevated ambient concentrations despite the demonstrated capacity for uptake by the dominant autotrophic species, *L. polyedrum*.

This opportunistic study clearly cannot evaluate the physiological condition and nutritional status of this bloom during either the formational period or the subsequent crash. Therefore, our results are more representative of a physiological 'snapshot' during a red

Table 4. Kinetic parameters for nitrate uptake of *Lingulodinium polyedrum* from culture and natural assemblages. There were no literature values for ammonium and urea uptake (except NH_4^+ K_s = 5.5; Eppley et al. 1969). The V_{max} value for Dugdale (1979) is in units of h^{-1}, since no cell counts were provided. Units for the other parameters are the same as Table 1. Parameters from Harrison (1976) were estimated from his Fig. 6

V_{max}	K_s	α_N	Source
–	9.50	–	Eppley et al. (1969)
0.14	0.50	0.280	Dugdale (1979)
7.82	10.5	0.745	Harrison (1976)[a]
3.20	3.46	0.945	Harrison (1976)[a]
1.13	7.20	0.157	Harrison (1976)
4.38	15.1	0.290	Harrison (1976)
0.13–0.50	0.5–2.0	0.250–0.260	Harrison (1976)[b]
2.24	2.40	0.933	Balch (1987)
0.480	0.467	1.03	This study

[a]Values from Eppley et al. (1969) and Eppley (pers. comm.) as reported by Harrison (1976)
[b]Values from low growth rate (0.25 d^{-1}) cultures

Table 5. Summary of the average nitrogen kinetic parameters — half-saturation constant (K_s) and maximum specific uptake rate (V_{max}) — determined for natural phytoplankton assemblages when urea uptake rates were determined. Range of study values are in parentheses

Area	Nitrate K_s (µg-at N l^{-1})	V_{max} (h^{-1})	Ammonium K_s (µg-at N l^{-1})	V_{max} (h^{-1})	Urea K_s (µg-at N l^{-1})	V_{max} (h^{-1})	Source
Oceanic							
Central North Pacific Gyre Subtropical (low [NO_3])	0.03	0.003	0.03	0.016	0.02	0.016	Sahlsten (1987)
Central North Pacific Gyre	0.24 (0.02–0.14)	–	0.055 (–0.14–0.13)	–	–0.017 (–0.35–0.20)	–	Eppley et al. (1977)
North Pacific							
Northern (J1–J7)	1.97[a]	1.11[b]	0.20[a]	2.79[b]	0.06[a]	0.60[b]	Kanda et al. (1985)
Tropical/Subtropical (J9–J23)	0.08[a]	0.58[b]	0.09[a]	3.48[b]	0.07[a]	1.82[b]	
Benguela Upwelling region	0.93	0.0082	0.10	0.0098	0.17	0.0041	Probyn (1985)
North Sea	–	–	–	–	0.27	0.002	Kristiansen (1983)
Coastal							
Oslofjord (Norway)	0.64 (0.1–1.0)	–	1.03 (0.1–2.0)	–	0.80 (0.2–1.8)	–	Paasche & Kristiansen (1982)
Southwest Finland	–	–	–	–	0.069–0.13[a]	0.037–0.094	Kristiansen (1983)
Washington coast	0.05	0.0058	0.71	0.00682	0.78	0.0046	Tamminen & Irmisch (1996)
Southern California							Dortch & Postel (1989)
Lingulodinium polyedrum bloom	0.467	0.0224	0.586[d]	0.0471	0.989	0.0616	This study
Western New Zealand							Chang et al. (1995)
Inshore	1.1	0.0138	0.5	0.0207	0.4–0.6	0.011–0.013	
Offshore	0.4	0.0104	0.4	0.0165	–	–	
Baltic Sea							
Nodularia spumigena bloom	0.22	–	0.02	–	0.27[c]	0.002	Sörensson & Sahlsten (1987)
Polar							
Barents Sea							Kristiansen et al. (1994);
$[NO_3] \geq 1$ µg-at N^{-1}	1.8		1.3		0.2		Kristiansen & Farbrot (1991)
$[NO_3] \leq 1$ µg-at N^{-1}	0.2		0.1		0.1		
Barrow Strait NWT	–		1.60		0.94		Harrison et al. (1990)
Ice algae							
Freshwater							
Lake Biwa (Japan)	2.59	0.0011	0.79	0.0094	0.73	0.0063	Mitamura (1986)
0.25 µm fraction during light	(0.82–6.87)	($4.0E^{-4}$–$1.4E^{-3}$)	(0.20–1.81)	(0.0063–0.0124)	(0.10–2.01)	(0.003–0.0117)	
Lake Kasumigaura (Japan)							Takamura et al. (1987)
Microcystis bloom	3.90 (0.93–8.6)	0.033 (0.025–0.046)	9.34 (5.53–13.2)	0.15–0.17	0.75	0.040	

[a]$[K_s + S]$ values used when ambient $[S]$ is unknown, or known with poor precision
[b]Absolute rates used (ng-at N l^{-1} h^{-1})
[c]Value from North Sea used in this study
[d]Presented for comparison only, ambient $[S]$ too high for accurate determination of K_s

tide event. However, we are confident that these data clearly demonstrate that *Lingulodinium polyedrum* exhibits K_s values typical of other coastal species, and that this species is capable of utilizing a broad range of both nitrogen concentrations and light fluences. It is not necessary to invoke vertical migration accompanied by dark-N uptake to meet the nutritional demands of this assemblage. This study also demonstrates that *L. polyedrum* can readily utilize urea as a nitrogen source. Although this is not surprising, it nevertheless remains one of the few studies demonstrating that dinoflagellates and other red tide organisms make use of this potentially anthropogenic source of nitrogen for growth.

MOST IMP !

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Toxic Fertilizers

Hazardous industrial wastes including arsenic, cadmium, lead, mercury, dioxins and even radioactive wastes are being used in common fertilizer with absolutely no testing, standards or disclosure. Fertilizer is so poorly regulated that hazardous materials can be called fertilizer and mixed with ordinary plant food if there's as little as 1% or more of a plant nutrient like nitrogen, phosphorus, potassium, zinc, boron or iron. There is no federal requirement that toxics be listed as ingredients on fertilizer labels. This questionable practice was first publicized five years ago by investigative journalist, Duff Wilson of the Seattle Times in a three-part, 1997 front page series of articles called "Fear in The Fields- How Hazardous Waste Becomes Fertilizer." His book, Fateful Harvest was published in 2001 and he was a finalist for the Pulitzer Prize for his investigative journalism.

Any material that has fertilizer qualities can be labeled and used as fertilizer, even if it has dangerous levels of chemicals and heavy metals. Instead of storing these hazardous materials safely, some companies are saving millions of dollars by re-packaging toxic wastes into fertilizers. Spreading heavy metals on farmland is perfectly legal, and has been going on for decades, but little research has been done to find out whether it's safe.

The health effects of these substances are widely disputed but there's undisputed evidence that these substances enter the plant roots that are grown in them. There is no safe level of exposure to dioxins, an extremely small amount can cause cancer. Since 1998, only four states, Washington, Texas, Oregon and California have limited hidden toxics in fertilizer. Unbelievably, The other 46 states have no limits on the amount of toxic substances allowed in fertilizer. (Effective Jan 1, 2002, California set limits for arsenic,cadmium and lead, with no mention of mercury or dioxins.

Home and garden fertilizers were also excluded from this ruling.) Canada is the only nation that tests and limits nine toxic metals in fertilizer. Canada has also taken the position to eliminate dioxins from posing health hazards to Canadians.

The US Environmental Protection Agency (EPA) actually encourages the "recycling" of toxic wastes into fertilizers because it's "economical" and saves industry money. The EPA created the IMEX program which pairs industries wishing to dispose of their hazardous wastes with fertilizer companies willing to take it. In 1976, Congress passed The Resource and Recovery Act (RCRA) which increased storage costs for hazardous wastes five-fold in twelve years. Industry began using the fertilizer loophole more to save money on the high costs of disposal. It would cost companies an extra $100 a ton to dispose of these materials properly. Heavy metals in fertilizers from recycled industrial flue ash wiped out more than a thousand acres of peanuts in Georgia with no press attention in the early 90's.

Wastes such as acids, ash, sludge, slags and tailings are derived from the steel and mining industries, electronic makers, brass, copper, and galvanizing industries as well as the nuclear industry and end up in fertilizers across the nation. Other contributing industries include; industrial chemical makers, coating and engraving services, secondary smelters and refineries, cement kilns and gypsum-makers. Every year nearly 600 coal and oil-fired power plants in this country produce more thann 100 million tons of wastes. About 25 million tons is sold to be made into cement, wallboard and fill. The rest is disposed, among other uses, in agricultural applications.

Industrial wastes may contain concentrated levels of arsenic, mercury, chromium, cadmium, dioxins and other toxic substances that can damage the nervous system and other organs, especially

in children. Heavy metals bioaccumulate in the fatty tissues of humans. The toxic heavy metal cadmium is one of the worst of these metals because it is readily absorbed into plants and builds up in animals. 90% of human exposure to cadmium comes from the food we eat. Long-term exposure leads to kidney damage, cancers and birth defects.

In January 2003, studies done by The Environmental Working Group (EWG), New York's Mt. Sinai Hospital and the Federal Centers for Disease Control and Prevention found low levels of industrial and agricultural chemicals building up in American's bodies. According to The World Health Organization (WHO), current levels of contaminants are already a threat to people and " food chain transfer is the primary route of human exposure to environmetnal pollutants." (1995) Europe and Australia limits cadmium in food but the U.S. does not. The US EPA has set no standard for safe food and there hasn't been a study done on the long-term cumulative effects of heavy metals on humans and the uptake in the food supply.

The EPA recently changed a loophole that the steel industry enjoyed since 1988, called the KO61 exemption for regulatory over-sight of electric arc furnace dust. This suit was brought on by the Washington Toxics Coalition and The Sierra Club. This exemption was especially dangerous because it allowed extremely high levels of dioxins to be released into the food supply via fertilizers. In 1980 The Bevel Amendment exempted mining waste from any kind of regulatory under the hazardous waste laws.

The organic industry is also threatened by these loose standards as topsoil has become the legal repository for wastes no longer allowed as emissions to air or water. Organic fish emulsion fertilizers are sometimes problematic because they may contain high levels of mercury.

Some "natural" rock phosphates, sometimes labelled "organic" are used in fertilizers and contain very high levels of arsenic, lead and cadmium (particularly from Idaho.)

Tests of 2,350 products in 1999 and 2000 showed about two thirds of them had higher levels of nine toxic chemicals than the natural level of soil. The nine chemicals are arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium and zinc. This means that two-thirds of all fertilizers are adding toxic heavy metals to topsoil. The Fertilizer Institute (with Hazardous waste recyclers on their board), and the American Plant Food Control Officials (AAPFCO) are pre-empting efforts to strictly regulate by providing their own proposals to States and encouraging lax restrictions. The public has a right to know what's in common fertilizers. Labelling requirements, testing and listing ALL ingredients is our right under proposition 65 in California.

Ideally this "recycling" practice needs to be stopped completely or at least manufacturers, retailers and regulators should disclose ALL ingredients on the fertilizer labels including any unadvertised, hidden toxic materials. Public health, the long-term welfare of the top-soil and the food supply are at stake. Ironically, the name of the State Senator currently sponsoring a bill in the California Legislature to allow small amounts of hazardous materials on farmlands is "Aghazarian".

Please contact me if you are interested in helping publicizing this issue and educating the public on this practice.

Thank you, SB - 876

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Monsanto's herbicide "Roundup" linked to deadly fungus

By Jeremy Bigwood

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Scientists are expressing alarm about the relationship between the application of a common weed killer to food crops and the resultant proliferation of potentially toxic fungal molds in the harvest. Monsanto's popular product Roundup, which contains a chemical called glyphosate is alleged to increase the size of colonies of the fungus Fusarium. It is a genus of often very toxic molds that occurs naturally in soil and occasionally invades crops, but usually held in check by other microbes. If true, these allegations not only call into question the world's number one weed killer, but they also jeopardize the world's acceptance of Monsanto's flagship line of genetically-engineered "Roundup Ready" crops.

"Glyphosate-treated wheat appeared to have higher levels of Fusarium Head Blight (a toxic fungal disease) than wheat fields where no glyphosate had been applied," said scientist Myriam Fernandez of the Semiarid Prairie Agricultural Research Center in Swift Current, Saskatchewan in a recent interview. Fernandez added "We have not finished analyzing the four years of data yet or written up the study." While Fernandez's research recently made headlines throughout Canada, it was not the first to discuss the relationship between glyphosate-containing weed killer formulations and the enhancement of potentially toxic fungi, but it was the first to report on the possibility of potentially toxic crop damage caused by the link in wheat and barley, two of Canada's most important crops.

Dr. Harvey Glick, head of Monsanto's Scientific Affairs, said, "It appears to be that Dr. Fernandez did a field survey looking at levels of Fusarium and then the factors that might be related. So, from what I can gather, that was not a cause and effect. It's just that they saw in the study area some fields that had higher levels of Fusarium, for whatever reason, and then they looked at a list of factors that might be related and one of them was there was Roundup used in those fields the previous year."

Maybe, but, over the last two decades, several scientists from New Zealand to Africa have noticed and investigated the glyphosate-fusarium relationship through small-scale experiments in the relative obscurity of their labs and reporting the results of their work through the hidden world of academic journals. The result of all of this work, is "just under 50 scientific papers," said Robert Kremer PhD., a soil scientist at the University of Missouri. This body of work shows an increase in Fusarium or other microbes after the application of glyphosate.

Monsanto's Dr. Harvey Glick disagrees. "Roundup is almost 30 years old and scientists have been looking at all aspects of its use for at least that long. So there is a tremendous amount of information available. And that is why there is such a high level of confidence that the use of Roundup, based on all of this earlier work, does not have any negative impacts on soil microbes. And a lot of it has been published."

Dr. Kremer's ongoing research deals with the effect of Glyphosate-Fusarium relationship on soybeans, not just regular soybeans, but also "Roundup Ready" soybeans. Monsanto has been producing a series of genetically-engineered "Roundup Ready" seed stock for various crops including, cotton, soybeans, wheat and corn to be used exclusively with their glyphosate weed killer Roundup. "Roundup Ready" crops are themselves unaffected by the Roundup weed killer, which will kill *all* competing plants such as weeds in the same area. Because they are genetically-engineered, these crops have not found easy acceptance in many countries outside the US, and they are still banned in Canada and Europe.

"The Fusarium fungus can produce a range of toxins that are not destroyed in the cooking process. These range from vomitoxin (which usually produces vomiting and not death) to more lethal compounds. These include fumonisin (which can cause cancer and birth defects) and the very lethal chemical warfare agent fusariotoxin, more often referred to as T2 toxin."

Dr. Kremer found that in his "Roundup Ready" soybean experiments that *"Glyphosate seems to stimulate Fusarium in the roots area of the plants,"* to such a degree that he considers the elevation of Fusarium levels to be glyphosate's "secondary mode of action." While he found enhanced Fusarium colonies in the roots of his plants, which could potentially reduce the harvest, he did not find it in the harvested soybeans themselves. Even so, he expressed concern about what this accumulation of Fusarium in the soil could lead to.

Dr. Kremer also said, "We didn't see enhancement of Fusarium when other herbicides were used." However, in the case of "Roundup Ready" crops, Roundup is to be used exclusively or in combination with other chemicals as a weed killer. To use other weed killers alone would be a violation of Monsanto's contract.

Thus, if Roundup increases Fusarium levels, then "Roundup Ready" crops that use Roundup as a weed killer could become potential disasters, increasing Fusarium levels in the soil to such critical levels it could produce an epidemic and move from field to field throughout a wide area.

In a recent article titled *GM cotton blamed for disease*, the *Farm Weekly*, an Australian publication, predicted that *"up to 90 percent of Australia's cotton belt could be inundated by the soil borne pathogen Fusarium wilt within the next decade" due to Roundup Ready cotton.*

Fusarium contamination of cereals, such as Fusarium Head Blight (FHB) in wheat and barley that Dr. Fernandez is studying in Saskatchewan has been responsible for serious crop losses. roughly a one fifth of the wheat crop in Europe *every year* is lost to FHB in Michigan during 2002 it was estimated that 30-40 percent of the crops were destroyed by Fusarium infestation. When the mold passes into the food-chain undetected, Fusarium epidemics on cereals can have even worse effects. A Fusarium epidemic of cereals was considered responsible for thousands of deaths in Russia during the 1940s and more recently in 2001, it caused a series of deadly birth defects among Mexican-Americans in Brownsville, Texas from eating infected tortillas.

When cultured on Petri dishes, Fusarium can display various colors, often ranging from orange to salmon-colored, and it has a varying appearance on different cereals and at different stages of its life cycle. On wheat and rye it can appear as a chalky white color. On barley it can appear as a black rust. On oats it can be black and reddish-orange colored. Small amounts of contamination of grains are invisible to the human eye, and chemical tests have to be done to detect it. Since such tests are at the expense of the farmer, minute amounts continually enter commercial food products. It is at the higher levels that it can become a serious problem.

The Fusarium fungus can produce a range of toxins that are not destroyed in the cooking process.These range from vomitoxin, which usually produces vomiting and not death, to more lethal compounds. These include fumonisin, (which can cause cancer and birth defects), and the very lethal chemical warfare agent fusariotoxin, more often referred to as T2 toxin.

During 2000, the U.S. Congress planned to use the fungus Fusarium as a biological control agent to kill coca crops in Colombia and another fungus to kill opium poppies in Afghanistan. However, these plans were dropped by then-president Clinton who was concerned that the unilateral use of a biological agent would be perceived by the rest of the world as biological warfare.

The Andean nations, including Colombia (where it was to be used in the drug war against coca cultivation) banned its use throughout the region. Sanho Tree, the director of the Institute for Policy Studies Drug Policy Project, commented about using a chemical that produces a banned micro-organism:

"The U.S. has supplied tens of thousands of gallons Roundup to the Colombian government for use in aerial fumigation of coca crops. We have been using a fleet of crop dusters to dump unprecedented amounts of high-potency glyphosate over hundreds of thousands of acres in one of the most delicate and bio-diverse ecosystems in the world. This futile effort has done little to reduce the availability of cocaine on our streets, but now we are learning that a possible side effect of this campaign could be the unleashing of a Fusarium epidemic in Amazon basin. The drug war has tried in vain to keep cocaine out of people's noses, but could result instead in scorching the lungs of the earth."

Because of the glyphosate-Fusarium link, Canada's National Farmers Union is already opposing the introduction of genetically-engineered "Roundup Ready" wheat. This issue shows no signs of going away. Time will only tell if Monsanto will be able to fix the problems of its "Roundup Ready" crops with more genetic engineering – this time to control Fusarium – or if their top weed killer and flagship line of "Roundup Ready" crops will be rejected by today's farmers.

Good News on GMOs from the United Kingdom

Government studies conclude GMO crops harmful to the Environment, Monsanto closes operations

Ryan Sarnataro

Europeans have long been better informed and more skeptical of agricultural biotechnology (AKA Genetic Engineering, GMO) than Americans. The awareness stems in part from the greater importance of local cuisine in culture while the skepticism stems from mad cow disease, which has claimed over 100 victims so far in the United Kingdom. Public opinion has forced all food suppliers in the UK to make pledges of being GMO free. All major supermarkets and fast food outlets are GMO free, including American multinationals like McDonald's and Heinz who would never make such an attempt here.

The news was worse for the GMO industry than simply losing in the UK. The Guardian reported that the "field study undertaken, has provided a legal basis for banning the two crops under European Union rules, which say that either health or environmental detriment must be proved."

Despite overwhelming public opposition, the right wing Labor government of Tony Blair has been doing whatever it can to introduce GMO crops. The Blair government has been pretty good environmentally, but in this area, similar to what played out in the US under Al Gore, the glitz of new technology has overwhelmed sound ecological logic. Both Labor and the Democrats decided to continue the policies of previous administrations rather than challenge the industry's claim of broad based benefits to all.

Part of the plan to gain acceptance for these products in the UK was a 5-year moratorium on commercialization combined with the largest testing program ever undertaken on GMO crops. Testing was limited to effects on weeds and wildlife, no testing was done on the health effects of eating GMO crops or their economic benefit to farmers. Researchers went to each field 15-20 times a year and inventoried plants and animals both in the borders and the fields.

There were widespread protests against even the testing of these crops. In August 1999, 28 Greenpeace activists were arrested for destroying trial plots whose location they had found through government documents. Unlike American activists who would be tried under Draconian terrorist statutes with extremely limited judicial latitude, the Greenpeace protestors were tried on simple criminal grounds and allowed to make their broader case to a jury. They were all acquitted in September 2000 on the grounds they were following a higher morality and attempting to prevent genetic pollution.

This past month, the first results of the unprecedented 273 field trials were published in the prestigious journal Science. The crops tested were Canola, which is widely planted in the US and Canada (and is at the center of the Monsanto lawsuit against the brave Canadian farmer Percy Schmeizer), sugar beets, which are not yet grown commercially in North America, and corn. The sugar beets were Monsanto's "roundup ready" herbicide resistant variety while the other crops were resistant to pesticides manufactured by Bayer. Interestingly, the corn tested was not the BT variety marketed by Monsanto that has been implicated in Monarch Butterfly deaths in the US.

The study found that GMO canola was readily cross pollinating with wild relatives and spreading rapidly. GMO pollen, carried by bees, was found up to 16 miles from test plots. The study estimated it would take 16 years for a field to recover from one year of planting GMO crops to the point where contamination would drop below 1%. GMO crops reduced forage seeds by a factor of 3 and it was speculated that popular bird species would go extinct as a result of the widespread commercialization of GMO crops. The GMO crops also reduced beneficial insect and bee populations.

The GMO corn did not show the same effect on insect populations. Unfortunately for the GMO industry the control plots used a pesticide now banned for other reasons and those tests will have to be redone before GMO corn could be declared safe. Since corn has no wild relatives in the UK there is no apparent danger of the GMO genes escaping into the environment like the beets and canola.

The news was worse for the GMO industry than simply losing in the UK. The Guardian reported that the "field study undertaken, has provided a legal basis for banning the two crops under European Union rules, which say that either health or environmental detriment must be proved." In other words the European position against planting GMOs is strengthened. It is also probable that these tests will be used to counter claims of unfair trade barriers being brought against the EU by the US through the WTO.

Just like in the US, the connection between Monsanto, the worlds leading GMO seed supplier and the government is incestuous. The Science minister has financial interests in GM crops and the Prime Minister's new communications director recently handled public relations for Monsanto. Nonetheless the news on the GMO study made the front page of most newspapers in the UK for several days running. All papers had editorial comment on the issue and even some of the most rabid tabloids like the Daily Mail stated the "evidence is against GM planting. Farmers won't benefit. Supermarkets don't want it. The public is flatly opposed."

Reaction to the release of the findings was swift and certain on Monsanto's part. In a story headlined "GM Giant Retreats from Europe" the staid Times of London reported that Monsanto "announced yesterday that it was pulling out of the European seed cereal business and closing its operation in Trumpington, Cambridge, with the loss of 125 jobs. The surprise move came as the Government prepared to publish the results of scientific tests on GM crops and their effects on the environment and wildlife, delighting anti-GM campaigners who scented victory in the battle over the controversial technology."

In other news it was reported by the Guardian that "Insurance companies are refusing cover for farmers considering growing GM crops or for conventional farmers anxious to insure against GM contamination of their crops. The main farming underwriting firms likened the idea of insuring against the dangers of GM to the situation with asbestos, thalidomide and acts of terrorism." Fitting company indeed!

Activists in the US can take heart from the fact that even a limited government study designed to put GMO crops in the best light have failed on objective terms. The US media reporting, legal and regulatory structures are much more GMO friendly than Europe however even these are likely to give way as the evidence of the harmful effects of agricultural biotechnology are revealed.

Cheney's Hawks 'Hijacking Policy'

Ritt Goldstein

(Excerpted)Sydney Morning Herald, Oct. 30, 2003

A former Pentagon officer turned whistleblower says a group of hawks in the Bush Administration, including the Vice-President, Dick Cheney, is running a shadow foreign policy, contravening Washington's official line. "What these people are doing now makes Iran-Contra [a Reagan administration national security scandal] look like amateur hour... it's worse than Iran-Contra, worse than what happened in Vietnam," said Karen Kwiatkowski, a former air force lieutenant-colonel.

"[President] George Bush isn't in control . . . the country's been hijacked," she said, describing how "key [governmental] areas of neoconservative concern were politically staffed". Ms Kwiatkowski, who retired this year after 20 years service, was a Middle East specialist in the office of the Undersecretary of Defence for Policy, headed by Douglas Feith. She described "a subversion of constitutional limits on executive power and a co-optation through deceit of a large segment of the Congress", adding that "in order to take that first step - Iraq - lies had to be told to Congress to bring them on board". Ms Kwiatkowski said the pursuit of national security decisions often bypassed "civil service and active-duty military professionals", and was handled instead by political appointees who shared common ideological ties.

In a separate interview, Chalmers Johnson, an authority on US policy, said that the Administration's neo-conservatives had in effect seized power from Mr Bush. Dr Johnson said the neo-conservatives had pursued an agenda outlined in the controversial 1992 Defence Planning Guidance. That document, drawn up at the direction of Mr Cheney when he was defence secretary, said the world's only superpower should not be cautious about asserting its power.

Source: www.truthout.com