cated, hence the need for regular phytoplankton monitoring and additional shellfish monitoring to ensure that seafood is safe for human consumption.

BALLAST WATER AND SEDIMENTS AS MECHANISMS FOR UNWANTED SPECIES INTRODUCTIONS INTO WASHINGTON STATE. **J. M. Kelly,** School of Marine Affairs, University of Washington, Seattle, WA 98195.

Ballast water and sediments from bulk cargo carriers have been implicated in the transfer of a diverse assortment of non-native species to near-shore marine environments worldwide. Dinoflagellate cysts present in discharged ballast sediments are believed to be responsible for the recent introduction of PSP-causing algal blooms and the subsequent disruption of the shellfish culture industry in Tasmania.

Examination of ballast water and sediments from Japanese woodchip carriers arriving at the ports of Tacoma and Port Angeles revealed the presence of living mollusc larvae, crustacea, macroalgae and numerous species of diatoms and dinoflagellates. With up to 20,000 metric tonnes of water and several cubic yards of sediment present in a cargo hold, the threat of introduction of harmful algae, pathogens, predators and resource competitors is realized. However, interviews with ships' officers indicated that at least some practice ballasting and deballasting procedures that may decrease the risk of introduction, such as offshore ballast loading, open-ocean exchange of ballast water and discharge of ballast sediments off-shore. Recent international, national and state policy efforts designed to prevent introductions via ballast discharge will be discussed.

"NON-TOXIC" DINOFLAGELLATE BLOOM EFFECTS ON OYSTER CULTURE IN CHESAPEAKE BAY. **Mark Luckenbach,*[1] Sandra Shumway,[2]** and **Kevin Sellner,[3]** [1]Virginia Institute of Marine Science, Wachapreague, VA 23480, [2]Bigelow Laboratory, West Boothbay Harbor, ME 04575, [3]The Academy of Natural Sciences, Benedict, MD 20612.

Dinoflagellate blooms appear to be increasing in frequency, magnitude and duration in Chesapeake Bay. During 1992 we documented dinoflagellate blooms of unprecedented intensity and distribution in the southern portion of Chesapeake Bay. Though the species involved in these blooms are generally termed non-toxic (from an anthropogenic perspective), their effects on suspension-feeding bivalves, including oysters, may be anything but benign.

Field and laboratory experiments were conducted to evaluate impacts of several dinoflagellate bloom species on the feeding, growth and survival of *Crassostrea virginica*. Hatchery-spawned oysters from a single cohort were deployed in off-bottom culture at twelve locations exhibiting varying degrees of bloom development, and growth and survival monitored. Laboratory experiments of 4 to 6 weeks duration were used to evaluate growth and survival of juvenile oysters fed monocultures of dinoflagellates and a diatom. Flow cytometry was used to determine grazing rates in short-term feeding trials. Results from both the field and laboratory suggest that growth and survival of juvenile oysters are affected by these dinoflagellate blooms. Our findings indicate potentially significant impacts on oyster culture in this region as a consequence of dinoflagellate blooms.

EFFECT OF THE TEXAS BROWN TIDE ON *MULINIA LATERALIS* POPULATIONS AND FEEDING. **Paul A. Montagna,* Dean Stockwell,** and **Greg Street,** The University of Texas at Austin, Marine Science Institute, P.O. Box 1267, Port Aransas, TX 78373.

In 1990, there was an unusual brown tide bloom of an aberrant Chrysophyte sp. in Baffin Bay and Laguna Madre near Corpus Christi, Texas. The bloom was coincident with the complete loss of shellfish in Baffin Bay, and a dramatic reduction in Laguna Madre. The dominant clam, *Mulinia lateralis,* disappeared for about one year. We performed a series of experiments to determine if *M. lateralis* disappearance was related to feeding and assimilation of the brown tide. Radioactive tracers were used to compare feeding on brown tide, *Isochrysis galbana, Dunaliella tertiolecta,* and *Heterocapsa pygmeae*. At low cell concentrations ($<$100,000 cells $\cdot$ ml^{-1}), *M. lateralis* grazing rates (cell $\cdot$ h^{-1}) increased with concentration and was not different among microalgal species. At higher concentrations grazing rates continued to increase on brown tide, but remained the same on the other microalgal species. This indicates that *M. lateralis* did have a different functional response to brown tide at bloom concentrations (500,000–6,000,000 cells $\cdot$ ml^{-1}). Assimilation efficiency by *M. lateralis* was about the same on all species of microalgae. The high grazing and assimilation rates of brown tide by *M. lateralis* indicate it is more likely that the bloom could have been due to loss of the clam population, rather than a negative trophic effect of the brown tide.

FACTORS CONTROLLING PARALYTIC SHELLFISH POISONING (PSP) IN PUGET SOUND, WASHINGTON. **Jack Rensel,** School of Fisheries, HF-15, University of Washington, Seattle, WA 98195.

PSP has spread throughout much of Puget Sound, Washington since the mid 1970's. Now all but parts of southern Puget Sound (SPS) and all of central and southern Hood Canal (CHC and SHC) are affected by PSP. The initial spread of PSP has been traced to major physical events, but lack of PSP in most of SPS and all of CHC and SHC has not been investigated until this study. Monitoring and experimental data suggest the lack of surface and subsurface (10 m) nitrogen in the unaffected areas prevents *Alexandrium catenella* growth.

In August of 1991 and 1992, filtered water from the surface and subsurface depths of CHC did not support any growth of *A. catenella* in the laboratory. However, growth of *A. catenella* oc-

curred with water from the same depths in SHC, although PSP has never been reported in that area. Slow estuarine-flow transport in CHC coupled with a seasonal lack of nitrogen in surface and subsurface waters forms a barrier to the passage of *A. catenella* cells to the more nutrient-rich SHC. Correlation analysis showed that PSP toxicity in mussels was related to elevated subsurface nitrogen concentrations and water temperature above 13°C. Increased nitrogen discharge from rapid urbanization and non-point sources could lead to annual PSP problems in areas presently unaffected by PSP, unless preventative measures are taken.

EFFECTS ON THE OYSTER *CRASSOSTREA VIRGINICA* CAUSED BY EXPOSURE TO THE TOXIC DIATOM *NITZSCHIA PUNGENS F. MULTISERIES*. **D. L. Roelke,* G. A. Fryxell,** and **L. A. Cifuentes.**

Domoic acid (DA) is produced by some diatom species and has become a problem to the shellfish industry. *Nitzschia pungens f. multiseries,* a known DA producer, has been discovered in Galveston Bay, Texas. The region produces a large part of the total national oyster harvest. The threat of contamination or mortality to the oyster fishery due to *N. pungens f. multiseries* was investigated by performing feeding experiments with *Crassostrea virginica* using clonal cultures of the diatom. Emphasis was placed on oyster feeding behavior, tissue toxicity, and depuration.

C. virginica readily fed on cell concentrations greater than natural blooms. The percentage of cells filtered from the seawater was consistently around 80%. The filtration rate ranged from 0.01 to 2.02 liters hr^{-1}. These variables along with oyster openness were not effected by the cell concentration, cell toxicity, or total toxicity of *N. pungens f. multiseries*. There were no detrimental effects observed to *C. virginica*.

Whole body analyzes showed DA accumulation ranging between 1 and 2 $\mu g\ g^{-1}$. The "gut" had five times the toxicity of the adductor muscle and the gills/mantle/labial pulps tissue fractions. Approximately 70% of the total DA in the oyster resided in the "gut." Oysters showed no correlation between whole body toxicity and whole body weight. Whole body depuration of DA from *C. virginica* was slow over a 72 hour period (14%).

Domoic acid outbreaks may not be confined to the coasts of North America. Two persons in the USA exhibited signs of ASP after eating smoked Korean oysters. Monitoring of several brands of this product was conducted, and domoic acid was not detected.

FISHERIES MANAGEMENT AND TOXIC PHYTOPLANKTON; THE RAZOR CLAM EXAMPLE. **Donald D. Simons*** and **Dan L. Ayres,** Washington State Department of Fisheries, Coastal Field Station, 48A Devonshire Road, Montesano, WA 98563.

In last decade, the popular razor clam (*Siliqua patula*) fishery on the coast of Washington State has undergone major turmoil following the devastation of the razor clam stocks by the pathogen NIX (Nuclear Inclusion X). In recent years, a conservative approach of regular short seasons began to return management of the fishery to a more predictable and positive condition.

Then, in November of 1991 the Washington State Department of Health informed the Washington State Department of Fisheries that razor clams being harvested by recreational users contained high levels of domoic acid. The fishery was closed by emergency order. This incident began an unprecedented period, in the sixty-plus year history of the razor clam recreational fishery, of extremely close monitoring of razor clam tissue from numerous locations for levels of domoic acid. In September 1992, just as domoic acid levels had reached a safe level, routine testing uncovered a new problem. Razor clam tissue was found to contain dangerously high levels of saxitoxin (the toxin responsible for Paralytic Shellfish Poisoning). Razor clams were now being monitored not only for domoic acid but also saxitoxin. This monitoring continues today. These incidents have resulted in closed or delayed fisheries, leaving the fishery users confused and angry. In addition new levels of cooperation are developing between Washington State Departments of Fisheries and Health, the US Food and Drug Administration, The National Park Service, various Indian Tribes and the fishery users, members of the public at large.

***PSEUDONITZSCHIA AUSTRALIS* FRENGUELLI AND OTHER TOXIC DIATOMS FROM THE WEST COAST OF THE U.S.A.: DISTRIBUTION AND DOMOIC ACID PRODUCTION.** **M. C. Villac,* G. A. Fryxell, F. P. Chavez,** and **K. R. Buck,** Department of Oceanography: Texas A&M University, College Station, TX 77843-3146.

Awareness of the phycotoxin domoic acid (DA), the cause of Amnesic Shellfish Poisoning (ASP), reached the United States west coast in the fall of 1991. Levels of DA in razor clams, mussels, and Dungeness crabs led to the closure of fisheries along the coasts of California, Oregon, and Washington. The diatom *Pseudonitzschia australis* was found to produce DA, and was observed from Southern California to the mouth of the Columbia River (San Diego, Newport, Monterey Bay, Coos Bay, and Ilwaco) during the DA outbreak. High cell concentrations and DA in phytoplankton net hauls were detected in Monterey Bay. A survey based on net haul samples and identification in SEM, carried out in Monterey Bay during the fall of 1992 showed that not only *P. australis* but other *Pseudonitzschia* spp. were present, including the DA producers *P. pungens* f. *multiseries* and *P. delicatissima*. There was no report of DA outbreak in the Bay in 1992. Clones of *P. australis* from Monterey Bay, Coos Bay and Ilwaco were established in 1991 (15°C; salinity = 30; 96 $\mu E/m^2 s$ in 12:12 hrs light:dark), and tested for domoic acid production (HPLC-UV detector; 250 µl injection volume; detection threshold of 0.01 µg/ml). Trace amounts of the neurotoxin were detected in late exponential phase (0.08–0.49 pg/cell), but not in two control cultures tested under continuous light. Tests for DA production in 1992 clones of *P. pungens* f. *multiseries* and *P. delicatissima* from Monterey Bay are underway.