

Effects of Calcium Oxide (Quicklime) on Non-target Organisms in Mussel Beds

Sandra E. Shumway,¹ Donald Card,¹ Rodman Getchell,¹ and Carter Newell²

¹Department of Marine Resources, West Boothbay Harbor, Maine 04575 and
²Great Eastern Mussel Farms, Inc., Tenants Harbor, Maine 04860

The use of quicklime (calcium oxide) as a deterrent to starfish predation is a longstanding practice amongst mariculturists and was first suggested by Wood (1908). Quicklime is a strong alkali that reacts with and immediately destroys the unprotected starfish tissues. It is a fairly inexpensive technique and has been reported by the National Oceanic and Atmospheric Administration (NOAA) to be nonharmful to oysters, other molluscs or fish. Since quicklime rapidly combines with water to form calcium carbonate, it does not introduce any long-lasting poison into the environment (North 1969).

Bottom culture of mussels (*Mytilus edulis*) has become a multi-million dollar industry in Maine. For periods of bottom grow-out longer than one year, starfish predation can account for considerable mortality. In one instance, starfish predation caused a loss of 6000 bushels of mussels (36,000 lbs; 7.92 x 10⁴ kg) over a 15 acre (4047 m²) lease section which amounted to 50% of the crop (Newell, unpublished).

On August 29, 1979, the U.S. Environmental Protection Agency deleted quicklime from their list of hazardous substances (Anonymous 1979). In spite of this acceptance and existence of data which indicate that quicklime is not detrimental to oyster beds (see discussion), controversy still exists regarding the use of large quantities of quicklime to control starfish populations on 'wild' shellfish beds. There have been few studies in which the possible effects of quicklime on other organisms of the treated areas have been investigated and the present study was undertaken to determine whether or not there would be any adverse effects of quicklime on mussel beds.

MATERIALS AND METHODS

Three experimental tanks were set up under identical conditions designed to resemble as closely as possible the conditions on a natural mussel bed. Each tank contained 10 cm of crushed gravel covered by a 5 cm deep layer of mud. The tanks were supplied with

Send reprint requests to S.E. Shumway at the above address.

running sea water from Boothbay Harbor (10°C) at a flow rate of approximately 10 L min⁻¹. The water depth in the tanks was approximately 10-15 cm.

The following species were included: *Mytilus edulis* (blue mussel), *Glycera dibranchiata* (bloodworm), *Nereis virens* (sandworm), *Homarus americanus* (lobster), *Littorina littorea* (periwinkle), *Asterias vulgaris* (starfish). Worms were placed in plastic basins (33 x 28 x 13 cm) which were filled with mud and buried in the tanks (See Fig. 1). Four basins, each containing 10 worms were used in each tank. The worm species were kept separate to avoid possible predation. *Littorina littorea* were placed on top of the basins and the basins were then covered with a 3-mm mesh screen to keep the snails from escaping the tanks. Each tank contained 50 periwinkles, *Mytilus edulis* (mean shell height 57 mm) were placed in the center of the tanks. Each tank contained a total of 120 mussels. Juvenile lobsters (mean carapace length 37 mm) were then introduced into the tanks and allowed to disperse at will. Ten lobsters were placed in each tank.

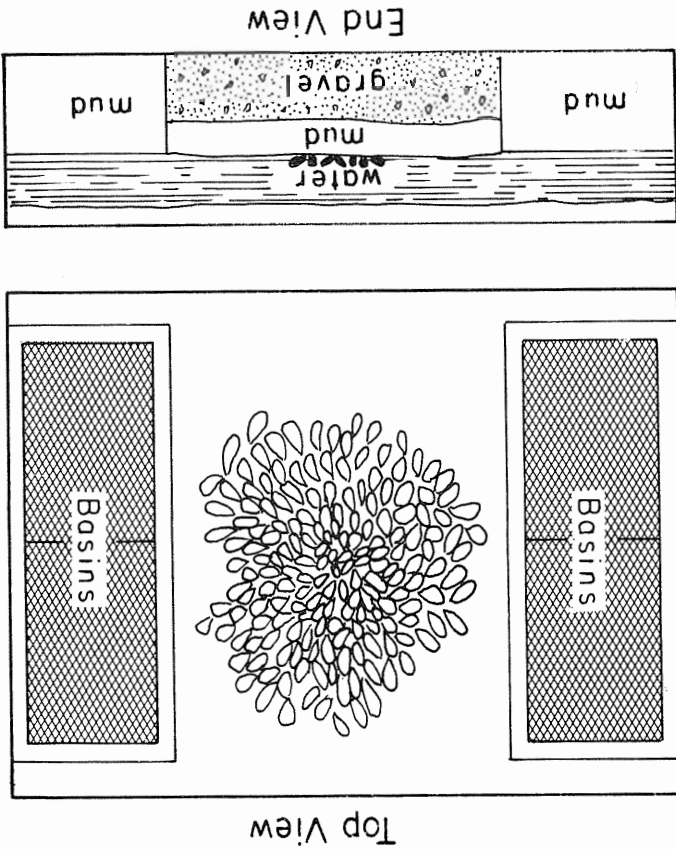


Figure 1. Diagrammatic representation of the experimental tanks. See text for explanation.

These results clearly demonstrate the efficiency of quicklime as an effective deterrent to starfish on mussel beds. More

Living 6 months after the experiments were terminated. Exception of starfish, showed no damage and all animals were still tissues. Further, gross examination of all species, with the photographs that there was no obvious damage to any of these damage from the quicklime. It can be clearly seen from the These tissues were considered to be the most prone to potential mussel gills both before and after exposure to the quicklime. Figure 2 shows photographs of lobster gills, worm parapodia and

however, most of the starfish simply dissolved. The lobster was seen to be feeding on a dead starfish; Living after this period and most had already decomposed after 72 was seen over the first 12 h of the experiments. No starfish were The efficiency of the quicklime method for eliminating starfish

managed to penetrate one of the worm basins. were seen to be feeding on the mussel bed, and one lobster had observations made during the course of the experiments. Lobsters or periwinkles. These results are easily explained by will also be noted that survival was not 100% for mussels, worms species tested, only the starfish were adversely affected. It Since the three experiments showed near identical results, the data have been pooled. The data clearly indicate that of all the The results of the three experiments are summarized in Table 1.

RESULTS AND DISCUSSION

with hematoxylin and eosin. In paraffin. Six-micron serial sections were prepared and stained series, cleared in Hemode (Fisher Scientific, USA), and embedded Davidson's fixative for 24 h, dehydrated through a graded alcohol histopathological examination. The tissues were fixed in Samples of mussels, lobsters and worms were taken for later

damage. At the termination of the experiment, all animals were removed from the tanks. They were counted and examined for any obvious

which lasted for 1 week. removed from the tanks prior to the completion of the experiment monitored for any obvious changes and/or deaths. No animals were tanks was turned on immediately and the tanks were subsequently (3.3 kg). Each tank measured 1.2 x 0.9 m. The water supply to the surface waters of each tank at a concentration of 1.5 lbs. tank Harbor, Maine. The quicklime was spread by hand over the entire (calcium oxide) was supplied by Great Eastern Mussel, Tenant's temporarily while the quicklime was added to the tanks. Quicklime and allowed to disperse. The water flow was then shut off eleven starfish (mean ray length 40 mm) were placed in each tank acclimation period of one week. At the start of the experiment, The assembled 'mussel beds' were then left undisturbed for an

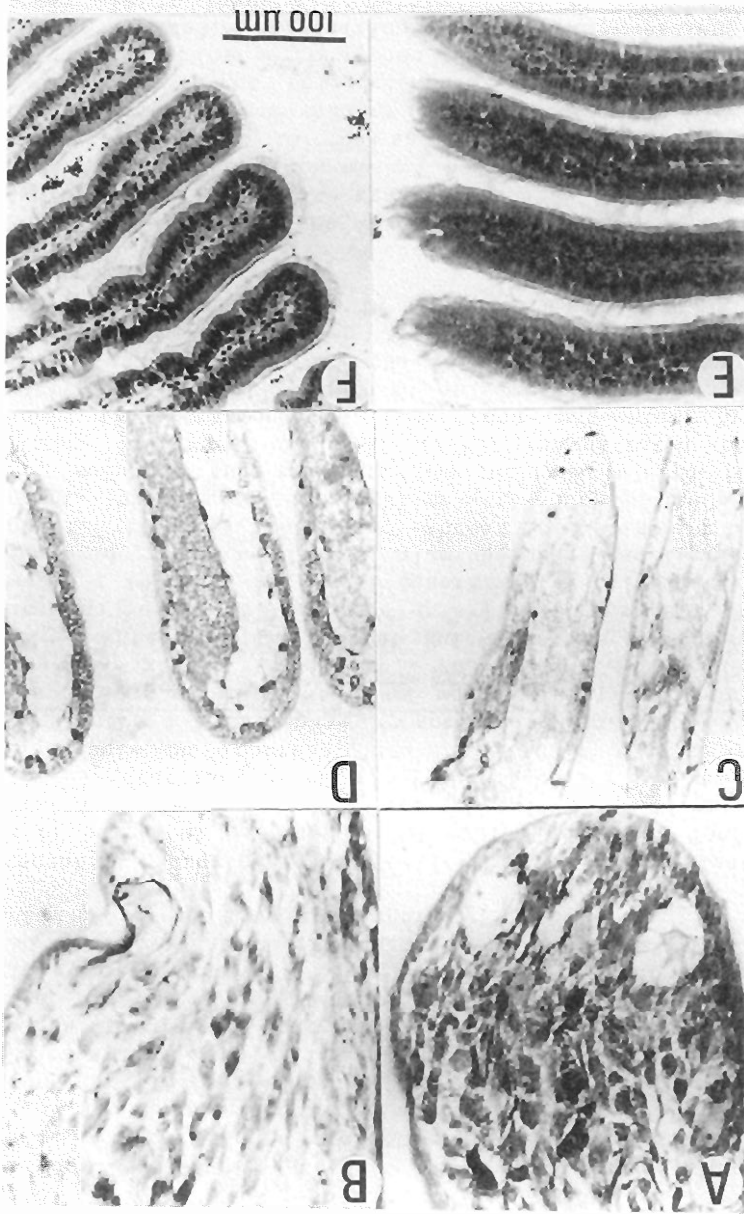
Loosanoff and Engle (1942) later showed that quicklime was a very effective means of controlling starfish predation on molluscs. Their study, like most of the other previous studies, was primarily aimed at clearing oyster beds of predators prior to seeding and during the subsequent grow-out years. They showed that concentrations of lime harmful to starfish do not seriously affect other commercially important forms of marine life (Mercenaria mercenaria, Mya arenaria, Mytilus edulis) or such species as Anomia, Crepidula, Urosalpinx and Nassarius. They did find that the lime was harmful to larval forms of flatfishes and to lobsters. Loosanoff (1962) later suggested the use of quicklime to control certain species of jellyfish.

importantly, the results indicate that other species likely to be present on the mussel beds are not adversely affected by the quicklime. Previous studies on the effects of quicklime on marine invertebrates were focused on oyster beds and associated fauna. Two of the first such studies were those of Galtsoff and Loosanoff (1939) and Needler (1940). Galtsoff and Loosanoff (1939) used the calcium oxide at a concentration of 300 lbs/acre (0.16 kg m⁻²) to clear oyster beds of starfish. They reported that within 5-10 days after being treated, all starfish were dead and more importantly, that the quicklime did not adversely affect other forms of marine fauna. Needler reported that after exposing oysters and lobsters to these animals after several months of exposure. He further reported that "other molluscs and crabs and shrimps were also unharmed in experiments". Of several fish tried in this study, only flounders were seriously affected by the treatment. Needler also showed that during the first 24 h after treating with quicklime, the phytoplankton populations were normal and that there was no apparent effect on the larvae of oysters and other molluscs even immediately after application of the quicklime.

Species	Number tank ⁻¹ (initially)	Number tank ⁻¹ (survivors)
<u>Mytilus edulis</u>	120	113 ± 8.1
<u>Homarus americanus</u>	10	10 ± 0
<u>Nereis virens</u>	20	19.2 ± 1.6
<u>Glycera dibranchiata</u>	20	18.5 ± 2.1
<u>Littorina littorea</u>	50	48.3 ± 2.6
<u>Asterias vulgaris</u>	11	0

Table 1. Number of surviving animals after 1 week of exposure to quicklime. Each number is mean ± s.d. of nine individual experiments.

Figure 2. Photomicrographs of A) Nereis parapodia before exposure to quicklime and B) after exposure (C) Homarus gills before and D) after exposure, F) Mytilus gills before and F) after exposure.



All of these previous studies were concerned with the effects of quicklime on oyster beds. The results obtained from these studies combined with our studies on mussel beds indicate that quicklime poses no major threat to the environment. In light of some indications from previous studies that quicklime may effect some larval forms, it might be prudent to limit the use of this material to those time periods when larvae are not present in the waters being treated. In addition, a number of questions remain unanswered: 1) Is there a long-term effect of quicklime on the reproductive organs of *Mytilus* or other bivalves; 2) are mussel spat in any way affected by the use of quicklime; 3) will routine liming produce resistant strains of starfish (or other organisms) 4) are changes in the community structures brought about by the removal of echinoderm species reversible, and if so, over what time frame?

An added advantage to the use of quicklime was demonstrated by Nishimura and Seki (1983). Since quicklime is composed mainly of calcium oxide (94-96%) and small quantities of calcium carbonate, magnesium oxide, silicon dioxide, aluminum oxide and ferric oxide, addition to seawater poses no threat of poisoning to the environment. Inasmuch as the quicklime will increase the pH of the seawater, sulphide and ammonium ions will be eluted from the bottom mud. Nishimura and Seki (1983) demonstrated that the subsequent transmutation of lime into magnesium hydroxide efficiently inhibited the growth of sulfate-reducing bacteria for a long term and consequently, the formation of hydrogen sulfide was reduced. The amount of lime necessary to prevent the formation of hydrogen sulfide in mariculture grounds was 100-200 g. m⁻².

More recently, Bernstein and Welsford (1982) investigated the effects of quicklime on a number of marine species. Their study demonstrated a devastating effect on all echinoderm species investigated (starfish, urchins and cucumbers). They reported no adverse effects on lobsters, crabs or adult finfish such as *Pseudopleuronectes americanus*, *Myoxocephalus* sp. or *Lycodes* sp. They also reported that *Modiolus modiolus* appeared undamaged.

Mackenzie (1977; 1983) reported that quicklime killed exposed animals such as diatoms, starfish and boring sponges but did not harm animals with tissues protected by shells or scales such as oysters, hard clams (*Mercenaria mercenaria*), crabs or fish. He also found that in treatments as heavy as 6.75 metric tons/hectare (3 U.S. tons/acre), quicklime dissolved within 18 days and that the growth of oyster spat was the same on both treated and untreated beds. It is particularly reassuring to note that quicklime has been used in Connecticut every year for over 40 years with no evident adverse effects on the density or annual regularity of potential oyster setting.

REFERENCES

- Anonymous (1979) Federal Register Part III. Environmental Protection Agency Vol 44 (169) p 50784
- Bernstein RB, Welford, RW (1982) An assessment of feasibility of using high-calcium quicklime as an experimental tool for research into kelp bed/sea urchin ecosystems in Nova Scotia. Can Tech Rep Fish and Aquat Sci 968, p 1-51
- Galtsoff PS, Loosanoff VL (1939) Natural history and method of controlling the starfish (Asterias forbesi, Desor). Bull Bur Fish 41(31):76-132
- Loosanoff VL, Engle JB (1942) Use of lime in controlling starfish. Res Rep 2. US Fish and Wildlife Service, Washington, DC, pp 1-29
- Loosanoff V (1962) Jellyfishes and related animals. Fish Leaflet 535. US Fish and Wildlife Service, Washington, DC
- Mackenzie CL (1977) Use of quicklime to increase oyster seed production. Aquaculture 10:45-51
- Mackenzie CL (1983) To increase oyster production in the Northeastern United States. Mar Fish Rev 45:1-22.
- Needler, AMH (1940) Use of quicklime for killing starfish on oyster grounds. Fisheries Research Board of Canada, Ottawa. Oyster Farming Circular 40-FRB-OFCL1.
- Nishimura A, Seki M (1983) Effects of lime for the improvement of mariculture grounds. Bull Jap Soc Sci Fish 49: 353-358
- North WJ, (1969) Project activities in San Diego County. California Institute Technology Keck Lab of Environmental Health Engineering. Annual Report. pp 6-28
- Wood FB (1908) Enemies and perils of the oyster. Report State of Connecticut Shellfish Commissioners 1907-1908. Doc No 30, Appendix to Rept pp 94-98

Received March 31, 1987; accepted August 1, 1987.

