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

Sandra E. Shumway,[1] Donald Card,[1] Rodman Getchell,[1] and Carter Newell[2]

[1]Department of Marine Resources, West Boothbay Harbor, Maine 04575 and
[2]Great 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mussels (36,000 lbs; 7.92×10^4 kg) over a 15 acre (4047 m^2) lease section which amounted to 50% of the crop (Newell, unpublished).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 instigated 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.

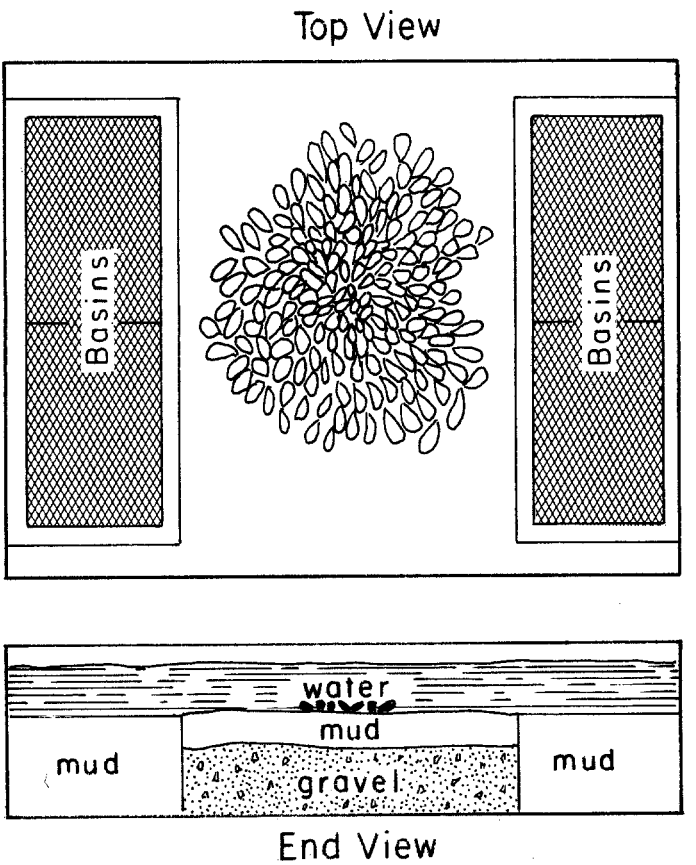

Figure 1. Diagrammatic representation of the experimental tanks. See text for explanation.

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

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

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

RESULTS AND DISCUSSION

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

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

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

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

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

Species	Number tank^{-1} (initially)	Number tank^{-1} (survivors)
Mytilus edulis	120	113 ± 8.1
Homarus americanus	10	10 ± 0
Nereis virens	20	19.2 ± 1.6
Glycera dibranchiata	20	18.5 ± 2.1
Littorina littorea	50	48.3 ± 2.6
Asterias vulgaris	11	0

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 ($\sim$0.16 kg m^{-2})to clear oyster beds of starfish. They reported that within 5-10 days after being treated, all starfish were dead and more importantly, that the quicklime did not adversely affect other forms of marine fauna. Needler reported that after exposing oysters and lobsters to 500 lbs ($\sim$0.27 kg m^{-2}) of quicklime/acre, there was no damage 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.

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.

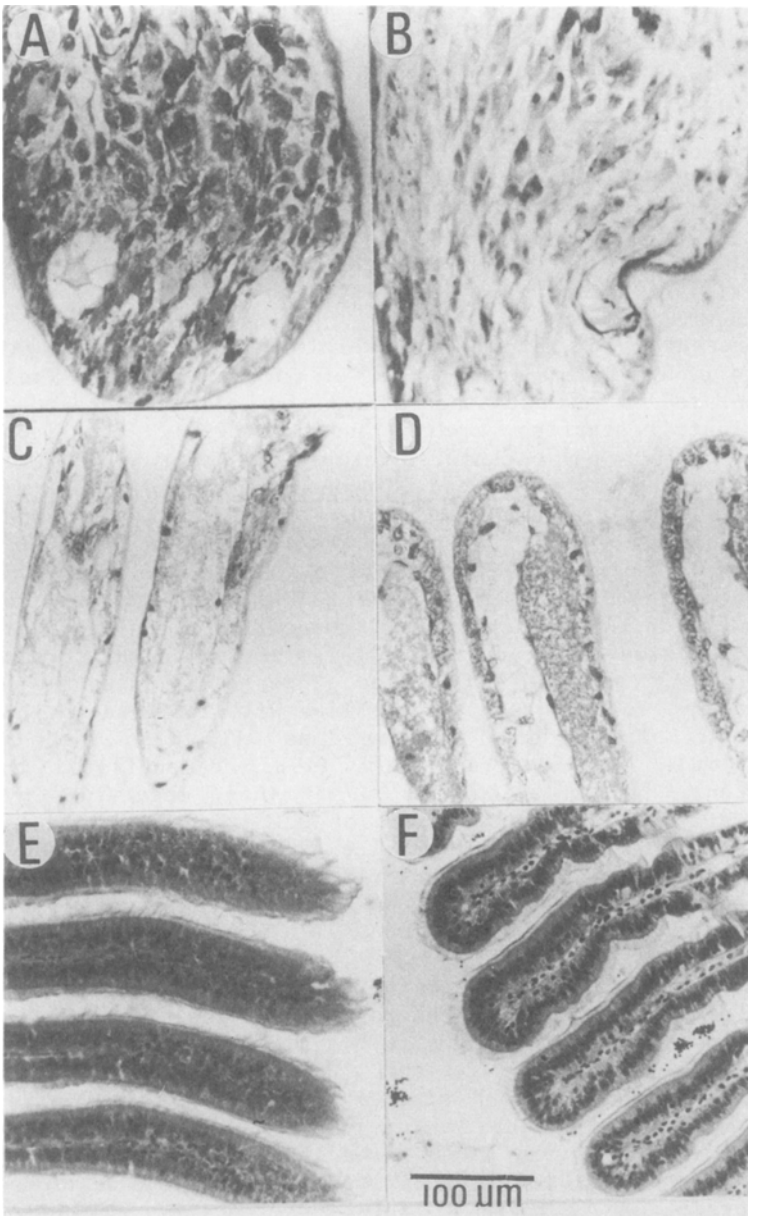

Figure 2. Photomicrographs of A) Nereis parapodia before exposure to quicklime and B) after exposure C) Homarus gills before and D) after exposure, E) Mytilus gills before and F) after exposure.

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.

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.

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 $g \cdot m^{-2}$.

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 encironment. 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?

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