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REVIEW OF POTENTIAL IMPACTS OF HYDRATED LIME TREATMENTS ASSOCIATED WITH PROPOSED EXPANSION OF MUSSEL PRODUCTION IN MALPEQUE BAY, PEI

Photo: PEI Agriculture & Fisheries

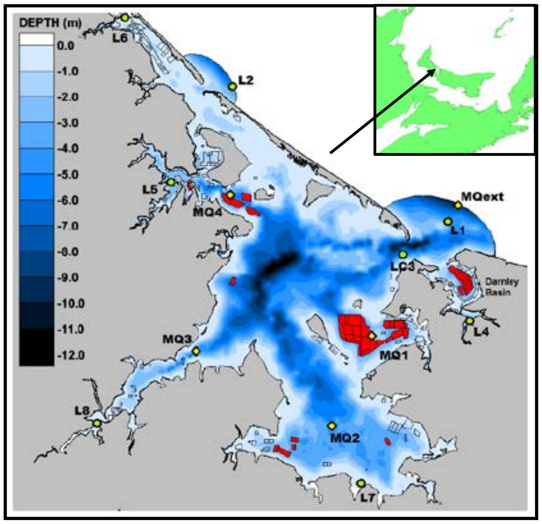

Figure 1. Map of Malpeque Bay (PEI) showing bathymetry and current mussel leases (red polygons) (DFO 2015).

Context:

Hydrated lime treatment has been used for several decades in Prince Edward Island (PEI) shellfish aquaculture to control biofouling and predators (tunicates and starfish), and is particularly used to control the invasive tunicate Styela clava. A treatment of hydrated lime on shellfish is also commonly required as a condition on Fisheries and Oceans Canada (DFO) issued Introductions and Transfer licenses to prevent the introduction or transfer of fellow travellers along with shellfish that are being moved from one area to another. A previous review based on the pathways of effects concluded that the risk posed by the use of hydrated lime to water column organisms was estimated to be low but a number of knowledge gaps remained (DFO 2010). Requests have been made to increase the leases and the production of mussels in Malpeque Bay, Prince Edward Island. In support of continued consultations on the proposed lease expansion, DFO Aquaculture Management asked for advice on whether the current use of lime in the mussel aquaculture industry changes significantly the environmental footprint of a mussel lease, specifically in the context of the expanded use of hydrated lime associated with proposed mussel lease expansions in Malpeque Bay. This report is the product of a regional science peer review meeting on the potential impacts of hydrated lime treatments associated with proposed expansion of mussel production in Malpeque Bay (PEI) held in Moncton (New Brunswick), February 8-9, 2016. Participants at the meeting were from DFO Science Branch from Gulf, Quebec and national headquarters, DFO Ecosystems and Fisheries Management, the provincial government of PEI, external experts, and the aquaculture industry.

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SUMMARY

- Hydrated lime application on mussel grow-out sites and seed lines in Malpeque Bay is used to manage the invasive clubbed tunicate (*Styela clava*) on aquaculture sleeves and associated infrastructure. Treatments typically occur from mid-July through to early November, with the most intensive application occurring in August and September.
- A saturated hydrated lime solution is highly alkaline, when it is introduced into the aquatic environment the immediate effect is an increase in pH of the receiving water. The pH change signal is characterized by both the time it takes the receiving water to return to ambient pH range and the distance at which the pH of the receiving water is changed from the ambient range.
- Application of hydrated lime in Malpeque Bay results in short term (minutes) and small scale (meters) effects on the pH characteristics of the water column in the vicinity of treatment activity.
- There is a limited number of studies on lethal and sublethal effects of hydrated lime on marine organisms. The lethal thresholds of pH (96 hr LC50) for several species are of similar pH but for longer duration than the measured field conditions during liming treatment. Therefore it is unlikely that lime treatments would have harmful effects on lobster and other non-target organisms.
- The planktonic life stages of crustaceans (lobster and rock crab) are present in the water column from mid-June through to mid-September and overlap with the periods of liming treatments.
- Benthic habitat classified as prime lobster ground that can support all life stages of lobster was found in one limited area that is being considered for expansion of mussel aquaculture. The remainder of the proposed area of expansion has benthic habitat that is classified as poor for lobster, serving as a transition zone.
- Liming activities associated with mussel lease expansions will result in an environmental footprint defined by transient increases in pH that last minutes and extend over a few meters when treatments occur.

INTRODUCTION

The shellfish (mussel, oyster) aquaculture industry in Prince Edward Island (PEI) has been affected by a proliferation of invasive tunicates which has necessitated the development of approaches for managing these fouling organisms. The primary goal of tunicate management in PEI is the removal of tunicates from aquaculture infrastructure, including mussel sleeves before they become large masses. The primary treatment method for the invasive solitary tunicate *Styela clava* involves either immersion or spraying with a saturated solution of hydrated lime. In a review of the pathways of effects of a number of chemical inputs from the aquaculture industry Burridge et al. (2011) indicated that the risk posed by the use of hydrated lime to water column organisms is estimated to be low based on known hazard information and exposure durations, however, a number of knowledge gaps remained particularly for sediment effects (DFO 2010).

In 1999 - 2000, a moratorium on further leasing for mussel aquaculture was initiated in PEI. In 2007, a request was made to review the moratorium and Malpeque Bay was identified as one of the areas in PEI for potential mussel aquaculture expansion. In 2013, DFO identified the need to develop a detailed spatial plan to accommodate the potential increase in aquaculture acreage in Malpeque Bay. DFO (2015) concluded that under current and projected levels of mussel culture and relative to the metrics of production carrying capacity used in the assessment, the production carrying capacity of Malpeque Bay would not be exceeded.

In support of continued consultations on the proposed lease expansion, DFO Aquaculture Management asked for advice on whether the current practices of lime use in the mussel aquaculture industry changed significantly the environmental footprint of a mussel lease, specifically in the context of the anticipated expanded use of hydrated lime that would result from the proposed mussel lease expansions in Malpeque Bay. To address the request for advice, the following questions were considered:

- review the current state of knowledge regarding hydrated lime use in aquaculture operations and its effect on the aquatic ecosystem including changes in water quality (extent and duration), benthic impacts, and effects on marine organisms (lethal, sublethal and behavioural);
- review the current industry practices in the use of hydrated lime in Malpeque Bay;
- quantify the duration of the treatment plume as indicated by pH changes from baseline within the lease boundaries;
- quantify the extent to which non-target organisms (specifically lobster) are present in areas being considered for the expanded leases in Malpeque Bay;
- quantify the extent to which non-target organisms (specifically lobster) would respond to chemical changes of the water expected with current industry practices for the expanded leases in Malpeque Bay; and
- advise on the extent to which the environmental footprint of the proposed leases and the associated expanded use of hydrated lime treatments in Malpeque Bay would be increased relative to the footprint of expanded leases in the absence of liming inputs.

ASSESSMENT

The Malpeque Bay system is located on the North shore of PEI. It is a large (19,640 ha) and shallow (max. depth 13 m) embayment composed of several basins (Fig. 1). An intricate river system discharges into Malpeque Bay at several points and the bay opens to the Gulf of St. Lawrence through multiple connections. Currently, most of the mussel aquaculture activity (red polygons in Fig. 1) is located in the Northeast area of the bay in two sub-basins, March Water and Darnley Basin, that are partially isolated from the main water body, with other areas spread along the shore within the bay characterized by more open circulation.

The proposed lease expansion being considered for Malpeque Bay represents 590 ha of lease area which would increase the leased spatial area coverage of Malpeque Bay from 7% to 10%. The exact locations in the bay where possible future mussel aquaculture leases could be added are still under consideration. The lease expansion scenario examined by DFO (2015) places the new leases in the central part of the system, south of March Water, and on the western shore, all areas at least 1500 feet (~457 m) from the shoreline and in waters at least 15 feet (~4.6 m) deep.

Chemical characteristics of hydrated lime

Calcium carbonate ($CaCO_3$) is a common substance in rocks in all parts of the world and the main constituent of both limestone and shells in marine molluscs. When calcium carbonate is heated at high temperatures, carbon dioxide (CO_2) is released forming quicklime (CaO) (Fig. 2). Quicklime, the product of calcination of limestone, consists of the oxides of calcium and magnesium (Fact Sheet Properties of Lime January 2007; accessed May 31, 2016). When mixed with water, quicklime picks up hydroxide (OH) from water and produces hydrated lime ($Ca(OH)_2$) in an exothermic reaction which liberates extreme heat.

Hydrated lime is a colourless crystal or white powder and is soluble in water at 0.160 g per 100 g (CRC 2005). A saturated hydrated lime solution in distilled water will have a pH of approximately 12.7 and is described by the equilibrium formula:

$$Ca(OH)_2(s) \leftrightarrow Ca^{++}(aq) + 2OH^{-}(aq)$$

Hydrated lime readily converts back to calcium carbonate in the presence of carbon dioxide (CO_2) in either air or in water. The rate of conversion from hydrated lime to calcium carbonate depends on temperature, the particle size of the lime, and the availability of carbon dioxide (typically 0.59 kg of carbon dioxide is required to convert 1 kg of hydrated lime). The solubility of calcium carbonate is low (0.00066 g per 100 g water) and there is therefore potential for precipitate to form and settle to the bottom as the reaction occurs. In the marine environment, some of the precipitate may also include magnesium carbonate as magnesium is a more abundant free element in sea water than calcium but also because commercial quicklime can also contain some MgO. Calcium carbonate may not necessarily accumulate in marine sediments as it can be disassociated to bicarbonate $2(HCO_3^-)$ and ionic calcium (Ca^{++}) (compounds normally found in the marine environment) in the presence of dissolved CO_2.

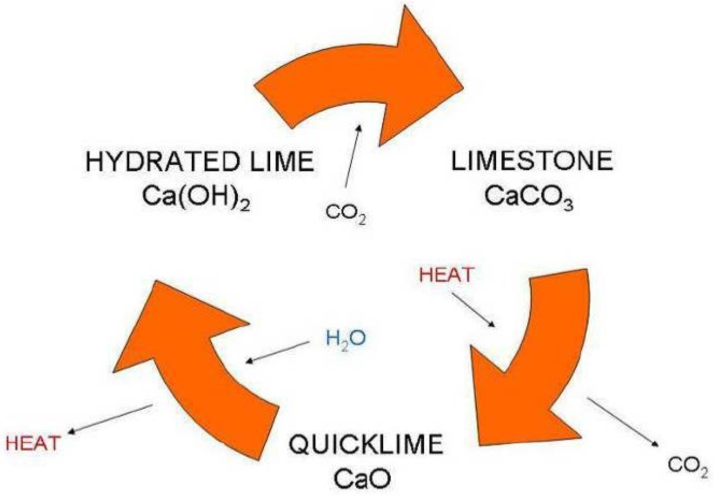

Figure 2. Chemical reaction cycle of limestone to quicklime to hydrated lime and return (figure from Ramsay et al. 2014).

Lime treatment practices in the industry

In the PEI aquaculture industry, hydrated lime is mixed with seawater to create a suspension at an approximate concentration of 4% (40 g of hydrated lime in 960 ml of seawater). The saturated lime solution is highly alkaline with a pH between12.3 and 12.8; this contrasts with seawater which has a normal pH range of 7.0 to 8.7. Treatment with hydrated lime is effective in lowering numbers of invasive tunicates to manageable levels with approximately 90% mortality of treated tunicates (DFO 2010). Mussel lines are treated using saturated solutions of hydrated lime using one of three methods (Ramsay et al. 2014):

- Immersion bath where mussel sleeves, lines and associated infra-structure are pulled through a trough containing a saturated solution of hydrated lime.

- Spraying manually a saturated solution of hydrated lime on mussel sleeves, lines and associated infra-structure in an open system with the treatment solution dripping directly into the environment.
- Spraying a saturated solution of hydrated lime on mussel sleeves, lines and associated infrastructure using a number of low-pressure shower nozzles in a closed system. There is a recovery container to capture/recover some of the treatment solution drip which is then reused to treat mussel sleeves.

The spray method, either open or closed system, is utilized primarily on grow-out mussel socks and is currently the standard industry method used for the control of fouling by clubbed tunicates (*S. clava)*. Mussel lines and socks are lifted from the water, allowed to air dry for approximately 20 seconds and the saturated lime solution is lightly sprayed on the socks. After being sprayed, the socks are slowly re-immersed into the water, allowing for an approximate 45 second air exposure. The air exposure following lime application is an important step in the process and is required to ensure high tunicate mortality.

There is no industry standard for when treatments are initiated. As a general rule, treatment takes place when tunicates are small and prior to tunicate fouling becoming large masses on mussel crop and infrastructure. Farmers self-prescribe and the decision to treat is based on tunicate counts and crop assessment. The activity typically begins in late July and extends to early November. Typically lines are treated once per year.

Growers in Malpeque Bay may also use lime to control starfish on spat lines, beginning in early July and extending to late August, and there may be up to three treatments per year.

The rate of hydrated lime use has been estimated at 1 to 2 bags (22.7 kg per bag) of lime per 600 ft line (400 sleeves). The open system spray treatment uses about 2 bags of lime per line and 6-10 lines can be treated per day (270 – 450 Kg per day with 1 boat). Growers using the closed system spray treatment can treat 10-12 lines per day and only use about 1 bag of lime per line (230 – 270 Kg per day with one boat). At the bay-scale, it was estimated the collective effort needed to treat all sleeves in Malpeque Bay was about 97 boat days, based on the open system spray treatment.

Effects of hydrated lime on the aquatic ecosystem

Changes in water quality (extent and duration)

Since a saturated hydrated lime solution is highly alkaline, when it is introduced into the aquatic environment the immediate measurable effect is a change in pH of the receiving water. A 4% solution of hydrated lime has a pH of about 12.7 (range 12.3 to 12.8). The pH footprint is defined in terms of the time it takes the pH of the receiving water to return to ambient range and the distance at which the pH of the receiving water is changed from the ambient range. Ambient range of seawater is 7.0 to 8.7 pH units.

The release of hydrated lime solutions from mussel lines following operational lime treatments in Malpeque Bay was studied in 2013 to 2015 by attaching pH probes directly to fouled mussel sleeves subjected to hydrated lime treatment. Measured pH (9.3 to 11.7) was highest immediately after sleeves were returned into the water column but thereafter pH rapidly declined to levels below below 8.7 pH units within 3.1 ± 0.5 minutes (mean ± standard error of the mean; range 0.3 to 10.5 min; n = 31 sleeves). There were differences in the duration of the measured pH change among boats, suggesting that the amount of hydrated lime released into the environment was largely governed by the grower and perhaps the level of tunicate infestation at the time of treatment.

Monitoring within 2-10 minutes post-treatment showed that the pH change was mainly confined to a depth range of 1.0 to 3.0 m, which is consistent with sleeve length, as measured within 5 m of the treated mussel sleeve. As growers were treating mussel sleeves, sensors deployed about 15 cm above the seabed detected a series of pH increases above ambient levels (Fig. 3). The pH increase from ambient varied from 0.02 to 0.48 pH units and the maximum recorded absolute value was 8.4 pH units. The duration of these pH changes ranged from 2.4 to 126.0 minutes, with a mean duration of 36.8 minutes (± 8.0 std. err.).

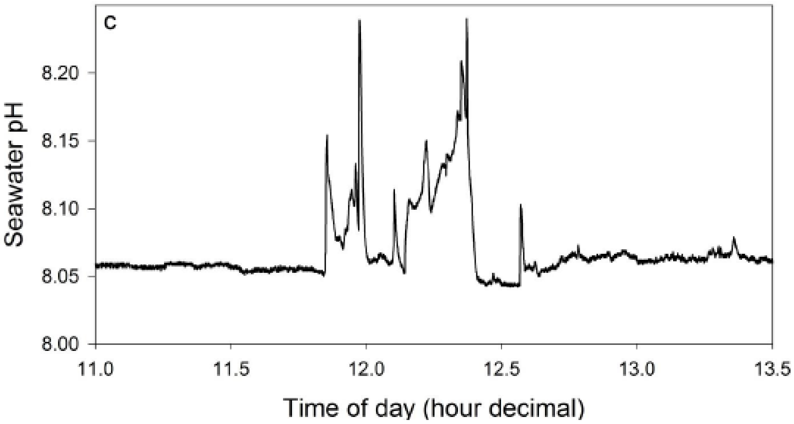

Figure 3 Example of pH fluctuation above the seabed during the treatment of nearby (< 90 m) mussel sleeves (Burridge and Comeau 2016).

Benthic impacts

In two treatments conducted in Darnley Basin and March Water areas of Malpeque Bay, divers observed a cloud of particles in the water column immediately below the area where the treated sock exited the lime trough or close to the surface spray. The particles drifted to the sediment and appeared to dissociate but the time to sink to the sediment and the fate of the particulate were not measured (Ramsay et al. 2014). Based on underwater photos of green AstroTurf carpets deployed under and between the treated lines in the Malpeque Bay study area, there was no visual evidence of precipitate on the carpets (Burridge and Comeau 2016). However, depositional modelling taking into account currents and settling rates indicated that the fine particles may have been carried over distances > 100 m. Over all these studies and many observations from field staff, there was no visual evidence of accumulation of carbonate particles on the bottom.

Malpeque Bay is large enough and has sufficient water flow dynamics to mostly assimilate and chemically convert hydrated lime (to carbonate) released from mussel operations. Subsequently, the presence of dissolved CO_2 in the water will promote the disassociation of carbonate that may be deposited in the sediment with the rate of disassociation affected by a number of factors related to the ambient water chemistry. Filgueira et al. (2015) discuss CO_2 cycling near mussel farms and, while they do not explicitly discuss liming and carbonate deposition, it is clear that inputs from this activity are likely inconsequential at the ecosystem level. However, little is known or measured regarding sediment chemistry differences between control sites and culture sites with regards to particulate carbonate. It is also likely, but not measured, that carbonate from lime treatment is a small input to the bays compared to biogenic sources.

Effects on marine organisms (lethal, sublethal and behavioural)

There are a limited number of studies on lethal and sublethal effects of hydrated lime on marine organisms (Burridge and Comeau 2016).

There is limited literature on the effects of alkalinity on bivalve embryonic development and larvae survival (Locke 2008). A 48-h exposure to 9.0 pH units was found to be lethal to *Crassostrea virginica* (eastern oysters) and *Mercenaria mercenaria* (hard clams) larvae under laboratory conditions. A 48-h exposure to 8.5 pH units lowered the percentage of *Mulinia lateralis* (dwarf surf clam) embryos that developed normally, and a 6-8 day exposure to 9.0 pH units decreased *M. lateralis* survival at the larval stage. However, these conditions are likely unrepresentative of field conditions based on duration of post treatment exposure and concentration.

The lethal thresholds based on 96 h static test exposures for several species are presented in Table 1. As a standard toxicity test, the 96 h LC50 results are useful for assessing relative toxicity but the conditions of the test are unrepresentative of field conditions based on duration of exposure and concentration (constant rather than decreasing).

The 14-day No Observable Effect Concentration (NOEC) test on sand shrimp, a concentration that results in less than 10% mortality over 14 days, was 32 mg/L (8.7 pH units), a 1250 fold dilution of the 4% treatment concentration used in the industry (Table 1). Observations on survival of larval lobsters exposed to a range of concentrations and exposure scenarios show that stage III lobster larvae were killed only at high concentrations of lime (600-900 mg/L) after one hour exposures (either single or multiple), a 42 to 67 fold dilution of the treatment concentration (Table 1).

Table 1. Results of toxicity tests of hydrated lime suspensions on sand shrimp, lobster larvae and stickleback fish (Locke et al. 2009; Burridge and Comeau 2016). NOEC is the No Observable Effect Concentration representing the concentration that results in less than 10% mortality over the duration of the experiment.

Test Exposure	Species	Mean (95% Confidence Interval)	
		$mg{\cdot}L^{-1}$	pH
LC50: 96 hour	Sand shrimp (*Crangon septemspinosa*)	158 (50 – 500)	9.70 (9.12 - 10.3)
	Lobster larvae (stage III) (*Homarus americanus*)	121 (73.5 - 198)	9.73 (9.47-9.99)
	Lobster larvae (stage IV)	998 (620 – 1,610)	10.3 (10.0 – 10.5)
	Three-Spine Stickleback (*Gasterosteus aculeatus*)	457 (262 – 785)	10.47 (10.26 - 10.52)
LC50: 14 day	Sand shrimp	53.1 (48.3 - 58.4)	9.20 (9.12 - 9.20)
LC50: after one hour pulse, followed by 12 days in clean seawater	Lobster larvae (stage III)	965 (633 - 1470)	10.6 (10.2 - 11.0)
LC50: after a one hour pulse on three consecutive days, followed by 9 days in clean seawater	Lobster larvae (stage III)	606 (336 - 1090)	10.5 (10.1 - 10.9)
NOEC: 96 hour	Sand shrimp	100 (na)	9.54 (na)
	3-Spine Stickleback	100 (na)	9.54 (na)

Test Exposure	Species	Mean (95% Confidence Interval)	
		$mg{\cdot}L^{-1}$	pH
NOEC: 14 day	Sand shrimp	32 (na)	8.17 (na)

Sublethal effects related to behaviour as indicated by the frequency of tail flicks and preferences of substrate media have been examined for lobster larvae and sand shrimp. Tail flicks in stage IV lobster is a documented response of the animals to stress. Lobster larvae (Stage IV) tail flicks increased when hydrated lime was introduced, with tail flicks decreasing as particles settled to the bottom (Burridge and Comeau 2016). It was suggested that the lobster were reacting to encounter of small particles of undissolved lime. In a lab-based experiment, sand shrimp given a choice of settling on hydrated lime treated or untreated sand bottoms in glass aquaria showed a preference for the untreated sand (Reebs et al. 2011). Under field conditions, it is likely that most or all hydrated lime entering the water column would have been converted to calcium carbonate by the time it reached the sea floor, whereas this was probably not the case in the aquaria.

Presence of non-target organisms (specifically lobster) in areas being considered for the expanded leases in Malpeque Bay

There are several wild bivalve and crustacean species of fisheries interest in Malpeque Bay. The main wild bivalves include eastern oysters, bar clams, soft-shell clams and quahogs. Crustacean species of interest include the American lobster and Atlantic rock crab. All these species have planktonic larval stages within their life histories which could interact with aquaculture liming activities in Malpeque Bay (Ouellette et al. 2016).

Based on limited sampling, larvae of oysters were present in high abundance in the water column in Malpeque Bay from late July to early August (Fig. 4). This phase was followed by successfully recruited (benthic) larvae in late August. The pattern for blue mussels was similar although advanced by approximately one-month with elevated planktonic larvae abundance from the end of May until the end of July, followed by high levels of settling size larvae. The continued presence but low abundance of planktonic blue mussel larvae from the end of July to mid-October indicates secondary spawning events.

Specific information for lobster and rock crab in Malpeque Bay is not available however characteristics for these species in the southern Gulf of St. Lawrence (sGSL) would apply. For lobster, hatching in the sGSL is normally observed in July and August. The larvae go through three free-swimming larval stages and a postlarval stage (IV) and are all highly concentrated at or very near the surface (within the first 2 m). Stages I to III are active but relatively weak swimmers, in terms of maintaining position or making headway in flowing water, compared to stage IV that display remarkable swimmer ability and capacity for rapid and directed swimming. In general, the stage duration decreases with an increase of water temperature. Stage I larvae could emerge as early as late-June with peak numbers in July and well into August. The molt to stage IV marks the transition from the planktonic to the benthic stage. Stage IV larvae are observed in the upper portion of the water column, but undertake repeated vertical displacements in search of suitable temperature and substrate conditions for settling. Transition through stage IV can take from 11 to 49 days dependent on temperature and is expected to be completed by early-September. As such lobster larvae would be expected to be present in the water column from late-June to early-September in any given year (Fig. 4).

Rock crab larvae hatch in the sGSL as early as mid-June with a peak larval abundance observed in August and September. Settlement to the bottom could be observed until mid-September (Fig. 4).

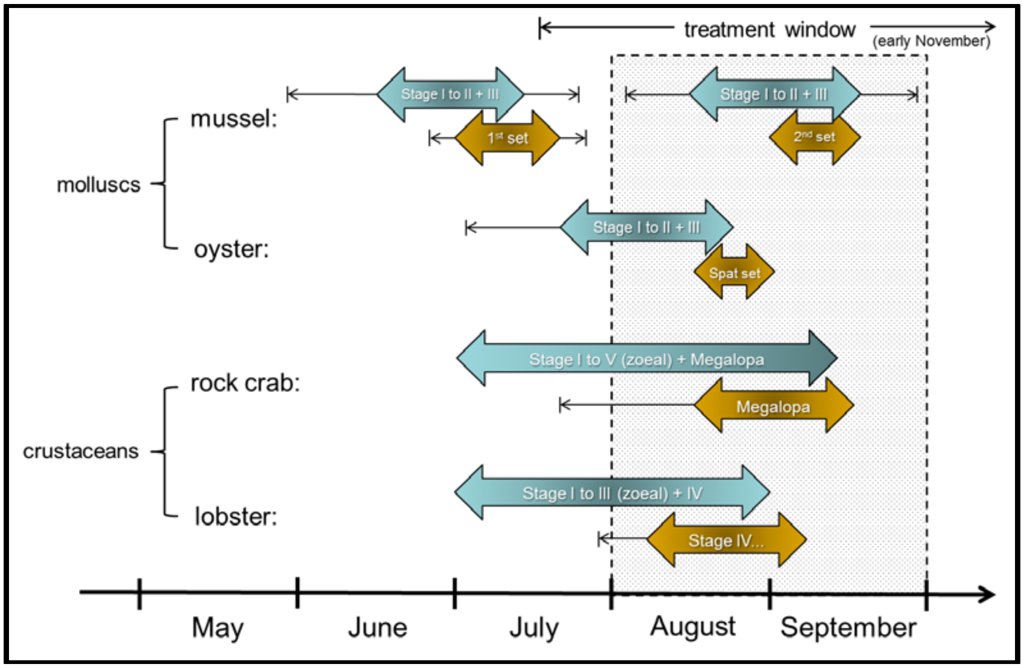

Figure 4. Summary of approximate temporal distribution of pelagic (green) and the first benthic (orange) life stages for shellfish species in the southern Gulf of St. Lawrence. Peak abundance periods are shown in broad arrows with shading indicating highest abundances, and ranges as narrow arrows. The timing of pelagic stages is mainly affected by water temperature and egg quality, whereas habitat type becomes an additional factor in the benthic stages. Also included is the general window (grey shaded rectangle and arrow showing range over season) of liming treatments from seed collectors and growout operations in Malpeque Bay.

In general lobsters are habitat specific and will select a more complex habitat with an assemblage of rocks (boulders) on a softer and mobile substrate (cobbles and gravel that can be mixed with mud and/or sand) to take advantage of rocks to excavate a shelter where they spend most of their time. The settling of stage IV lobster to the bottom is mainly driven by temperature and habitat type. A rocky habitat in shallow (<10 m) warm water (≥12°C) is especially important to promote the transition from the pelagic to the benthic stage (stage IV) to shelter from predators. Shelter-restricted juveniles (≤33 mm of carapace length; CL) are most abundant in cobble and cobble/boulder substrates and very low in mud flats. Based on tagging studies, movements of lobsters >51 mm CL within the sGSL are mostly limited to small distances; in the Malpeque area, the average traveled distance is 10 km with exchange between the bay and the adjacent coastal waters of the Gulf.

Rock crab of all sizes occur over a wide range of depths and habitat types with mostly larger animals abundant on both mud-dominated and sandy substrates but also on rock and cobble substrates. Higher abundances of smaller animals (<65 mm carapace width) are mostly observed in rocky areas. Rock crabs also occur well up into small, very warm, estuaries where pronounced seasonal migrations in and out of these small estuaries were observed.

There is limited fine scale information on lobster and rock crab fishing activities in Malpeque Bay. The commercial lobster fishery in Lobster Fishing Area (LFA) 24 which includes Malpeque Bay usually operates from 1 May to 30 June. Local knowledge indicates that there is an increase in lobster fishing activity in Malpeque Bay in June as harvesters move traps into the bay coinciding with the increase of water temperature. In 2012 to 2014, a lobster fishing buoy survey was conducted and showed that the areas used for fishing were mostly the channels at the mouth of the bay and the deepest depth contour edges. There were no fishing activities in the northwest, east (March Water) and southwest portions of the bay where shellfish aquaculture leases are present (Ouellette et al. 2016) (Fig. 5). There is no fine scale information on rock crab fishing activities specifically for Malpeque Bay. A rock crab fishing buoy survey conducted in 2012 and 2013 indicated that the fishing pattern for rock crab was similar to that of lobster, with a continuous fishing effort mostly concentrated in the deeper channels that start at the mouth of the bay heading southeast and then southwest.

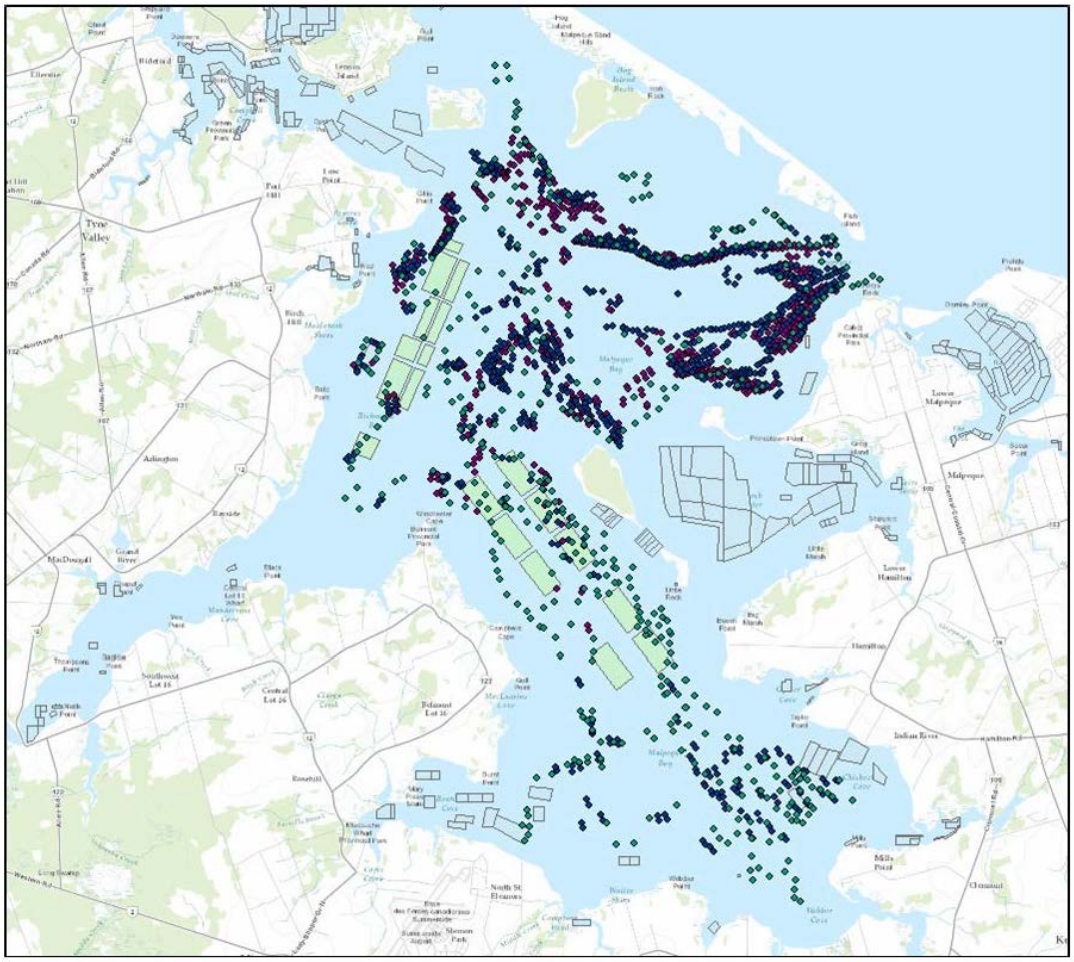

Figure 5. Spatial coverage of lobster buoys (shown as dots with colours by year) in Malpeque Bay, PEI based on a survey conducted in 2012 to 2014 by the DFO Aquaculture Leasing Division. Also shown is one scenario of the proposed shellfish aquaculture sites (light green polygons) and current (grey polygons) shellfish aquaculture leases.

Acoustic seabed classification with ground-truthing by scuba diving was used to characterize habitat in the proposed scenario for lease expansion in Malpeque Bay for their potential importance to lobster abundance. Lobster densities and size frequency correlate with the type of habitat. Prime lobster habitat (Type I) is characterized by boulders and cobbles on top of a combination of hard sandstone, sand and mud. Good lobster habitat (Type II) is comprised of small reefs with combinations of boulders, cobbles, mud, sand and hard sandstone separated by simple soft habitat (mud and sand). Based on seabed characteristics, the area of the south block is a poor habitat for lobster (Type IV; soft bottom) and seems to be a transitory zone (Fig. 6). The southern portion of the west block is a prime lobster ground (Type I and II) and is considered as a residency zone (Fig. 6).

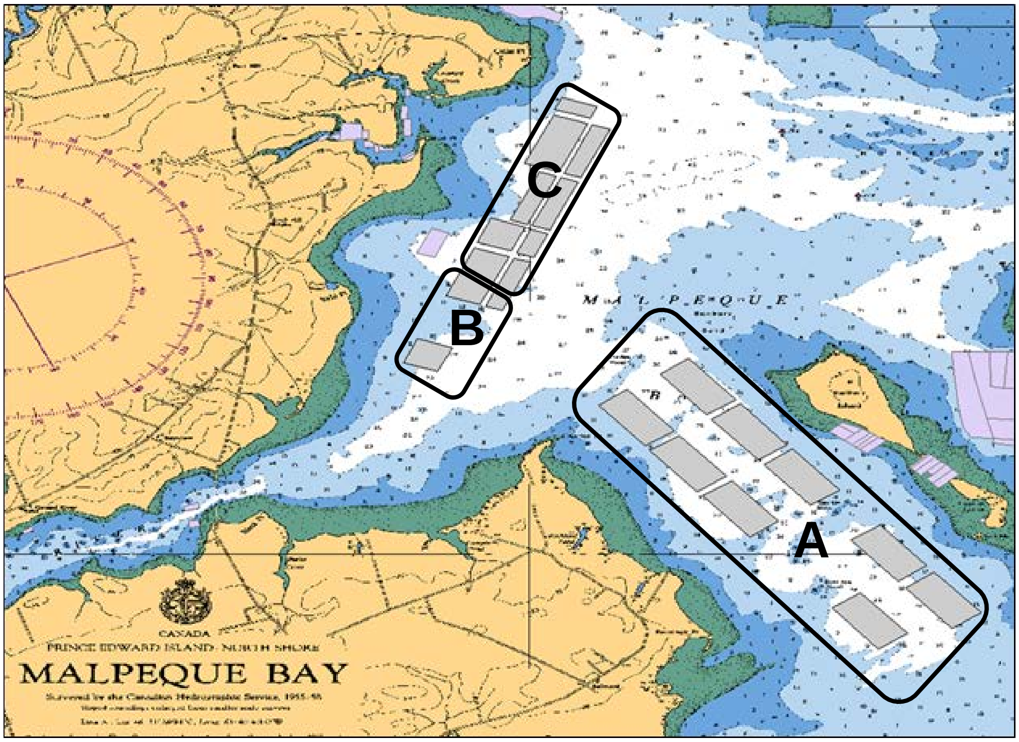

Figure 6. Summary of the spatial assessment of lobster habitat in the proposed scenario for lease expansion in Malpeque Bay, PEI. The habitat within the polygons marked (A) and (C) is considered poor habitat for lobster and serves as a transitory zone. The habitat within the polygon marked (B) is considered prime lobster ground and serves as residence habitat for all benthic life stages and size groups of lobster.

Extent to which non-target organisms would respond to chemical changes of the water expected with current industry practices for the expanded leases in Malpeque Bay

Spraying a saturated (~4%) and highly alkaline (~12.7 pH units) hydrated lime solution directly onto cultivated blue mussels elicited a negative behavioural response. Following re-immersion, sprayed mussels demonstrated a delay in opening of the valves of approximately seven minutes compared to control mussels. This is a short time which should have had no meaningful impact on physiology.

Lobster, crab and bivalve larvae are likely to be present in the water column while liming activities take place.

Stage I and potentially stage IV are the two lobster larval stages which have the greatest potential to interact with liming activities because of their seasonal timing of occurrence and their vertical distribution in the water column. Any larvae present in an approximately two meter post treatment plume would be subjected to high alkalinity for a short duration, i.e. minutes. Compared to the available toxicity information, it seems unlikely that hydrated lime treatments, as currently practiced, would have harmful effects on lobster larvae.

Mobile benthic stages of crustaceans are likely capable of moving out of elevated pH water masses of the spatial and temporal scales measured in the field. Empirical measurements of pH levels below treated mussel sleeves in Malpeque Bay show very small increases in pH from ambient levels and for relatively short periods of time.

Sources of Uncertainty

There is no specific information on the presence and the spatial / temporal distribution of lobster larvae in Malpeque Bay that can be compared to the spatial and temporal aspects of the liming treatment operations. In addition, inter-annual variation in larval stage timing remains undocumented for Malpeque Bay.

There is no information on the medium to long term consequences of short (minutes) pulses of exposure to increased pH from liming treatments to individual animals.

The characterization of the extent of the pH signal, which is used to define the spatial extent of the treatment effect, is not well quantified due to the 3-dimensional dynamics of the mixing environment and the ongoing chemical reaction. However, empirical observations indicate that the pH changes are weak and undetectable beyond five meters from the treatment site.

There is limited information regarding the fate of carbonate (calcium and magnesium) in sediments. There have been no reported studies on the toxicity of hydrated lime incorporated in bottom sediments to sediment dwelling organisms and there are no sediment quality guidelines for lime in Canada (CCME 1999). Calcium carbonate may be persistent indicating the potential for sediment accumulation with continued use. However, these compounds are expected to be inert and in the presence of CO_2, calcium carbonate may be converted to bi-carbonate and calcium. Cycling of CO_2, particularly that associated with mussel culture and tidal turnover, may serve to maintain dissolved CO_2 and thus reducing the calcium carbonate foot print.

The total amount of lime used during treatments within and over the entire year in Malpeque Bay is not reported. There is variation in the timing of treatment application among lease owners, in the equipment used, and in the quantity of lime used in individual treatments. This precludes any robust calculation of the total loading of lime in Malpeque Bay and subsequent assessment of bay wide effects on non-target organisms.

CONCLUSIONS AND ADVICE

Hydrated lime industry practices in Malpeque Bay result in short term and small scale effects on the pH characteristics of the water column in the vicinity of spraying activity. The risk posed to non-target organisms by use of hydrated lime depends on hazard (toxicity) and exposure. Although peak pH values due to treatment are at levels known to cause harmful effects, the duration of exposure is shorter than those in laboratory experiments which were shown to cause lethal or sublethal effects.

Planktonic larval stages of many bivalve and crustacean species would be expected to be in the water column during liming treatments in Malpeque Bay, the latter can occur from late July to November. The lethal concentration (LC50) for stage III lobster larvae based on a one hour pulse exposure is much higher than what would be encountered immediately in the water column after re-immersion of the treated socks.

In Malpeque Bay, the majority of the assessed seabed habitats in the proposed lease expansion scenario examined was considered to be poor quality habitat for lobster. The only exception was the southern portion of the west block (Fig. 6) which was characterized as prime lobster ground (Type I and II). If liming treatments within the sites resulted in carbonate precipitation to the sediments, the consequence to lobster production would depend upon the habitat type within the lease. From empirical observations, there was no visual evidence of particles precipitating to the seabed.

Liming activities associated with the lease expansions are unlikely to result in an environmental footprint which would be much greater than the footprint associated with the mussel farms.

SOURCES OF INFORMATION

This Science Advisory Report is from the February 8 and 9, 2016 meeting on the Review of potential impacts of hydrated lime treatments associated with proposed expansion of mussel production in Malpeque Bay, PEI. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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