GOALS	RECOMMENDATIONS	Action to Date	Future Action
1. Invest in Maine's Capacity to Monitor and Investigate the Effects of Ocean Acidification and Determine Impacts of Ocean Acidification on Commercially-Important Species and the Mechanisms Behind Those Impacts	*1.1. Enhance monitoring and create a database sufficient to support the development of regulatory and non-regulatory approaches to reduce and limit nutrients and organic carbon from sources that are contributing significantly to acidification of Maine's marine waters. Enhanced monitoring should begin in one or more pilot estuaries where impacts are presently occurring.*	…….	……..
	1.2. Expand monitoring of ocean acidification to establish its natural variability and to detect trends in water chemistry and related biological responses.	…..	…..

	1.3. Develop new tools with which to assess and understand acidification and its impacts in Maine waters.	The recruitment box was invented in 2015 to give information about recruitment of clams and other bivalves in an acidified environment.	DEI has submitted a proposal to establish a statewide clam settlement monitoring network using recruitment boxes. This would be similar to the post larval collection that is part of the American Lobster Settlement Index.
	1.4. Determine the causes and relative importance of acidification in the waters and sediments of Maine.	DEI has recently hired a post-doc in Marine Carbonate Chemistry (start date 15 August 2019) who will be examining the impacts of acidified waters and sediments on Maine's commercial marine species in the lab and in the field. The position will continue for at least 2 years.	The post-doc will be assembling a lab at DEI that is focused on determining how different pH or saturation state of calcium or aragonite affect shell formation in shellfish. He will conduct examine manipulative field experiments to examine how current and future carbonate chemistry of seawater and sediments affect life-history dynamics of local shellfish.
	1.5. Identify the impacts of acidified waters and sediments on Maine's commercial species.	In addition to the Marine Carbonate Chemistry post-doc, DEI has conducted numerous manipulative field experiments examining the effects of sediment and seawater on clam survival, growth, and recruitment. In Machiasport and Cutler in 2018 sediment and seawater pH was measured over a field experiment and it was found that despite a highly acidic environment at both sites the cultured clams	See above re: Marine Carbonate Chemistry post-doc who will assemble the OA lab at DEI as well as conduct manipulative field experiments.

		survived in areas that were protected from predators. These findings were similar to the findings from 2014-2017 in Freeport. DEI conducted a series of field trials (8) on the effects of sediment buffering on clams over the course of 3 years (2014-2017) in 5 different low pH coves in Freeport. In every field trial (8) the addition of crushed shell to sediment buffer did not result in an enhancement of soft-shell clam recruits compared to experimental units containing no sediment buffering. In 5 of the 8 trials significantly more clam recruits (p value < 0.001)were found in netted plots regardless on whether these units contained shell or other material.	
2. Reduce Emissions of Carbon Dioxide	*2.1. Strengthen coordination and continue participation with existing national, state, and regional initiatives regarding the reduction of atmospheric CO_2 levels.*	….	……

	2.2. Encourage key leaders and policymakers to synchronize in establishing a comprehensive and unified strategy to reduce carbon dioxide emissions.	……	……
	2.3. Expand actions at the state and local levels that may help in reducing CO_2 emissions.	……	……

3. Identify and Reduce Local Land-Based Nutrient Loading and, Organic Carbon Contributions to Ocean Acidification and Freshwater Runoff by Strengthening and Augmenting Existing Pollution Reduction Efforts and Making Groundwater Recharge a Land Use Priority.	*3.1. Identify and reduce nutrient loading and organic carbon from point source and nonpoint discharges determined to cause or contribute to ocean acidification.*	**…….**	**…….**
	3.2. Assess the need for water quality criteria relevant to ocean acidification.	**….**	DEI may incorporate pH measurements into our standard sediment sampling practices.
	3.3. Ensure that state staff and other practitioners are working with the best information and most effective technology.	It is our observation that more education is needed even among practitioners about the best practices for pH sampling [i.e. sampling many locations in the flat within each tidal height, understanding that pH readings change through the season and sediment pH can change with length of tidal exposure], especially when it comes to declaring a cove "acidic".	In addition to continuing to work with municipal, industry, and organizational partners on work to measure and/or restore clam flats, DEI has a proposal to institute a network of clam recruitment monitoring stations across the coast of Maine.

		DEI has reports from field experiments we have done across the coast on our website and data clam recruitment and green crabs datasets from Freeport and other locations w/ recruitment boxes.	
	3.4. Investigate incentive programs for pollution and freshwater runoff reduction.	…	….
	3.5. Support and reinforce current planning efforts and programs that address the impacts of nutrients and organic carbon and freshwater runoff into coastal waters.	…..	…..
	3.6. Enhance education and outreach programs that provide landowners with information about best practices for reduction of nutrient pollution.	….	…..

4. Increase Maine's Capacity to Mitigate, Remediate and Adapt to the Impacts of Ocean Acidification	*4.1. Preserve, enhance and manage a sustainable harvest of kelp, rockweed and native algae in bivalve areas and adjacent shoreline, and preserve and enhance eelgrass beds.*	Eelgrass and marsh grass are impacted by green crab foraging. DEI has data on rockweed harvesting from 2011 & 2013. Also, the first appraisal of growth and productivity of eelgrass in eastern ME(2004) can be found here: https://downeastinstitute.org/publications/eelgrass/.	
	4.2. Encourage bivalve production to support healthy marine waters.	From 2013-2018 DEI conducted 33 different field trials at 87 locations in Freeport to determine the cause of the clam decline and methods to enhance clams. It was found that the best way to enable clams to survive to harvestable size is to protect them from predators. Since 2017, DEI has been teaching Shellfish Committees (7 different Committees representing 9 towns) in eastern ME how to protect their clams, measure survival and to also measure clam recruitment in different coves. This year (2019) we are also conducting the first ever statewide test of the traditional clam enhancement technique of	DEI will continue to produce shellfish in our hatchery for public fisheries stock enhancement. We will also continue to work with industry, municipalities, and organizations on field research that enhance and monitor shellfish populations. The experiments to determine the efficacy of the brushing technique to enhance clam populations will be completed at the end of the year and results will be known by early 2020.

	"brushing". The experiments are deployed in each of the three regions of the ME coast. Results will be known at the end of 2018/ early 2019.	
4.3. Spread shells or other forms of calcium carbonate ($CaCO_3$)in bivalve areas to remediate impacts of local acidification.	Our 8 field experiments done over 3 years at 5 different coves showed that the addition of crushed shell (no matter what size) to sediment buffer did not result in an enhancement of soft-shell clam recruits compared to experimental units and plots containing no sediment buffering. Therefore DEI recommends that towns interested in enhancing clam populations do not attempt to do so by spreading crushed clam shells to buffer sediments.	
4.4. Increase the capacity of the fishing and aquaculture industries to adapt to ocean acidification.	All DEI's research, conducted across the coast shows that clams are under much more threat from predation, caused by warming waters, than OA.	
4.5. Identify refuges and acidification hotspots to prioritize protection and remediation efforts.	Eastern ME may be a cooler water refuge. This cooler water could mean greater acidification because cold water absorbs MORE CO2 than warm water, so eastern Maine could become a hotbed for research on OA.	If OA becomes more of an issue in eastern ME DEI will be poised to help lead that work with our location, new Post-doc and OA lab.

	4.6. Encourage the enhancement and creation of research hatcheries.	DEI has been a public research hatchery since 2003. We raise up to 10 different species: soft- shell clam, razors, European and American oysters, quahogs, Arctic surf clams, Atlantic surf clams, Sea scallops, and lobsters, and mussels.	DEI will continue to provide the public with information about the fate of many commercially-important shellfish as we continue our field trials with shellfish grown in the hatchery.

5. Inform Stakeholders, the Public, and Decision-Makers about Ocean Acidification in Maine and Empower Them to Take Action.	*5.1. In addition to providing the commission's report, its key findings should be communicated to the Governor, Maine's legislative leaders, Maine's Congressional delegation, the press and the general public in a series of briefings by commission members.*		DEI is definitely interested in sharing information in this manner.
	5.2. Continue efforts to increase the understanding of ocean acidification among key stakeholders, targeted audiences and local communities to help implement the commission's recommendations.	We have done our best: presenting in communities where we have done research, presenting in interested communities, presenting at the Fishermen's Forum, scientific presentations.	DEI is interested in working with other organizations on this effort.

	5.3. Enhance the existing communication network of engaged stakeholders, state agency representatives and the research community.		
	5.4. Develop, adapt and use curricula on ocean acidification in K-12 schools and institutes of higher education and increase interdisciplinary university programs to equip young leaders with the skills to find solutions to complex multidisciplinary problems such as ocean acidification.	DEI has been providing experiential, hands-on science and math education to kindergarten-12th grade students since 2011. Many local schools attend *Marine Science Days* on an ongoing basis. In addition we hold the Coastal Science Academy for teachers and Marine Science Summer Camps. This program has generated data on clam growth and survival 2010 in downeast ME.	Our work in this area will continue through our Education Center.

6. Maintain a Sustainable and Coordinated Focus on Ocean Acidification.	*6.1. Create an on-going ocean acidification council.*		Important to include other impacts of climate change/disruption/breakdown, such as warming waters, as well due to the negative impacts on shellfish populations.

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