EcoSystem Indicator Partnership

Information on change in the Gulf of Maine

Aquaculture in the Gulf of Maine

The aquaculture industry has had a home in the Gulf of Maine/Bay of Fundy for decades, with oyster sites cultivated in Nova Scotia for nearly a century. In its current form, the industry began in the 1970s. Despite its importance to local economies and debated impacts to the environment, the roles of the numerous agencies that monitor sites are difficult to identify and understand as is the true density of aquaculture in the region. Regulations are distinctly different between various states and provinces and have greatly shaped the growth of the aquaculture industry. As a result, aquaculture has emerged as a dominant industry in parts of the Bay of Fundy while some southern locations have seen more modest growth.

The most dominant species in the region are listed in the table below.

In 2006 the Gulf of Maine Council on the Marine Environment formed a partnership to assess the health of the Gulf of Maine ecosystem through the use of indicators. The EcoSystem Indicator Partnership (ESIP) was created as a direct result of the recognized need to understand ecosystem status and trends in the Gulf of Maine. The Council has many efforts that look at the health of the Gulf of Maine through monitoring and restoration. ESIP is an attempt to bring together information from these and other efforts in the region.

Why use indicators?

Simply put, indicators are one of the best tools for understanding the complexities of the Gulf of Maine/Bay of Fundy. Like lights on the dashboard of a car, indicators can work in concert with each other to provide an essential look at the larger system. They can be combined into complex calculations, like the Dow Jones Index, or be relatively simple, like body temperature. Simple indicators are often driven by complicated pressures and responses. The two indicators that ESIP has chosen for aquaculture in the Gulf of Maine are:

1. The economic value of aquaculture
2. Acres of permitted aquaculture

Common Name (in alphabetical order, not importance)	Scientific Name	State or Province
Atlantic salmon	*Salmo salar*	Maine, N.B., N.S.
Bay scallops	*Aequipecten irradians*	Mass.
Blue mussels	*Mytilus edulis*	Mass., N.H. , Maine, N.B., N.S.
Cod	*Gadus morhua*	Maine, N.B., N.S.
Eastern/American oysters	*Crassostrea virginica*	Mass., N.H., Maine, N.S.
European oysters	*Ostrea edulis*	Maine, N.S.
Giant sea scallops/Sea scallops	*Placopecten magellanicus*	Mass., N.B., N.S.
Halibut	*Hippoglossus hippoglossus*	Maine, N.B. N.S.
Quahogs	*Mercenaria mercenaria*	Mass., Maine
Rainbow trout	*Salmo gairdneri kamloops*	N.S.
Soft shell clams	*Mya arenaria*	Mass. N.B.
Surf clams	*Spisula solidissimia*	Mass.
Urchins	*Strongylocentrotus droebachiensis*	N.H., Maine

WHAT IS IMTA?

Fulfilling aquaculture's growth potential requires responsible technologies and practices. Sustainable aquaculture should be ecologically efficient, environmentally benign, product-diversified, profitable, and beneficial to society. Integrated multi-trophic aquaculture (IMTA) has the potential to achieve these objectives by cultivating fed species (e.g. finfish fed sustainable commercial diets) with extractive species, which utilize the inorganic (e.g. seaweeds) and organic (e.g. suspension- and deposit-feeders) excess nutrients from fed aquaculture for their growth.

By using IMTA systems, extractive aquaculture produces additional valuable biomass, while simultaneously providing biomitigative services for the surrounding ecosystem and humans. Through IMTA, some of the uneaten feed and wastes/nutrients/by-products considered "lost" from the fed component are recaptured and converted into harvestable and healthy seafood of commercial value, while biomitigation takes place (partial removal of nutrients and CO_2, and supplying of oxygen). In this way, some of the externalities of fed monoculture are internalized, hence increasing the overall sustainability, profitability, and resilience of aquaculture farms.

IMTA is an emerging aquaculture practice in the Western World and will certainly evolve as experience is gained. Several areas in the Gulf of Maine are on the leading edge of research, development, and commercialization of this concept, with IMTA systems being granted permits for operations and being commercially implemented. Examples and further information can be found at **www.unbsj.ca/sase/biology/chopinlab**.

Economic Value of Aquaculture

Indicator 1

Aquaculture in the Gulf of Maine is a productive and valuable sector of the economy. In 2008, total finfish and shellfish economic value was placed at over $240 million USD ($260 million CAD). The relative importance of aquaculture varies between the various states and provinces and is displayed in the table below. The States of Maine and Massachusetts, as well as the Province of New Brunswick, provided records to allow ESIP to examine changes to the industry over time. New Brunswick's aquaculture production numbers have been recorded from 1999 through to the present day. These records represent salmon production and show that the economic value of salmon aquaculture during the last 11 years has remained relatively constant. In contrast, Maine's salmon aquaculture values declined from a high of $90 million USD ($134 million CAD) in 2000 to a low of approximately $20 million USD ($25 million CAD) in 2007 before rebounding in 2008. The proportion of total economic value based on shellfish as opposed to finfish also varies between states and provinces. For example, Massachusetts' aquaculture sector in the Gulf of Maine relies upon shellfish whereas Maine, New Brunswick, and Nova Scotia have a larger portion of aquaculture value derived from finfish with salmon being the dominant species. No single indicator can fully assess the importance of aquaculture in the Gulf of Maine; however, economic indicators such as shellfish and finfish production allow for a better understanding of the impact of aquaculture on the communities that surround the Gulf of Maine.

Photo: Thierry Chopin

Integrated Multi-Trophic Aquaculture (IMTA) at a Cooke Aquaculture site in the Bay of Fundy, Canada. This system combines fed species (salmon at left) with extractive species that recapture excess inorganic and organic nutrients for growth of additional crops (seaweeds at right background, and mussels at right foreground).

Total Finfish and Shellfish

State/Province	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
US dollars											
Nova Scotia[1]										$ 8,159,494	$14,388,509
New Brunswick[2]	$100,952,980	$122,205,566	$116,254,264	$123,856,970	$127,723,786	$134,458,147	$185,699,887		$168,972,986	$180,241,486	$139,232,191
Maine[3]	$67,496,007	$90,725,385	$72,763,840	$37,469,592	$33,108,547	$46, 932,595	$30,805,697	$28,126,057	$23,380,090	$52,348,904	
New Hampshire[4]							$255,848	$380,014	$334,345	$329,300	$371,690
Massachusetts[5]	$1,098,230	$3,490,231	$2,611,327		$2,877,796	$2,865,958	$2,788,008	$4,177,511	$4,987,231	$6,498,583	
Canadian dollars											
Nova Scotia[1]										$8,698,137	$16,431,351
New Brunswick[2]	$150,000,000	$181,500,000	$180,010,000	$194,500,000	$179,000,000	$175,000,000	$225,000,000		$181,609,000	$192,140,000	$159,000,000
Maine[3]	$100,288,283	$134,745,560	$112,668,718	$58,840,740	$46,400,362	$61,083,722	$37,325,181	$31,897,581	$25,021,004	$55,804,679	
New Hampshire[4]							$309,994	$430,972	$359,348	$351,039	$424,462
Massachusetts[5]	$1,631,794	$5,183,700	$4,043,421		$4,033,121	$3,730,102	$3,378,041	$4,737,689	$5,360,183	$6,927,582	

Data represent Gulf of Maine only. Average annual exchange rate utilized for calculating USD:CAD. Data not available in blank fields.

1 Values from Nova Scotia Department of Fisheries and Aquaculture.
2 Values from New Brunswick Department of Agriculture, Aquaculture, and Fisheries and represent salmon production only. Remainder of species determined to not be significant in the Bay of Fundy.
3 Values from Maine Department of Marine Resources and calculated utilizing data from lease holders. Data pre-2005 not included for shellfish as data deemed unreliable.
4 Values from New Hampshire Fish and Game utilizing reported sales of product.
5 Values from Massachusetts Division of Marine Fisheries utilizing data reported by lease holders.

Acres of Permitted Aquaculutre

Indicator 2

The amount of acreage permitted for aquaculture varies by state and province in the Gulf of Maine. Shellfish acreage in production varies, with Maine and Nova Scotia leading at 650 acres and 4,796 acres respectively. The majority of leased areas in New Brunswick are for finfish aquaculture, like salmon, while Maine has acres evenly divided between the two. For the length of records obtained there has been relatively little change in the amount of acreage permitted.

It is important to note that while the scale of aquaculture relative to the overall area of the Gulf of Maine is quite small (less than 0.02% of the Bay of Fundy is permitted for aquaculture) impacts at the local level may be significantly larger since aquaculture activities tend to be concentrated in areas where environmental conditions are favorable for sustainable operations. For example, there are 130 acres permitted for shellfish production in Maine's upper Damariscotta River alone.

Finfish

State/Province	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Nova Scotia[1]										249	249
New Brunswick[2]	3,313	3,313	3,783	3,783	3,835	3,921	3,943	4,054	4,232	4,255	4,255
Maine[3]	738	750	750	745	745	759	708	604	615	636	650
New Hampshire[4]							30	30	30	30	0
Massachusetts[5]	0		0	0	0	0	0	0	0		

1 Values from Nova Scotia Department of Fisheries and Aquaculture.
2 Values from New Brunswick Department of Agriculture, Aquaculture, and Fisheries.
3 Values from Maine Department of Marine Resources.
4 Values from New Hampshire Fish and Game. Data for urchins also available and equal to two acres from 2005–2009. Data do not include land sites that utilize pumped water.
5 Values from Massachusetts Division of Marine Fisheries.

Data not available in blank fields.

Shellfish

State/Province	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Nova Scotia[1]										4,796	4,796
New Brunswick[2]					32	32	32	32	32	32	
Maine[3]	401	477	521	542	582	650	659	669	713	656	651
New Hampshire[4]							11	13	13	13	13
Massachusetts[5]	451			510	527	561	541	555	560		

1 Values from Nova Scotia Department of Fisheries and Aquaculture. Value does not include soft shell clams.
2 Values from New Brunswick Department of Agriculture, Aquaculture, and Fisheries.
3 Values from Maine Department of Marine Resources.
4 Values from New Hampshire Fish and Game. Data for urchins also available and equal to two acres from 2005–2009.
5 Values from Massachusetts Division of Marine Fisheries.

Data not available in blank fields.

Climate Change

Climate change impacts in the Gulf of Maine/Bay of Fundy range from air and sea temperature changes, to sea level rise, to increased frequency of intense storms and heavy precipitation. Some influences of climate change are already apparent including the adverse effects of ocean acidification on wild shellfish populations. All of these impacts can play a role in what species are chosen for aquaculture, where aquaculture takes place, and what adaptations may be necessary to keep aquaculture production successful.

One of the most direct impacts is the projected increase in sea surface temperature (SST) across the Gulf over the next 50 to 100 years. As SST increases, species type and viability will be impacted. While some species thrive at warmer temperatures, others may have too narrow a window of temperature acceptable for productivity.

Sea level rise (SLR) may not impact "at sea" production facilities directly, but coastal infrastructure that supports aquaculture may be at risk. SLR indicates a permanent loss of land. It also exposes more coastline to inundation and erosion. More intense storms have several characteristics that put aquaculture at risk to damage and loss. Wind and wave damage to farming infrastructure can be highly detrimental to overall production. This includes coastal as well as "at sea" structures. Wind and wave action may also increase the risk of farmed species lost to the open ocean. Heavy precipitation, typically associated with these more intense storms, will increase runoff into the small embayments where aquaculture is often situated.

Adaptation strategies related to these impacts may include appropriate species choice, flexibility in siting and in farming structures and appropriate decisions related to prevention of land runoff and contamination of nearshore environment. Links to more information are available at the ESIP webpage **www2.gulfofmaine.org/esip**.

Common Name	Scientific Name	Optimal Temperature[1]
Atlantic salmon	*Salmo salar*	42–60°F (5.6–15.6°C)
Blue mussels	*Mytilus edulis*	41–68°F (5–20°C)
Eastern/American oysters	*Crassostrea virginica*	64–81°F (18–28°C)
Giant sea scallops/Sea scallops	*Placopecten magellanicus*	43.7–60.8°F (6.5–16°C)
Quahogs	*Mercenaria mercenaria*	64.4–77°F (18–25°C)
Soft shell clams	*Mya arenaria*	60.8–68°F (16–20°C)
Surf clams	*Spisula solidissimia*	57.2–86°F with optimal at 71.6 °F (14–30°C with optimal at 22°C)

1 Optimal temperatures cover the various life stages of the species in question.

Environmental Effects of Bivalve Shellfish Culture

Commonly cultured bivalves, such as oysters, clams, and mussels, are filter feeders. As a result, bivalve aquaculture is very different from the culture of other aquatic animals. Unlike finfish, for example, bivalves feed on plankton naturally occurring in the water, thus avoiding the need for commercial feed. No net nutrients are added to the water body as a result of shellfish aquaculture. Bivalves consume and concentrate plankton and other small particles from the water column, which are then either digested and the wastes released as feces, or, as in the case of non-food particles, are concentrated (but not digested) and released as pseudofeces. The feces and pseudofeces are then deposited to the benthic sediments. When bivalve shellfish are harvested, the result is a net removal of nutrients from the water body.

In most cases, water clarity and light penetration is improved due to bivalve aquaculture activities since they remove many of the small particles from the water column. In addition to water clarity, other water quality parameters can be improved by the presence of bivalve shellfish culture. However, care must be given to not create low dissolved oxygen conditions in the benthic sediments underneath intensive bivalve shellfish cultivation operations as has been observed in certain situations in Maine.

Ecological services of bivalve shellfish aquaculture include providing additional habitats for other species through the use of complicated three dimensional cultural structures such as long lines and floating cages. Local species abundance and the diversity of fish and invertebrates are usually increased.

Harvesting of bivalve shellfish with dredges can cause changes in sediment structure and benthic communities. However, with proper management, bivalve shellfish activities can minimize the environmental impacts of harvesting and provide benefits to the surrounding ecosystem.

Scarborough Beach State Park

Photo: Esperanza Stancioff

Indicator Reporting Tool

All data used for the two indicators discussed in this fact sheet are available for graphing and downloading via ESIP's Indicator Reporting Tool **(www2.gulfofmaine.org/esip/reporting)**. The reporting tool uses familiar mapping programs to enable users to locate aquaculture data in the region and build graphs for time periods of interest. The snapshots provided by the tool can provide critical information in a timely fashion for those faced with making decisions quickly. Questions such as the ones that follow below can be answered using the tool.

- How has the economic value of aquaculture varied over time as compared to extreme precipitation trends?
- What analysis have been done at nearby Gulfwatch (Blue Mussel) sites?
- Where is eelgrass present that might be affected by an aquaculture site?

To see the answers visit the ESIP webpage: **www2.gulfofmaine.org/esip**.

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www2.gulfofmaine.org/esip

For more information on any of the ESIP products, please visit our website at www2.gulfofmaine.org/esip. You may also contact the ESIP Program Manager at ctilburg@securespeed.us. We always welcome new members to our work.

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Gulf of Maine Council on the Marine Environment

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