Seasons in the Sea

By Ann Michelle Morrison, SD

New Englanders are familiar with the signs of the changing seasons. We expect cold, snowy days in the winter and long, hot days in the summer. The seasonal patterns we observe also go beyond the weather. We see the return of birds like robins and flowers like crocuses each spring, and we notice the changing colors of tree leaves each fall.

These seasonal patterns that are so familiar to us happen here on land. In the ocean, there are no spring flowers or leaves changing color, but beneath the blue, wavy water of the Gulf of Maine, the sea, like the land, changes with the seasons. The Gulf of Maine is the relatively shallow water located off the coasts of Massachusetts, New Hampshire, Maine, and Nova Scotia, Canada.  The region is home to some of the most productive fisheries in the world and hosts at least 18 species of marine mammals throughout the year.

***Winter***

The Gulf of Maine cycle begins in the dark and stormy months of winter.  Nor’easters and other large storms cross the Gulf, churning the water with strong winds.  During winter, the deep and shallow waters of the Gulf of Maine are roughly the same temperature, which allows movement of nutrients (particularly nitrogen) from the deep waters to the surface waters.

Despite the high concentration of nutrients in surface waters during the winter, relatively few organisms are found near the surface during this time of year. The deep ocean is always dark, but in the winter even the surface has reduced light levels because of winter's short and frequently cloudy days.  Under these conditions, the tiny floating plant-like organisms, called phytoplankton, are less abundant.  Zooplankton, the small animals that feed on phytoplankton, are also relatively few in number in the winter.

Some zooplankton species, such as the copepod *Calanus* *finmarchicus*, hide out in the deep basins of the Gulf of Maine until these waters develop the conditions the copepods need for growth and reproduction. Copepods are a category of zooplankton with almost transparent bodies and long antennae.  For young fish such as cod and redfish in the Gulf of Maine, the presence of zooplankton along the sea floor means plentiful food. These fish benefit from the abundance of zooplankton as they spend the winter months living along the bottom of the Gulf of Maine.

***Spring***

As the angle of the Earth changes and the northern hemisphere tilts towards the sun, sea surface temperatures increase, and the days get longer.  Storm frequency decreases, and there is less mixing in the ocean due to wind.  Warming of surface waters creates a layer of water called a thermocline, which acts as a barrier and further reduces mixing between the warm waters above it and the cold waters below.

Life in the Gulf of Maine awakens in the spring.  Phytoplankton that need light and nutrients to thrive multiply rapidly in the warm surface waters above the thermocline.  The surface waters are rich in nutrients in the spring thanks to winter mixing from the deep.  This combination of light, warmth, and nutrients initiates the annual “Spring Bloom,” in which the surface waters fill with phytoplankton.

 In early spring, populations of the copepod *C. finmarchicus*, which have been sheltered in the deep basins of the Gulf of Maine, rise to the surface waters.  With the arrival of the Spring Bloom, *C. finmarchicus* numbers rapidly increase alongside the growing phytoplankton population.  Other species of zooplankton follow soon after.  By the end of the spring phytoplankton bloom, zooplankton concentrations have increased substantially since the availability of food, or phytoplankton, allows zooplankton to multiply.

This zooplankton is a rich source of food for growing fish larvae, and many fish in the Gulf of Maine time spawning (egg laying) to make the most of the Spring Bloom.  Once a year, usually in April, female cod spawn by releasing millions of eggs that float on the surface of the ocean where they are fertilized.  The fertilized eggs develop into larvae that feed on zooplankton in the surface waters.

The cod and other fish are more abundant some years than others. One hypothesis explaining this suggests that differences in fish abundance result from differences in the timing of the Spring Bloom. The Spring Bloom does not occur each year on the same day or even the same week.  This hypothesis suggests that an early Spring Bloom results in an earlier zooplankton population, which provides a large source of food for the hungry young fish.  These conditions are thought to produce a strong fish population from that year’s larvae.  On the other hand, a late Spring Bloom could mean that there is little food available for the young fish because the fish are born before their food becomes available.  Fewer fish will survive, producing a lower fish population from that year’s larvae.  Changes like early spring warming or frequent spring storms that can affect the timing of the Spring Bloom may indirectly affect some fish species.

***Summer***

In summer, the sea surface temperatures continue to rise, and storm frequency continues to decline. The thermocline between the warm and cold waters of the Gulf of Maine intensifies and further restricts flow of nitrogen from the nutrient-rich deep water to the now nutrient-depleted surface waters.  The increased light intensity of summer is beneficial to phytoplankton, but the reduced nitrogen supply limits phytoplankton growth.

Zooplankton continue to increase in numbers through the summer as they consume phytoplankton.  Populations of some zooplankton species peak in July, some peak in August, and others peak in the fall.

While larval fish born in the spring continue to feed on zooplankton, other fish species are preparing to spawn.  Herring adults fatten up on the large zooplankton population before they release their eggs on the ocean floor at the end of summer.  Fertilized herring eggs develop into larvae that rise up to the surface waters to feed.  The herring larvae then drift with the plankton for about 6 months before they metamorphose into juvenile herring.

***Fall***

The arrival of fall brings reduced temperatures, reduced light intensity and duration, and an increase in storms that promote mixing.  Nutrients again rise up to the surface waters where there is still enough light for phytoplankton to multiply.  A “Fall Bloom” is common in the Gulf of Maine.  The Fall Bloom is typically smaller than the Spring Bloom because the upward movement from the deep waters is mainly mixing from storms rather than the more continual mixing that occurs in the spring. This fall mixing allows just enough nitrogen to rise to the surface to stimulate phytoplankton growth once more.

The Fall Bloom is beneficial to zooplankton and fish alike.  Larval herring that were spawned in the Summer continue to drift and feed off the plankton in the surface waters throughout the Fall and into Winter.   Meanwhile, the larval cod that have grown throughout the summer are now juvenile fish.  In fall, these juvenile cod swim out to deeper waters and sink to the bottom of the sea where they will feed through the winter.  Some adult cod actually spawn again in the Fall.  Then the new cod larvae feed on the abundant food from the Fall Bloom and the zooplankton growth that follows.

*Back to the beginning . . .*

Fall leads into winter, and the seasonal cycle of the Gulf of Maine begins again.  Bacteria that live on the ocean floor have decomposed zooplankton and other animals that died throughout the year as well as fecal material that dropped through the thermocline and settled on the bottom.  Decomposition released the basic nutrients into the water column again.  Some of these nutrients will be mixed into the surface waters during the winter as the waters of the Gulf of Maine become uniform in temperature again, weakening the thermocline barrier.

Life is not easy in the Gulf of Maine.  Of the millions of fish eggs spawned each year, perhaps 1% will become adult fish.  Predation from fish, other animals, and humans can affect fish populations. However, the seasonal temperature changes and movement in the water that drive phytoplankton and zooplankton abundance may also have a significant influence on early fish survival.  It is said that “timing is everything,” and that adage may be fitting for life in the Gulf of Maine.  Scientists are studying how and why the Spring Bloom happens when it does and how the rest of life in the Gulf of Maine is impacted.  If scientists can begin to unravel the interconnectedness of weather, tide, current, sunlight, nutrients, phytoplankton, zooplankton, and other animals further up the food chain, we may begin to understand how to best manage and sustain fisheries, shellfisheries, and marine mammals within the Gulf of Maine.

This information has been adapted from:

Cushing, D.H., 1990. Plankton Production and Year-class Strength in Fish Populations: an Update of the Match/Mismatch Hypothesis. Advances in Marine Biology 26, 249-293.

GMA, 2005. Herring Biology: Life-Cycle. Gulf of Maine Aquarium.  http://www.gma.org/herring/biology/life\_cycle/default.asp.

GoMOOS, 2002. About the Gulf of Maine.  http://www.gomoos.org/aboutgulfme/.

HBOI, 2005. Gulf of Maine Copepod Primer. Harbor Branch Oceanographic Institution.  http://www.at-sea.org/missions/maineevent4/docs/copprimer.html.

Manning, C.A., Bucklin, A., 2005. Multivariate analysis of the copepod community of near-shore waters in the western Gulf of Maine. Marine Ecology Progress Series 292, 233-249.

Minister of Supply and Services, Canada. Redfish.  **[Error! Hyperlink reference not valid.](http://%22/)**.

Platt, T., Fuentes-Yaco, C., Frank, K.T., 2003. Marine ecology: Spring algal bloom and larval fish survival. Nature 423, 398-399.

Runge, J., 1988. Should we expect a relationship between primary production and fisheries?  The role of copepod dynamics as a filter of trophic variability. Hydrobiologia 167/168, 61-71.

Ryan, S., Department of Fisheries and Oceans, Canada., The Evening Telegram, NFFAUW, Human Resources Development Canada, DataDisk, Inc., 1996. Northern Cod- A matter of survival.  **[Error! Hyperlink reference not valid.](http://%22/)**.

Townsend, D.W., Thomas, A.C., Mayer, L.M., Thomas, M.A., Quinlan, J.A., 2004. Oceanography of the northwest Atlantic continental shelf (1,W). In: Robinson, A.R. and K.H. Brink (Eds.), The Sea: The Global Coastal Ocean: Interdisciplinary Regional Studies and Syntheses. Harvard University Press, Boston.