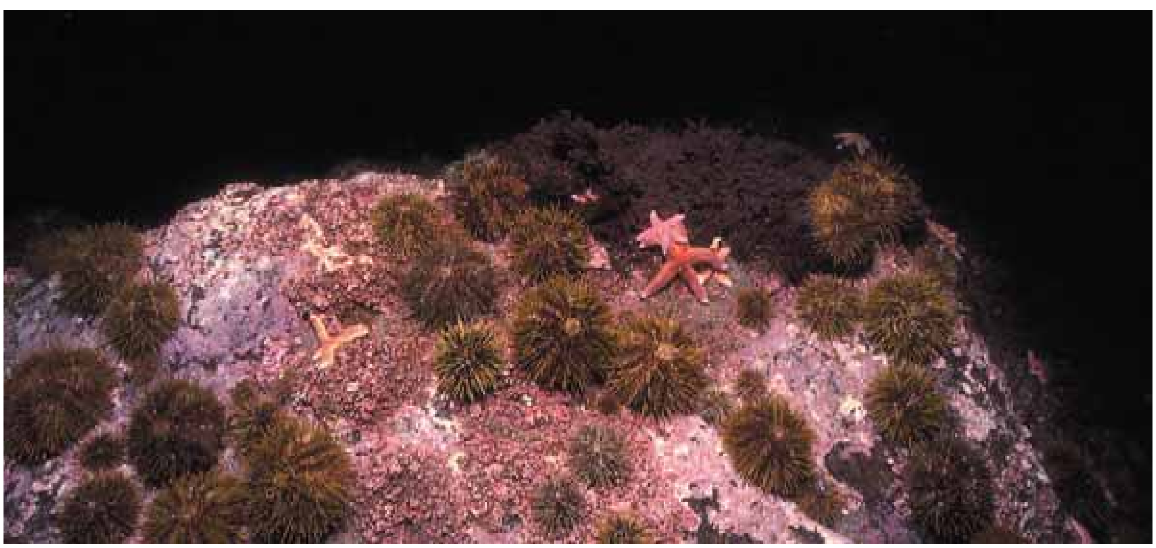
Green Gold

Scientific Findings for Management of Maine's Sea Urchin Fishery



By Peter H. Taylor

Maine Department of Marine Resources

This publication was authorized, edited, and funded by the Maine Department of Marine Resources and the Sea Urchin Zone Council.

Partial funding for this publication was provided by the Science Translation Project of the Gulf of Maine Council on the Marine Environment.

Gulf of Maine Council on the Marine Environment

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Citation

Taylor, P. H. 2004. *Green Gold: Scientific Findings for Management of Maine's Sea Urchin Fishery*. Maine Department of Marine Resources, Boothbay Harbor, Maine.

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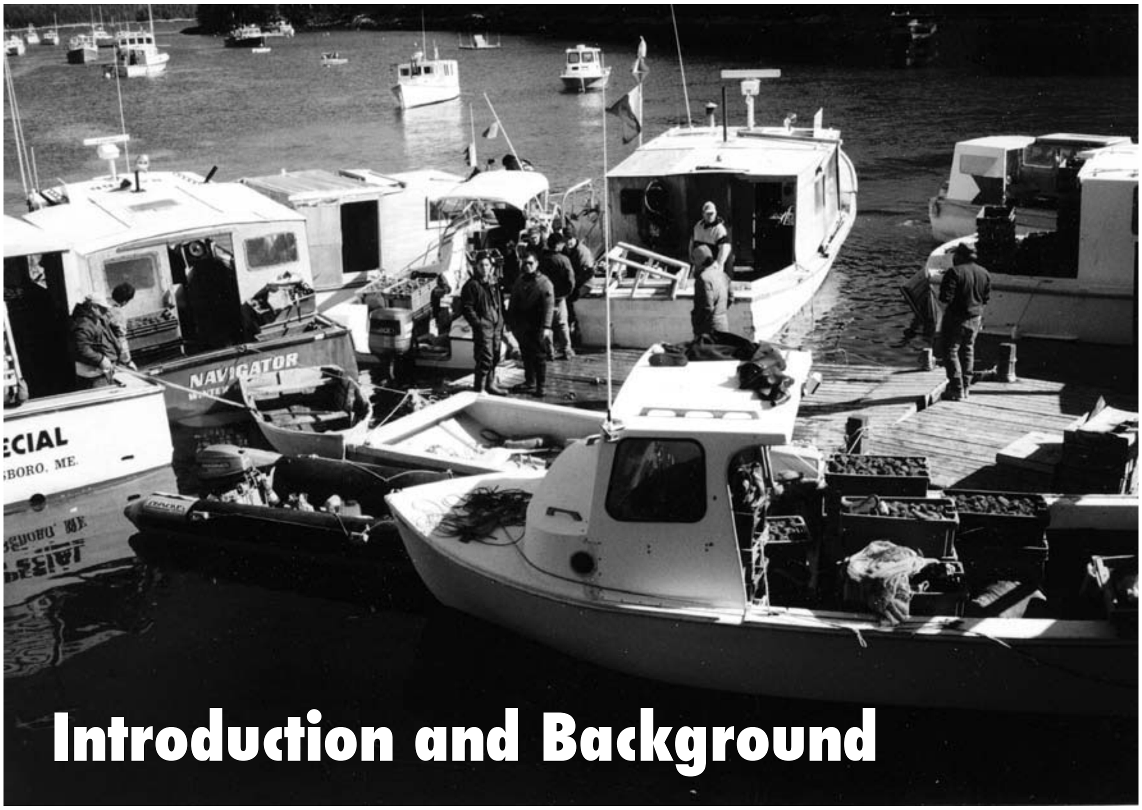


Edwin Creaser

Urchin divers wait to unload their catch at the dock in Winter Harbor, Maine, in 1997.

Overview

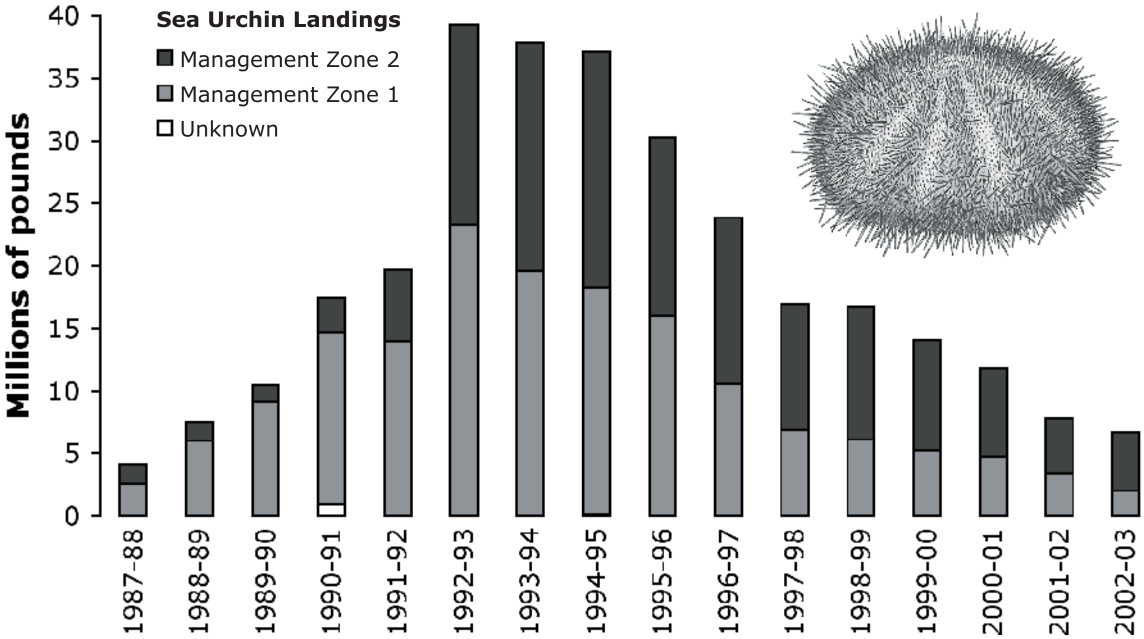
The green sea urchin fishery contributes millions of dollars per year to Maine's economy. It developed rapidly in the late 1980s as a result of expanding export markets, and landings peaked at 39 million pounds in the 1992-93 season. The fishery's value hit $36 million in 1994-95, second only to the state's lobster fishery. Since 1993, however, urchin landings have declined steadily because of a large decrease in the urchin stock due to fishing. In 2002-03, only 6.7 million pounds of urchins were harvested.

Processors crack harvested urchins and remove the roe, or reproductive organs. Most roe produced in Maine is shipped to Japan, where it is called *uni* and used in a variety of culinary dishes. At its peak, Maine's urchin fishery employed some 2,700 licensed harvesters (divers and draggers) and hundreds of buyers, processors, truck drivers, and other workers.

The decline in the urchin stock has been dramatic. In the late 1980s, urchins were abundant throughout the Gulf of Maine. Their voracious grazing of kelp and other seaweeds changed many areas of the seafloor from kelp beds to barrens. Now urchins are scarce all the way from Kittery to Penobscot Bay. Harvesters still find reasonable numbers of urchins in eastern Maine, but it is not known if the urchins are producing enough young to replenish the population.

Along with economic impacts, the reduction in the urchin stock has caused important ecological changes in the Gulf of Maine. Kelp beds have returned to dominate southern Maine and are becoming more extensive into eastern Maine. While this change may benefit lobsters and other creatures, it makes it difficult for urchins to recover because kelp beds harbor predators.

Maine's urchin fishery faces major challenges. During the boom years of the late 1980s and early 1990s, the state did not take action to manage the newly emerged fishery. The Maine Department of Marine Resources (DMR) focused on established fisheries and had little capacity for managing rapidly developing fisheries. The management actions taken in subsequent years have not been sufficient to halt or reverse the decline.

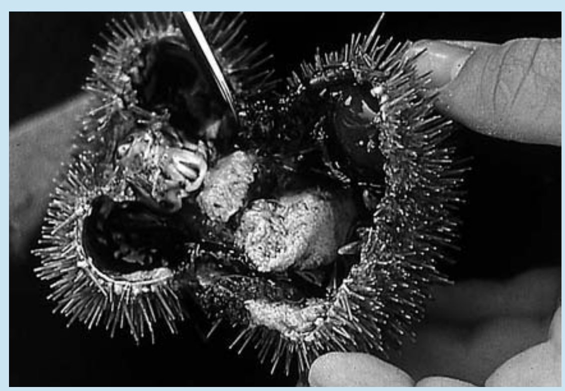


Urchin illustration by Ethan Nedeau, biodrawversity.com

After peaking at 39 million pounds in the 1992–93 season, urchin landings in Maine have declined steadily. Intense fishing, which was largely unmanaged until the mid-1990s, has sharply reduced the urchin stock. Through the Sea Urchin Research Fund, the urchin industry has sponsored approximately $2 million in research into urchin biology, ecology, and fisheries. Based on the findings, the Sea Urchin Zone Council and state resource managers are attempting to reverse the decline and help the fishery to provide reliable income for Maine's fishing communities.

As part of efforts to improve management, the state established the Sea Urchin Research Fund (SURF) in 1995 and the Sea Urchin Zone Council (SUZC) in 1996. Composed of seventeen members of the urchin industry and two independent scientists, the SUZC is part of a co-management system intended to share authority in management decisions. Currently, the fishery is managed with a cap on the number of licenses, a minimum size limit, a maximum size limit, and a restricted season. In addition, the state's coastal waters are divided into two exclusive urchin management zones.

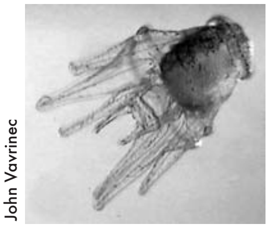
Over the past decade, the SURF—paid for by license surcharges from harvesters, processors, and dealers—has funded a series of studies that have led to an improved understanding of Maine's urchin fishery, ecology, and market. The purpose of this booklet is to summarize key findings from SURF-funded projects and related research. The information provides a basis for well-informed management decisions to stabilize and rebuild the urchin fishery and to sustain the green sea urchin's role in the ecosystem.



Larry Harris

What Is Urchin Roe?

When an urchin is cracked open, most of the inside is filled with five orange or yellow organs called the gonads, which store nutrients for reproduction as well as eggs or sperm. This is the part of the urchin that people eat. Gonads are called roe in the urchin industry or *uni* in Japan. The size and quality of roe varies with the urchin's sex, the seasons, and the urchin's diet. The best roe is usually found in urchins gathered in a feed line along the edge of a kelp bed.



John Vavrinec

Urchin larva (pluteus) magnified.

Co-Management of Maine's Sea Urchin Fishery

In Maine, the state government has legal authority to regulate commercial marine fisheries within coastal waters for the benefit of all citizens. The state uses a system of co-management in which fishermen and government share decision-making power to manage the fishery. Worldwide, many governments are involving the fishing industry directly in management decisions as an alternative to top-down management.

Larry Harris

Biologist Rebecca Toppin (University of New Hampshire) and fisherman Leo Murray talk urchins during a research trip on a dragger in Maine.

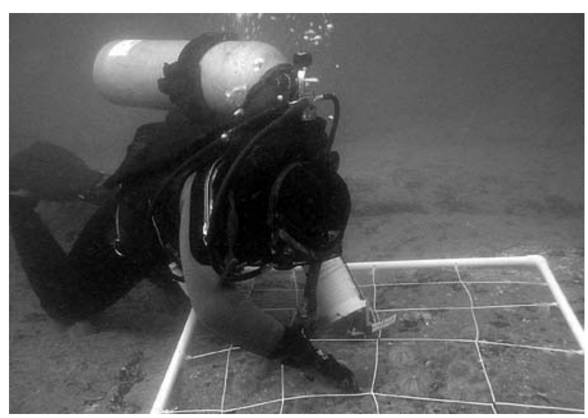
Fishermen who have been granted responsibility for making management decisions may be stronger stewards of the resource and help create regulations that are practical and supported by the entire industry. An effective co-management process should lead to sustainable commercial fisheries as the biological needs of the targeted species are balanced with the economic needs of the fishermen.

Sea Urchin Research Fund

In Maine, landings of urchins have declined steadily since 1993. Co-management of the fishery began in January 1995 when the legislature created the Sea Urchin Research Fund (SURF) at the request of industry leaders concerned about the sustainability of the booming industry. The surcharge on licenses has raised over $2.5 million and is an example of fishing-industry support for science-based management. SURF-funded research has improved scientific understanding of urchin ecology and the fishery. Much of the information in this booklet comes from SURF-funded studies.

Sea Urchin Zone Council

In 1996, state legislators expanded the co-management process for the sea urchin fishery. They passed laws that created the Sea Urchin Zone Council (SUZC), which has representatives from sectors of the state's urchin industry, and gave it authority to make recommendations to the Commissioner of the Department of Marine Resources concerning the length of the urchin season. Between 1997 and 1999, the legislature granted additional powers to the SUZC, including authority to recommend how to spend the Sea Urchin Research Fund. Under Maine's current co-management system, the authority for managing the sea urchin fishery is legally shared among the Sea Urchin Zone Council, Maine Department of Marine Resources, and Maine Legislature.



John Vavrinec

A scientist counts sea urchins in a study funded by the Sea Urchin Research Fund.

Basic Biology of Sea Urchins

What Are Sea Urchins?

Sea urchins belong to a group of ocean-dwelling animals known as echinoderms, which also includes sea stars, sand dollars, sea cucumbers, and sea lilies. A sea urchin has a hard shell that is covered with spines for protection against predators. An urchin can use its hundreds of tube feet with tiny suction cups to move across the seabed or up a kelp frond to feed. The mouth is located on the bottom side of the shell. Several urchin species inhabit oceans around the world, but only the green sea urchin is harvested in the Gulf of Maine.

Spawning

During summer and fall, urchin roe swells with stored nutrients. The end of fall is when it is most valuable, especially if the animal has dined plentifully on kelp, which gives roe the color, texture, and taste favored by the Japanese market. In the Gulf of Maine, spawning takes place in the spring. Female urchins shed up to two million eggs into the water, where eggs may be fertilized by sperm released by males. During spawning, roe shrinks rapidly and declines in market value.

Young, Drifting Urchins

Fertilized eggs turn into larval urchins, called plutei, which do not look like adult urchins but resemble tiny spaceships. For the next four to eight weeks, the larvae drift with ocean currents, possibly many miles, and feed on tiny drifting algae (phytoplankton).

Settlement

Eventually, young urchins may settle onto the seafloor and change into bottom-dwelling juveniles. At this point, they look like adults but are only as big as a pinhead, approximately one-half millimeter in diameter.

Growth and Survival

As urchins grow, the plates that form their shells get bigger, and they grow new plates. Urchins usually begin to spawn by approximately age three, when their diameter is about 1 or 1.5 inches (2.54 to 3.81 cm). Urchins of legal size in Maine (2 1/16 inch) are typically four to eight years old and possibly much older. Throughout their lives urchins face many threats. Predators include crabs, fish, and other creatures. Disease and environmental conditions can kill urchins. Since the 1990s, fishing has been the most important cause of mortality for adult urchins in Maine.

John Vavrinec

Green sea urchins feed on a blade of kelp.

Green Sea Urchin

Scientific name: *Strongylocentrotus droebachiensis*

Range: East coast of United States and Canada; Alaska; Washington; Greenland; Iceland; northern Europe; Russia; Korea; Japan.

Habitat: From tidepools to waters as deep as a thousand feet. Most common in areas shallower than 150 feet.

Diet: Kelp and other seaweeds, as well as small animals and microbes.

Predators: Crabs, fish (cunner, winter flounder, American plaice, ocean pout, wolf fish), lobster, sea stars, amphipods, gulls, eider ducks.

Other Causes of Mortality: Fishing, disease, and environmental factors such as ice scouring, storm surge, and low salinity.

Ecological Role: Urchins can transform dense kelp beds into barren seafloor.

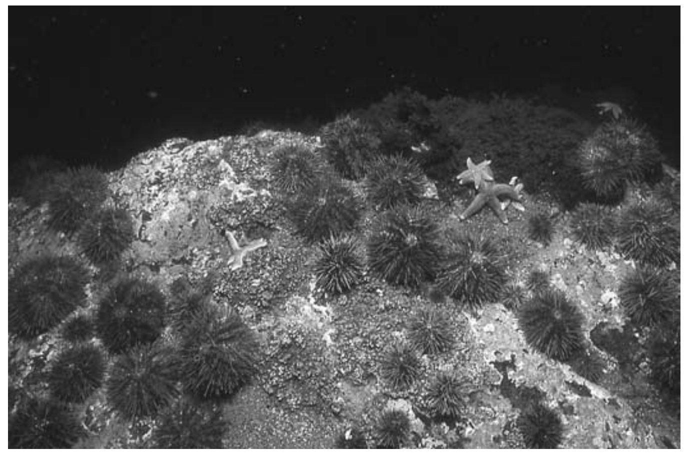
Sea Urchins in the Gulf of Maine

The green sea urchin is the only urchin that is harvested in the Gulf of Maine. In the 1970s, urchins were less plentiful in this region, and there was only a small fishery for them.

But their population grew dramatically until by the 1980s they carpeted the Gulf's seafloor. At the same time, demand in Japan for urchin roe was strong, and the dollar-yen exchange rate was favorable. These factors fueled the rapid growth of an urchin fishery in the Gulf of Maine.

The huge numbers of urchins in the Gulf of Maine ate large amounts of seaweed and quickly wiped out many kelp beds. These widespread shifts from kelp beds to urchin barrens radically transformed the ecosystem. Now that urchins are scarce, kelp beds are returning.

John Vavrinec



Larry Harris

In the 1980s, coastal areas in the Gulf of Maine transformed from kelp beds (top) to urchin barrens (above), as the spiny creatures became abundant and ate the kelp. Now, kelp beds are expanding as urchins become scarce due to fishing.

Disease caused massive urchin die-offs along the Atlantic coast of Nova Scotia between 1980 and 1983, and in 1993, 1995, and 2000. The outbreaks of disease, caused by an amoeba called *Paramoeba invadens*, did not spread into the Gulf of Maine. Urchins on Nova Scotia's Atlantic coast seem susceptible to the amoeba because warm water from the Gulf Stream occasionally bathes the coastline. Localized die-offs happened in midcoast Maine from 1999 to 2002, but it is unclear if the amoeba was responsible.

Fishing, rather than disease or environmental factors, has caused a decrease in urchins throughout the Gulf of Maine since the early 1990s. Scientists believe that the sea urchin population is quite volatile and that growth rates, proportion of urchins of different sizes, and rates of population replenishment do not remain constant. This increases the difficulty of modeling and effectively managing the fishery.

Kelp Beds and Urchin Barrens

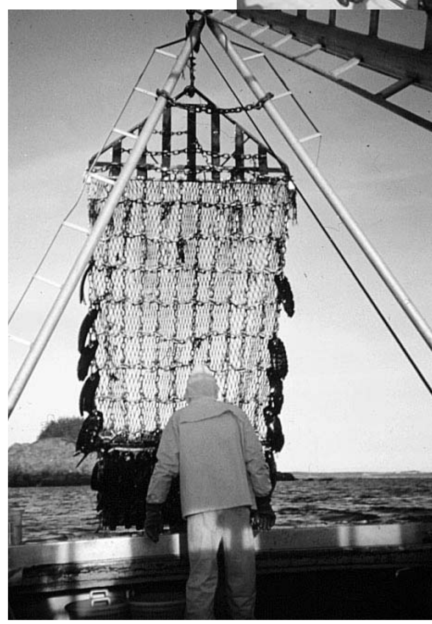
Urchins can bring about astounding changes in the undersea landscape. When they are plentiful, urchins can eat so much that entire kelp beds disappear. The cleared areas, known as urchin barrens, usually become dominated by hard, crusty coralline algae, which are resistant to urchin grazing. Urchins in the barrens tend to be small, grow slowly, and produce little roe. The habitat change also affects the fish, lobsters, and other animals that thrive in kelp beds. Conversely, when urchins are scarce, kelp forests tend to be widespread.

In the 1980s, when urchins were abundant in the Gulf of Maine, they wiped out kelp beds throughout the region. Now that the fishery has reduced the number of urchins, kelp beds are returning to many areas. SURF-funded research shows that kelp and other fleshy seaweeds dominate the southwestern Maine coast, due to the lack of urchins. This shift is spreading east as fishing reduces the number of urchins in eastern Maine. While this widespread shift may benefit other animals, it poses a challenge for revitalizing the urchin fishery. Many predators of young urchins live in kelp beds.

Fishing Methods

In Maine, SCUBA divers bring in 80 percent of the state's total landings. An urchin diving team consists of a boat operator/tender, one or more divers, and sometimes a culler. The divers collect urchins from the seafloor and put them into a mesh bag. The tender hauls up the bag, empties it into a bin on deck, and checks for roe quality. Undersized and oversized urchins are culled either on the bottom or on the boat. The latter method leads to greater mortality. In eastern Maine, where strong currents make diving difficult, urchins typically are harvested by boats that drag gear across the seafloor. The most common type of drag gear is a lighter version of the chain sweep, a modified scallop dredge. Draggers account for about 20 percent of the state's total catch. A few people harvest urchins using rakes along the shoreline, accounting for a tiny fraction of the total catch.

Robert Russell



Edwin Creaser

Urchins are harvested by draggers (above) and divers (top).

Urchin Fisheries Around the World

Worldwide landings of sea urchins have declined since reaching a high of 120,306 tons in 1995. Outside the Gulf of Maine, fishermen harvest a variety of urchin species. Chile leads world production, accounting for more than half of the total landings. Maine's fishery ranked third in 1999.

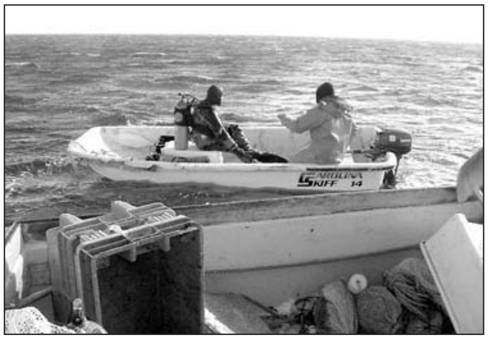
Most urchin fisheries are unsustainable at current fishing intensity. Management practices vary widely from minimal regulation to a mix of traditional gear and catch regulations to ecosystem-based management. According to a recent scientific review, the fisheries in Chile, Japan, Maine, California, and Washington were overfished as of 2001. Canada, South Korea, and Japan have improved management by taking into account the interactions of sea urchins with the rest of the ecosystem. While Japan, Korea, and the Philippines have attempted to enhance wild populations through aquaculture and other methods, the effectiveness of these efforts has been difficult to evaluate.

	Production (tons)	
Urchin Fishery	**1995**	**1998**
Chile	**54,609**	44,843
Japan	**13,735**	13,653
Maine	**16,845**	7,688
British Columbia (Canada)	**6,895**	6,270
California	**10,097**	4,782
Baja California (Mexico)	**3,188**	1,841
New Brunswick (Canada)	**1,658**	1,621
Russia	**2,344**	1,590
Alaska	968	**< 1,428**
South Korea	**3,707**	1,410
Nova Scotia (Canada)	1,021	**1,299**

Bold indicates year with greater production.

(Adapted from N. L. Andrew *et al.*, 2002)

From Seafloor to Airfreight



1) In Maine, most urchins are harvested by divers, who collect urchins by hand.

2) Urchins are also caught by boats called draggers that tow fishing gear across the seafloor.

3) When they surface, divers bring a bag of urchins. Some may be under or over legal size.

4) Under- and oversized urchins are culled aboard the boat and tossed back into the water.

5) DMR monitoring staff visit urchin buyers to measure and weigh samples of the catch.

6) At a processing facility, workers crack the urchins and remove the roe.

7) The roe is checked for quality and rinsed in preparation for packing.

8) These packages of roe are ready to be airfreighted to the Japanese market.

Credits: Jim Berke (1, 4), Edwin Creaser (2L, 2R, 6, 7, 8), Kerry Lyons (3, 5)

Economics of the Urchin Fishery

The Global Market

Japan imports more than 80 percent of the world's production of sea urchin roe. In Japan, it is called *uni* and is served raw (as sashimi), with rice (as sushi), preserved in brine or alcohol and salt, and in casseroles and other dishes. Cultures in Asia, Polynesia, Chile, and the Mediterranean have long traditions of eating urchin roe. France is the second leading importer behind Japan. Historically, Maine has shipped roe to France, Spain, and ethnic markets in the United States, but currently most of the state's product goes to Japan. A SURF-funded economic analysis of the market for Maine sea urchins was completed in 1997.

Trends in the Global Market

Japan began to increase its imports of urchin roe dramatically in the 1980s. Previously, the country's domestic catch had remained steady at 22 to 27 thousand metric tons for decades, but it had dropped because of declining stock. At the same time, the Japanese yen gained value compared to the U.S. dollar. These factors spurred the rapid growth of Maine's urchin fishery in the late 1980s. In recent years, declines in Maine's urchin population and in the strength of the yen have reduced the profitability of Maine's urchin fishery.

Importance of Roe Quality

Sea urchin roe varies in color from bright yellow to orange to grey. Its texture, size, taste, and firmness also can vary depending on what the urchin has been eating, as well as the urchin's sex, time of year, and habitat conditions. Although differences in quality can appear subtle to the untrained eye, quality can sharply affect the value and the types of foods for which roe is used. The Japanese market prefers large, firm, light-yellow roe. Some processors pay harvesters a premium for urchins containing ten to twenty percent roe because it reduces processing costs. Buyers determine roe quality based on freshness, color, size, texture, firmness, uniformity, taste, and wholeness.

Key Findings

Lowering the minimum legal size for urchins probably would not benefit the Maine market. Processing costs increase prohibitively for smaller urchins, and the stock could be affected by the reduced reproduction.

In general, raising the minimum legal size could benefit the Maine market. It allows more reproduction and population replenishment.

Setting a minimum legal roe content would not be useful for management. The regulation would be difficult to enforce, and urchin dealers can bring about the same result by paying an incentive to harvesters for urchins with high roe content.

Prices paid to Maine urchin harvesters depend primarily on urchin quality and Japanese demand. Demand depends on the strength of the Japanese economy, seasonal holidays, the yen-dollar exchange rate, and the availability of urchins or alternative seafood products from elsewhere in the world.

Roe Quality	Uses in the Japanese Market
High	**Restaurants, Sushi Bars** Sidedish Sushi Uni with sashimi
Medium	**Gift Packs** Cured or flavored in jars Mixed with herring, jellyfish, scallops
Low	**Supermarkets** Chinmi Uni with sashimi tray Dried, salted, steamed Individual packets and trays

Roe quality depends on color, texture, and other factors. In Japan, low- and high-quality roe are used in different products.

What Are the Challenges Facing Maine's Urchin Fishery?

History

Native Americans collected and ate sea urchins thousands of years ago in what is now Maine, and the earliest recorded commercial catches in the state date to 1929. Until the 1970s, however, the value of the landings was less than $50,000 per year, and the product was shipped mainly within the United States.

When Maine's fishery exploded in 1987, the state quickly developed the world's largest fishery for green sea urchins. Dealers began airfreighting whole urchins and processed roe directly to Japan. By 1992-93, landings hit 17,821 tons, and by 1995 the catch's value peaked at $36 million. The fishery quickly became extraordinarily lucrative for many people in Maine, like a gold rush.

Jim Berke

Snowstorms during the urchin fishing season present a minor challenge compared to the problem of the declining urchin stock.

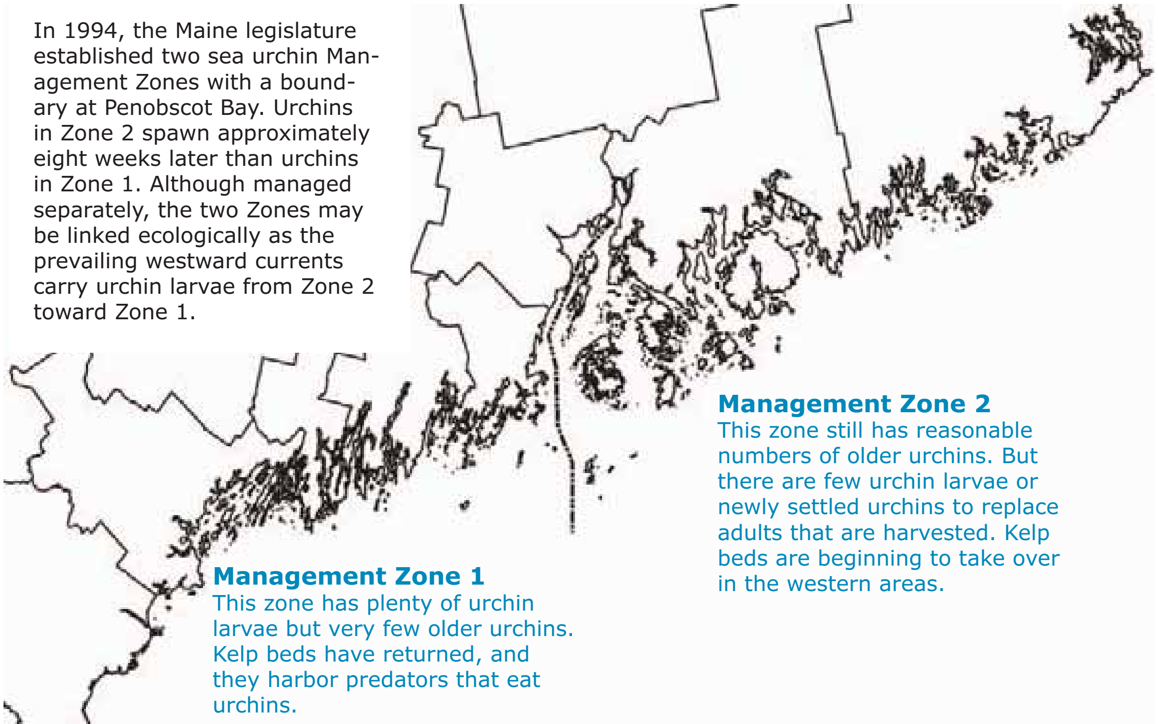
Changes in Management

In the early years of Maine's urchin boom, many people viewed the spiny creatures as pests that interfered with the lobster fishery by destroying kelp beds and by damaging and clogging traps. Indeed, so many urchins lived in the state's coastal waters that they seemed inexhaustible. The emerging fishery seemed a possible way to reduce their numbers.

At the time, the Maine Department of Marine Resources focused primarily on well-established fisheries, such as lobster and groundfish. It lacked the staff and budget to monitor and effectively manage new fisheries. Although the urchin catch grew rapidly, the DMR did not implement a management plan for several years. By 1992, some members of

Timeline of Notable Urchin Management Actions in Maine

Before	Commercial fishing license ($20) required annually.
1992	$89 sea urchin licenses required for hand harvesting and dragging annually.
1993	Minimum size limit of 2 inches with a 10% tolerance. Sea urchin boat tender license required for tenders. Season closed May 15 to August 7 in 1993 and to August 15 in 1994. Urchin drag width restricted to 5.5 feet.
1994	Sea Urchin Research Fund established: $160/harvester, $500/buyer, $2500/processor annually. Moratorium on new licenses. Two fishing zones established with seasons: Zone 1, closed Apr. 1–Aug. 15 Zone 2, closed May 15–Oct. 1
1995	Hand-raking and trapping license added ($89 plus $160 research surcharge annually).
1996	Sea Urchin Zone Council established consisting of 3 draggers, 3 divers, and 1 buyer/processor from each zone plus 2 scientists. Fishing days limited to 150 per year in Zone 1 and 170 in Zone 2.
1997	Fishing days limited to 120 per year in each zone.
1998	Lottery for issuing a limited number of new licenses established.
1999	Six small areas closed for research.
2000	Minimum size tolerance reduced from 10% to 5%. Season reduced to 110 days per year. Maximum size of 3.5 inches established, with a 5% tolerance.
2001	Season reduced to 94 days per year. Minimum size increased to 2.0625 inches. Maximum size reduced to 3.0 inches. Processor's research surcharge reduced to $1000.
2003	Zone 1 divers must "cull on bottom," 20% tolerance. Zone 1 dragger season shortened to 84 days. Western Zone 2 closed for an additional 10 days. Zone 2 divers must use large-mesh catch bags. Zone 2 draggers must use large-mesh "escape panel" in top of drag. License fees increased to $111 for harvesters and tenders and to $385 for buyers and processors.



In 1994, the Maine legislature established two sea urchin Management Zones with a boundary at Penobscot Bay. Urchins in Zone 2 spawn approximately eight weeks later than urchins in Zone 1. Although managed separately, the two Zones may be linked ecologically as the prevailing westward currents carry urchin larvae from Zone 2 toward Zone 1.

the urchin industry and scientific community believed that pressure on the urchin stock was too intense. They lobbied for legislation and regulations regarding harvest methods and limits on the number of licenses. Even so, the number of licensed harvesters more than doubled from 1,075 in 1992 to 2,725 in 1994.

Since 1992, the state has established a variety of regulations, including a cap on the number of new harvesters entering the fishery, a minimum size limit, a maximum size limit, and a restricted season. The management plan has not incorporated total catch limits, individual catch limits, closed or rotated areas, or other possible options. As of 2003, management actions, which started well after the fishery emerged, had not successfully halted or reversed the decline. By 2002–03, landings had dropped to 6,700,632 pounds, approximately one-sixth of the 1992–93 peak.

Current Status

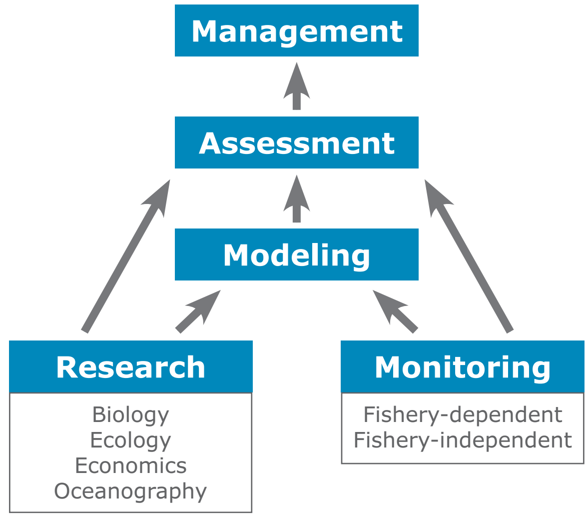
Now urchins are nearly gone in western Maine, and fishing pressure remains intense in eastern Maine. According to SURF-funded research, the urchin stock in Washington County continued to be depleted in 2002–03. Urchin harvesters are mining out old urchins that won't soon be replaced because few young urchins settle there. The return of kelp beds along the Maine coast hinders the recovery of urchin populations and impacts the urchin fishery.

A Framework for the Future

Sea urchins are no longer viewed as pests but as a valuable fish stock that has the potential to provide much-needed income to Maine communities during winter months. But in order to have a sustainable fishery—that is, a fishery that can be counted on indefinitely—new urchins must be born and grow more quickly than the older urchins die from natural causes. When this happens, the stock is producing a surplus that can be harvested. In order to determine whether a surplus exists and how many urchins can be harvested, scientists must have an understanding of the basic processes of reproduction, growth, and natural mortality.

Extensive scientific research over the past decade provides a strong basis for helping the fishery. Basic research has provided insights into key aspects of urchin ecology. Monitoring of the commercial catch and the wild population reveals important changes over time. Now scientists and managers are building computer-run models that simulate the changes in the population of urchins along Maine's coast. The models, which are continually refined based on research and monitoring data, provide a framework for scientific understanding, assessment, and resource management. Important findings from research, monitoring, and models are summarized on the following pages.

What is the Process for Developing Solutions?



Management decisions are based partly on an assessment of both the stock and the fishery, which incorporates research, modeling, and monitoring.

When Maine's urchin fishery exploded in the late 1980s and early 1990s, some aspects of urchin ecology were not well understood. Management was hampered by lack of information about the number and distribution of urchins, spawning seasons, size and age at maturation, rates of growth and population replenishment, and sources of mortality. Understanding has increased dramatically through the collaborative efforts of many groups. SURF and other funding sources, such as Maine Sea Grant, have supported a wide variety of crucial studies that involved scientists, managers, and harvesters working side by side. To obtain funding from SURF, researchers submit competitive proposals that are reviewed rigorously by experts. SURF-funded researchers produce detailed reports on their findings and often publish articles in peer-reviewed journals.

Now there is scientific information to facilitate decision-making about managing the urchin fishery. People involved in co-management of the fishery use the findings to understand the fate of urchins from birth to death, monitor the status of the stock, and develop management strategies. Getting this information requires an ongoing combination of approaches.

Research

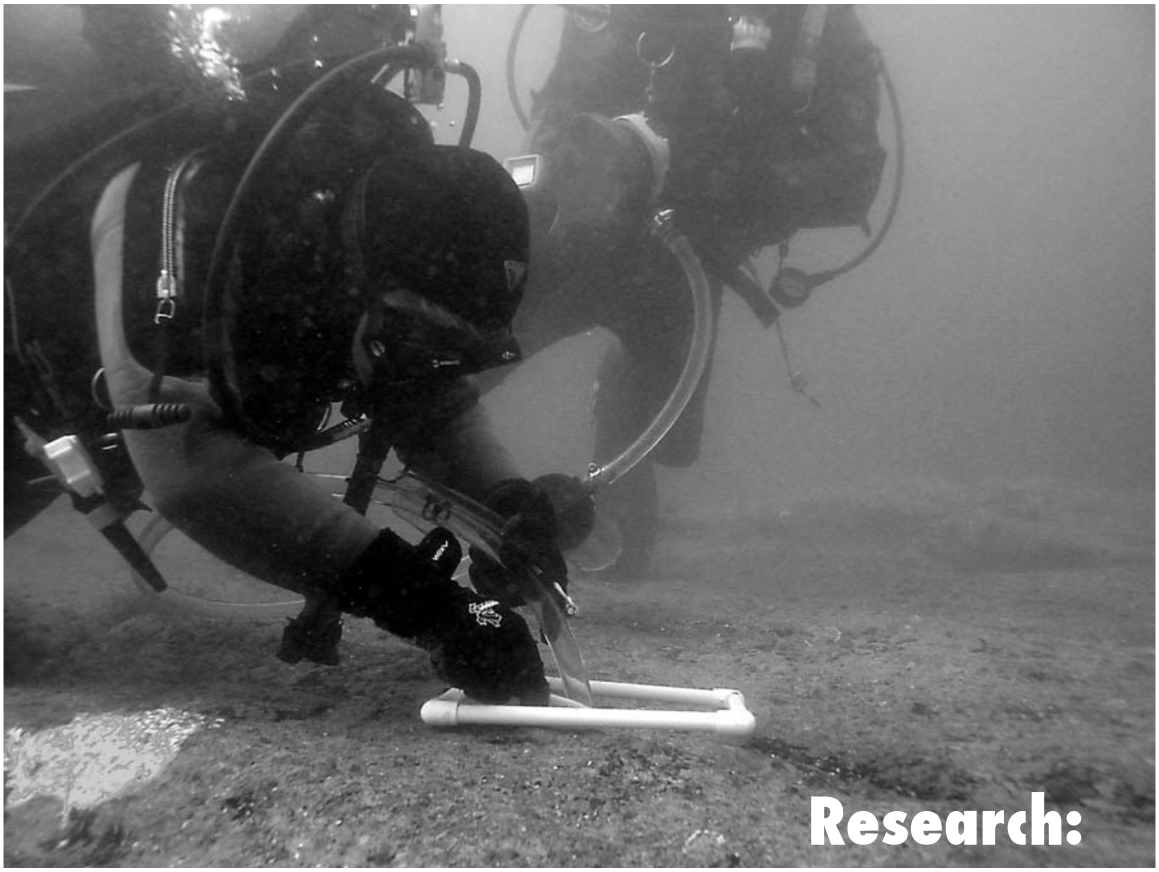
Research projects funded by SURF are carefully designed, scientific studies of urchin biology, fishery practices, and the ecosystem, focusing on key aspects that influence the abundance and distribution of urchins. These basic research studies help managers to identify the causes of population increases and declines, which makes it possible to understand observed changes in the population and predict changes. For example, basic research funded by SURF has enabled scientists to identify the importance of predation on urchins by Jonah crabs.

Monitoring

Maine DMR keeps track of urchin landings, and each year divers count and measure urchins at over 200 sites along the coast. The data reveal changes in the population and the effectiveness of management actions. Any complete monitoring program for fishery management includes information gathered directly from the fishery (fishery-dependent data) and apart from it (fishery-independent data). Fishery-dependent data include catch statistics and size measurements for harvested urchins; these numbers show what the fishery is extracting from the wild population. Fishery-independent data indicate the number, distribution, and sizes of urchins living in the wild. For example, fishery-independent data can show how many young, undersized urchins exist to replace harvested, adult urchins.

Assessment

Scientists and managers create models that pull together information from monitoring and basic research. The models involve mathematical equations that simulate the ups and downs of urchin numbers over time and provide a framework for everything that's known about Maine's urchins. Models include the effects of fishing, which is a major source of mortality for urchins. Managers use modeling to evaluate the status of the population, predict future trends, and simulate the effects of potential management strategies. Models are always being refined with new data from monitoring and research. SURF-funded programs of monitoring and basic research contribute greatly to scientists' ability to model and assess Maine's sea urchin population.



John Vavrinec

Research: Understanding the Life of Urchins

Overview

Scientists conduct research in coastal waters and in the laboratory to learn about key aspects of the green sea urchin's life. These studies help managers understand the factors that cause urchin populations to increase or decrease. In addition, the information is used to create mathematical models that simulate the urchin population. Models provide a framework for what's known about urchins and are one decision-making tool for resource management.

Top: Scientists use a suction device to collect and count tiny green sea urchins in Maine.

Reproduction

Kerry Lyons

Urchins begin to reproduce by the time they are about three years old. The large, light-colored clumps in these cracked urchins is the roe, which contains eggs or sperm. To mate, urchins release their eggs or sperm into the water.

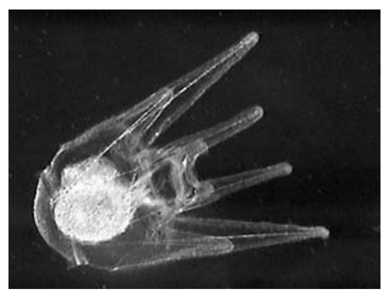
The green sea urchin grows slowly and has a relatively long life span. Its growth rate can change dramatically depending on environmental factors such as food availability.

Juveniles grow 0.1 to 0.66 inch (2.6 to 17 mm) per year. Typically, urchins become sexually mature by age three, when their diameter is approximately 1 to 1.5 inches (25 to 38 mm). Then growth may accelerate to 0.08 inch (2 mm) per month. Scientists estimate that it can take 1.7 to 18.6 years—depending largely on food availability—for an urchin to reach a diameter of two inches (51 mm), which is just under the legal minimum harvest size of two and one-sixteenth inches.

Annual Cycle

The process of reproduction by green sea urchins in the Gulf of Maine has three main phases over the course of a year. The roe grows rapidly through the summer and fall as it stores nutrients. During the winter, sperm and eggs mature and are stored in the roe. Spawning happens in the spring, when urchins release their eggs or sperm into the water.

In the Gulf of Maine and Gulf of Saint Lawrence, the tremendous growth of phytoplankton during the spring, along with warming water, may be among the most important environmental cues for urchins to spawn. Urchins apparently detect chemicals released by phytoplankton and know the time is right for spawning. New larvae depend on phytoplankton for food to develop and grow while they drift.



John Vavrinec

A fertilized egg grows into a drifting, larval urchin called a pluteus (above, magnified).

Larger urchins (1.38–1.57 inches) produced twice as many eggs as urchins in the next largest size class (1.19-1.37 inches). (Data from Vadas and Beal)

Urchin Size (inches)	Average Age (years)	Average Number of Eggs
< 0.79	4.00	703
0.79–0.98	3.25	40,240
0.99–1.18	4.50	35,495
1.19–1.37	4.63	66,026
1.38–1.57	5.29	132,114

John Vavrinec

This cluster includes green sea urchins of many sizes and ages. Large urchins produce disproportionately more eggs or sperm than small urchins.

Timing of Reproduction and Size of Roe

At sites from Casco Bay to Jonesport, Robert Vadas of the University of Maine at Orono and Brian Beal of the University of Maine at Machias monitored roe characteristics; spawning timing; and water temperature, salinity, and phytoplankton abundance. They found that spawning happens about eight weeks earlier along the southwestern part of the Maine coast than in eastern Maine. Spawning tended to begin when water temperature increased and the phytoplankton population exploded in the spring. The quantity of grade A roe per urchin declined from west to east and peaked just prior to spawning. Urchins reached harvestable size sooner in kelp beds than in urchin barrens because of the plentiful food.

Bigger urchins produced disproportionately more roe than smaller urchins, although the proportion of roe to total body weight stopped increasing in urchins larger than 1.8 inches (45 mm) in diameter. A large female urchin may produce ten to one hundred times as many eggs as a smaller urchin. Consequently, big urchins play an especially important role in helping to sustain the population. When this study was completed in 1999, the smallest legal harvest size in Maine was two inches (50.8 mm). Now the minimum legal size is two and one-sixteenth inches (52.4 mm), providing urchins more time to reproduce. In addition, the State has adopted a maximum size limit of three inches (76.2 mm) to protect large urchins.

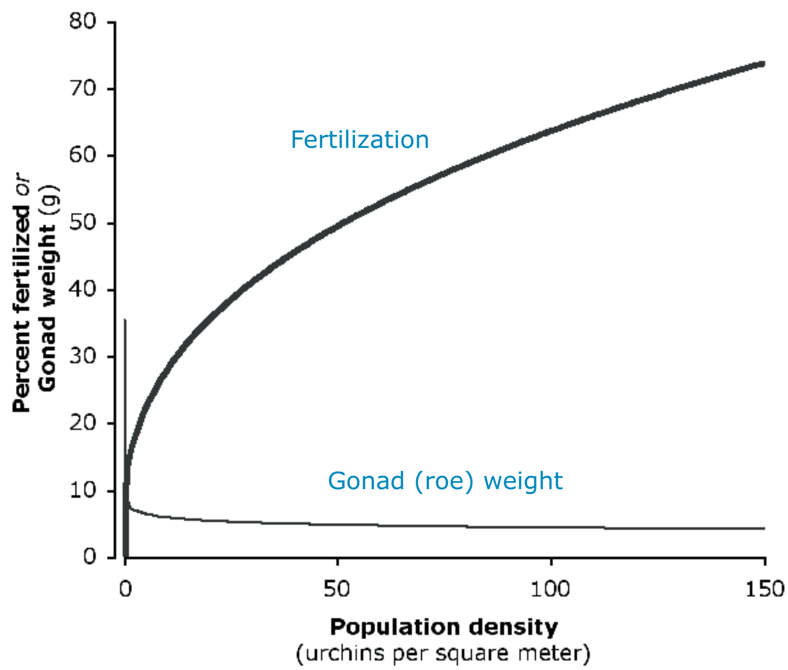
Key Findings

Spawning happens eight weeks earlier along the southwestern part of the Maine coast than in eastern Maine. This finding supports the concept of dividing the coastline into separate zones for management.

Urchin spawning in the spring correlates with rising water temperature and the phytoplankton bloom.

Although the two-inch size limit (at the time of this study) for harvesting allowed some mature urchins to survive, it did not provide a large safety factor.

Bigger urchins produce much more roe than smaller urchins. Setting a maximum size limit protects an urchin brood stock.



The percentage of eggs that are fertilized tends to decline when few urchins live near each other, even though each urchin may produce more roe, according to research by Richard Wahle and Hoyt Peckham. Sperm and eggs released into the water have less chance of encountering each other.

Reproductive Trade-offs in Small Populations

When urchins are scarce, they face less competition for foods such as kelp. As a result, the quantity of roe in individual urchins tends to increase, fueled by the plentiful diet. Even so, urchins can have difficulty reproducing if their population becomes too small or too sparse. Eggs and sperm released into the seawater have less chance of being fertilized if few urchins live nearby. Consequently, although urchins living in a small or spread-out population may have bigger roe, they might have difficulty producing a new generation.

In SURF-funded research, Richard Wahle and Hoyt Peckham of the Bigelow Laboratory for Ocean Sciences examined this trade-off in small populations and its implications for the fishery. At shallow sites, they found that individual urchins living in low-density populations of less than one urchin per square meter contained twice as much roe as urchins living in high-density populations.

However, in field experiments simulating a range of population densities, fertilization success plummeted in the low-density populations, suggesting that in a natural population any reproductive advantage of larger roe would be counteracted by low fertilization rates. The problem might be offset if urchins gather into groups to spawn, as do other invertebrates.

At deep sites, roe was consistently small, regardless of population density, apparently because the food supply was so poor that it limited roe development. Under such conditions, the problems of poor fertilization rates in small populations would be magnified.

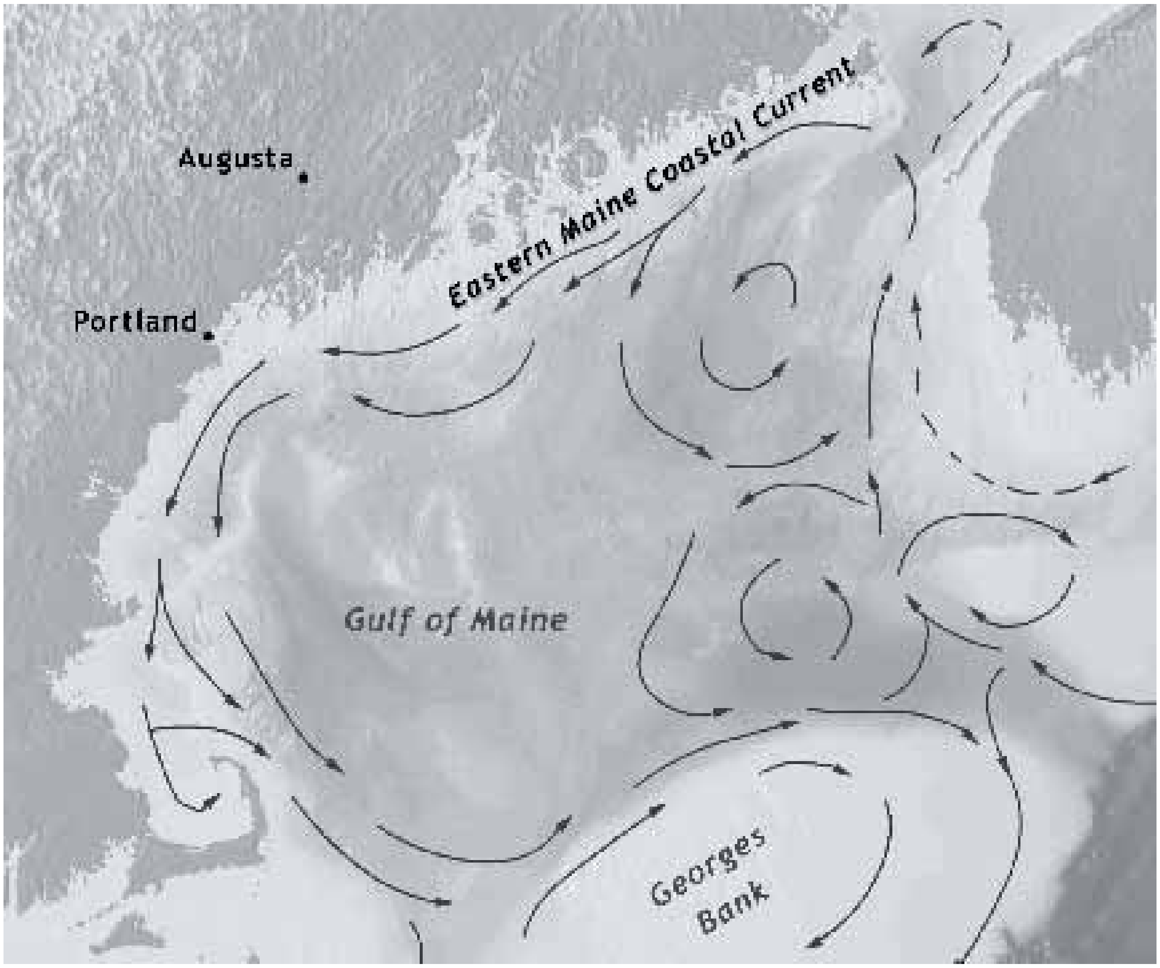
Key Findings

Fertilization rates may drop substantially when urchins become scarce, even though individuals might have more roe.

This drop could contribute to a further decline of the urchin population.

It is unknown if urchins along the Maine coast have become scarce enough to have affected fertilization rates.

Urchins living in barren areas may contain little roe but have high fertilization rates. Therefore, they could be important to protect as sources of young urchins.



Chris Brehme, redrawn from map by Neal R. Pettigrew

Scientists believe that the Eastern Maine Coastal Current may carry larval urchins westward from Zone 2 toward Zone 1. Arrows indicate currents.

Early Life of Urchins

Young Urchins Drift with Currents

Unlike adult urchins, newborn urchins do not live on the seafloor. Instead, these tiny, young urchins—which are called larvae and don't look like adult urchins—spend some four to eight weeks drifting with the currents. During this time, they might be carried miles away from their parents. Many kinds of fish, snails, mussels, barnacles, and other ocean-dwelling creatures also begin life as tiny, drifting larvae. In laboratory studies, urchin larvae consume one-celled algae. It is not well known what they eat in the wild, but the amount of food that a larva eats can influence its growth rate and survival. Many small animals prey on urchin larvae. High temperatures, low salinity, and ultraviolet light also can kill the young, drifting urchins. In fact, studies indicate that urchin larvae face a one-in-four chance of dying each day, and only a small percentage of them survive to become juveniles. To compensate, adult urchins spawn huge numbers of larvae.

Where Do They Go?

It is impossible to track tiny urchin larvae as they drift, so nobody knows exactly how far they travel or where they go. However, scientists studying urchins in the Gulf of Maine believe that the Eastern Maine Coastal Current carries urchin larvae (as well as lobster larvae) from eastern Maine toward Penobscot Bay. This "conveyor belt" might account for the scarcity of juvenile urchins in eastern Maine, despite the relatively abundant adults. Conversely, although the southwestern part of the coastline receives large numbers of urchin larvae from the east, few survive to adulthood because predators living in seaweed beds eat them.

Settling into a Seafloor Home

After spending the first month or two of life drifting with the currents, young urchins need to find a place on the seafloor where they can live as bottom-dwelling adults. In part, their home-hunting relies on luck, since they are at the mercy of the currents to carry them to a good place. But they can swim weakly and sense certain characteristics of the seafloor. If currents bring a larva to a possible home, it can touch bottom briefly, check out the habitat, and decide whether to stay or keep drifting. Larvae do not seem extremely picky about where they settle, but certain cues—including the presence of red coralline algae, which are typical of urchin barrens—apparently convince them to settle. After an urchin settles onto the seafloor, its body quickly changes to look like an adult urchin. At this point, the juvenile is only the size of a pinhead and not sexually mature.

John Vavrinec

Juvenile urchins find shelter in a clump of horse mussels, where they hide from predators.

When and Where Do Urchins Settle?

In the Gulf of Maine, young sea urchins typically drift as larvae in April and May and then settle onto the seafloor in June. In contrast, settlement along the Atlantic coast of Nova Scotia peaks in July and tapers off into October. The number of settlers varies dramatically among sites. In one scientific study, 1,000 to 10,000 urchins settled per square meter at sites in the Gulf of Maine. Yet only 100 urchins settled per square meter on the Atlantic coast of Nova Scotia, and as few as 10 settlers per square meter showed up at sites in the Bay of Fundy. Ocean circulation probably influences these differences by delivering more larvae to some sites than others.

The number of urchin settlers declines from west to east along the Maine coast. Thousands settle per square meter in the York region, but as few as one or two urchins settle per square meter around Jonesport. One theory is that this pattern occurs because the Eastern Maine Coastal Current carries larvae from east to west, causing a scarcity of young urchins in eastern Maine—and causing them to accumulate to the west where flow is slower. The lack of settlers could make it difficult for urchins to persist in eastern Maine. Experts believe the existing population, which includes urchins of varied ages, represents the cumulative effect of low settlement over many years.

Settlement also varies with depth. In the southwestern Gulf of Maine, biologists Larry Harris and Charles Chester of the University of New Hampshire found more than 15,000 urchins settling per square meter in shallow waters (20–30 feet; 6–9 meters). At depths between 40 feet (12 meters) and 83 feet (25 meters), however, only approximately 1,500 urchins settled per square meter. Even deeper, the number dwindled to 150.

On a small, local scale, the quirks of water flow around headlands and other features can influence the number of urchins settling. The currents can retain larvae at a given site or carry them away.

Variations Over Time

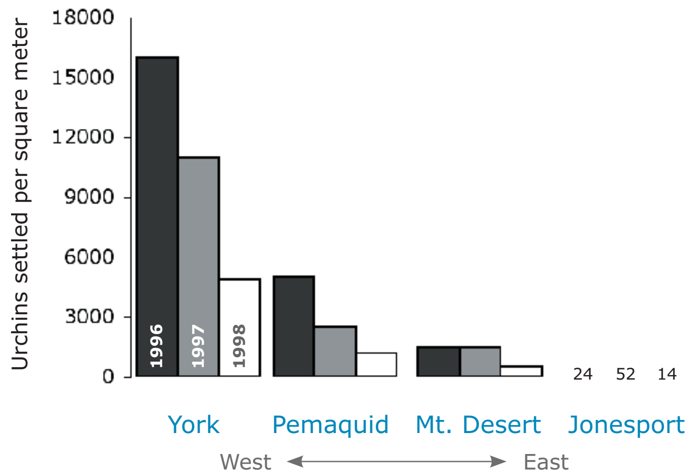
The number of young urchins settling onto the seafloor can vary greatly from year to year. In the early 1990s, for example, the number of settlers in the Gulf of Maine and Nova Scotia fluctuated ten-fold for reasons that are not well understood. In British Columbia, increases in settlement have been attributed to colder water, but the number of settlers in Nova Scotia and Washington seems to correlate with higher water temperatures. The warmth might speed up growth of newborn urchins, enabling more of them to survive the dangers that they encounter while drifting as larvae.

Settlement and Survival of Green Sea Urchins in Maine

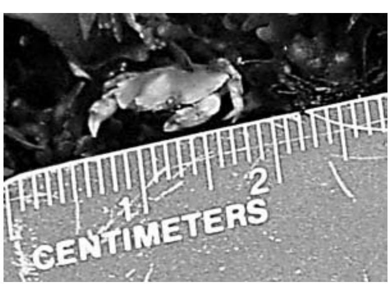
From 1996 to 1998, biologists Douglas McNaught and Robert Steneck of the University of Maine conducted a study of urchin settlement along the Maine coast. Their goals were to identify patterns of abundance of larvae, assess the survival rates of urchins as newly settled juveniles and in later adult stages, and evaluate the effect of kelp on settlement and survival of urchins. Using special collectors made of AstroTurf-like material, they monitored the number of larvae and settlers at four sites each within the York, Pemaquid, Mt. Desert, and Jonesport regions.

The study showed that the supply of larvae and settlement of urchins were consistently lowest in eastern Maine and increased to the west. Even though the York region consistently had the highest numbers of urchin settlers—5,000 to 16,000 per square meter—very few survived to become juveniles, much less adults. The mortality rate for newly settled urchins was a hundred times higher than in eastern Maine.

McNaught and Steneck found that kelp beds harbored small predators such as crabs and worms that devoured the tiny urchins. Urchin harvesting reduces the number of urchins grazing on kelp, which allows kelp beds to grow more extensive. In turn, these kelp beds host predators that eat newly settled urchins. As a result, urchin harvesting might indirectly prevent the rejuvenation of urchin populations by promoting the growth of kelp beds.



Biologists monitored the number of small urchins replenishing the population at four sites in Maine. They found that population replenishment declined from west to east and over time (1996–1998).



John Vavrinec

Tiny, young crabs eat juvenile urchins, which are as small as one-half millimeter in diameter.

Key Findings

Eastern Maine has a shortage of larval and juvenile urchins. The population may be slow to recover once the existing urchins are fished out.

Kelp beds are inhospitable to newly settled urchins because they harbor abundant predators. Once an area becomes dominated by kelp, it may return to barrens only if larger urchins immigrate, which is a slow process. Therefore, urchin barrens might deserve safeguarding, especially because they act as urchin nurseries.

Effective management of the fishery might require retaining enough large urchins to eat kelp and prevent kelp beds from taking over.

Survival and Growth

Shortly after settling onto the seafloor, juvenile urchins look like adults but are tiny. Vulnerable to predators, they hide in the crevices of mussel beds and among cobbles to avoid being eaten. As they grow, urchins live in more exposed areas, usually on rocky bottoms, as their spines offer protection. They often cluster at the edges of kelp beds and climb onto seaweed fronds to feed. They also congregate in cleared areas, called urchin barrens, where they have eaten all the seaweed. If necessary, they can survive long periods with little food.

John Vavrinec

This crab's next meal might be a sea urchin.

Predators

Rock crabs, lobsters, sea stars, small fish, hermit crabs, and amphipods eat newly settled, tiny urchins. Bigger urchins are eaten by such fish as cunner, wolf fish, winter flounder, American plaice, and ocean pout, along with rock crabs, Jonah crabs, lobsters, and sea stars. Eventually, urchins can grow so big—if they live long enough—that only the largest lobsters, crabs, sea stars, and wolf fish are capable of cracking their shells. Gulls, eider ducks, and other birds eat urchins that they find along the rocky shoreline at low tide.

John Vavrinec

Cunner and some other fishes eat sea urchins.

Disease

Disease does not seem to be a major cause of death for urchins in Maine. On the Atlantic coast of Nova Scotia, however, an amoeba called *Paramoeba invadens* sometimes infects urchins and causes massive die-offs. Disease struck in 1980–83, 1993, and 1995, and evidence suggests that similar die-offs happened in the past. The amoeba seems to flourish during periods of warm water, such as when waters from the Gulf Stream bathe the Nova Scotia coastline. The amoeba does not seem to have posed as much of a threat in Maine, apparently because Georges Bank acts like an underwater wall that keeps warm water from the Gulf Stream from entering the Gulf of Maine. However, urchin die-offs along Maine's midcoast during 1999 to 2002 may have been caused by *Paramoeba*. The extent and severity of these die-offs are unknown.

Other Causes of Death

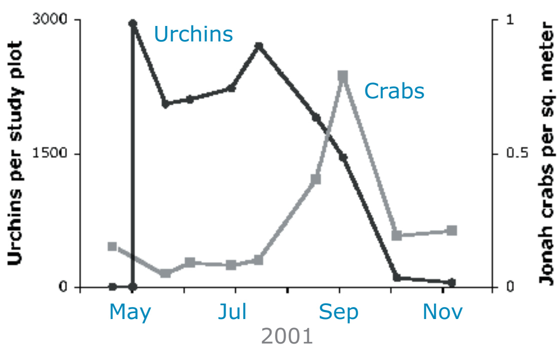
While fishing is the major cause of death for adult urchins in the Gulf of Maine, environmental factors such as low salinity, oxygen-poor water, ice, and waves sometimes kill urchins.

Growth Rates

Green urchins grow 0.1 to 0.66 inch (2.6 to 17 mm) per year until age two. After that, growth may exceed 2 mm per month. Growth rate depends partly on food availability. However, one SURF-funded study found slow- and fast-growing forms of green sea urchins at Allen Island, Maine. In theory, if these forms were genetically based and widespread, harvesters would tend to remove more of the fast- than the slow-growing urchins, so eventually the slow-growing urchins would dominate the population. However, the slow-growing form has been found only at Allen Island, and there is little concern that it will influence the fishery.

Could Adult Urchins Be Relocated to Mow Down Kelp?

Along much of Maine's coast, urchins have become scarce due to harvesting. Now the decline in urchins is allowing kelp beds to take over barren areas. SURF-funded research showed that kelp beds are inhospitable to small urchins because they harbor crabs and other predators (see page 19). So the spread of seaweeds might be good news for creatures such as lobsters that thrive in kelp beds, but it is bad news for the urchin fishery. If urchins were collected and moved to kelp beds, would they act like lawn mowers, clearing the area and creating a safer home for young urchins? A SURF-funded study tested this idea. The study was led by Amanda Leland, John Vavrinec, and Robert Steneck of the University of Maine and was made possible by the participation of urchin harvesters and other volunteers.



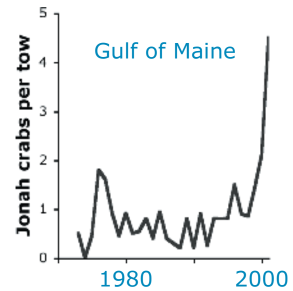
Crabs devoured the urchins that had been relocated to the site.

Wiped Out by Crabs

Over two years, the researchers moved 51,000 adult urchins into a kelp bed near Cape Elizabeth. Then they monitored changes in the abundance of seaweeds, urchins, and urchin predators. The site had supported a productive urchin fishery in the past, but harvesting had left it devoid of urchins.

The results of the study were not encouraging. In 2000, Jonah crabs killed all the transplanted urchins within one month. In the following year, a new batch of larger reintroduced urchins lasted for several months and grazed on seaweeds. However, once again in late summer Jonah crabs killed nearly all the urchins. The scientists found that each crab ate an average of 2.4 urchins per day.

In the Gulf of Maine, Jonah crabs have emerged recently as important predators on the seafloor. Their numbers were low from 1973 to 1999 but rose four-fold by 2001, according to NMFS survey data. Depletion of groundfish predators and of urchins grazing on kelp may have caused the outbreak in Jonah crabs. Groundfish such as cod historically were the top predators along the seafloor.



Abundance of Jonah crabs has skyrocketed.

Can Relocation Help Increase Roe Content?

Another SURF-funded study of urchin relocations was conducted by Robert Russell (Maine Department of Marine Resources) in 2001. He worked with harvesters, other researchers, and local University of Maine Cooperative Extension and Sea Grant staff to drag poor-quality urchins from deep water in Cobscook Bay and move the urchins to shallow sites nearby with plenty of food. Although roe content rose from 3 percent to 18 percent within seven months, more than half of the relocated urchins died at one site and nearly three-quarters at the other. The findings indicated that relocating urchins using this method to improve roe content would not be cost effective.

Key Findings

Jonah crabs are key predators of urchins in kelp beds. Since 1999, their numbers have quadrupled in the Gulf of Maine.

Relocating urchins into kelp beds is not a viable way to stop the spread of kelp because the urchins get eaten by crabs.

Mathematical models of the urchin population may need to incorporate high mortality due to crabs.

Robert Russell

Monitoring:
How Many Urchins Are There, and Is Management Working?

Overview

Monitoring the urchin population is essential for effective management. In Maine, the Department of Marine Resources gathers landings data from divers and draggers. This fishery-dependent information reveals how much harvesters are removing from the wild population. The DMR also conducts surveys using divers and video to count urchins living along the coast. This fishery-independent survey provides a comprehensive understanding of the wild population. Managers can use a combination of fishery-dependent and -independent data to document trends, assess the effectiveness of management actions, and build mathematical models of the urchin population.

Top: A diver prepares for the next site during DMR's annual fishery-independent urchin survey.

Fishery-Dependent Survey: Keeping Track of the Commercial Catch

Since 1994, researchers from Maine's Department of Marine Resources have visited ports during the urchin fishing season to interview harvesters and to measure and weigh samples of the urchins. In particular, they document roe condition and content, urchin size, shell condition, and catch per unit of fishing effort (time spent fishing), also called catch rate. The state requires dealers to report landings. This information enables the DMR to assess the status of the resource, monitor compliance with the size limits, keep track of changes in the fishery over time, and develop models and other management tools.

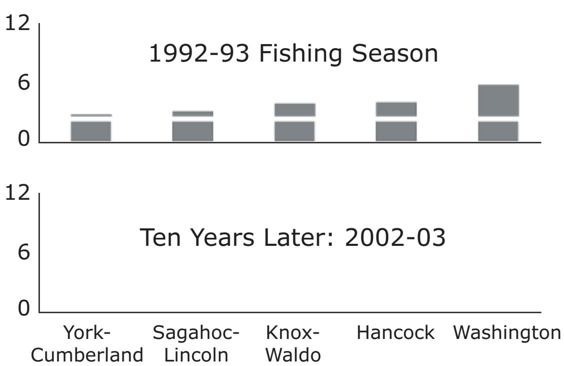
Key Findings

Total urchin landings continued to decline through 2003.

Catch rates (pounds caught per hour of fishing) have been higher in eastern areas (Zone 2) than in western areas (Zone 1) but have been dropping steadily. Catch rates in Zone 1 had already bottomed out by the time monitoring began. Catch rates may no longer be a good indicator of stock abundance for this fishery.

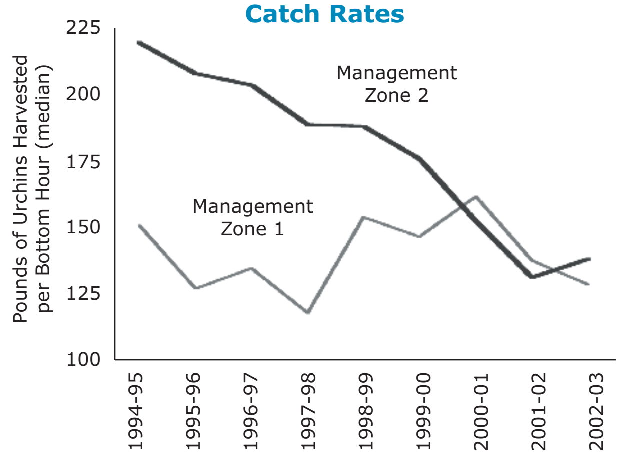
Below: This graph shows both the overall decline and a dramatic shift in the fishery from west to east from 1992-93 to 2002-03.

Maine Sea Urchin Landings in Millions of Pounds, by County



Below: In Zone 2, divers are harvesting fewer pounds per hour, indicating that urchins have become more scarce. In Zone 1, the number of pounds has not declined steadily, apparently because less efficient divers have left the fishery. Only divers capable of harvesting approximately 125 pounds per hour—despite the scarcity of urchins—still participate.

Catch Rates



Annual landings of sea urchins in Maine (pounds) have declined by more than 65 percent since 1996-97.

Season	Diver	Dragger	Raker	Unknown	Total	Value ($)	Price/Lb.
1996-97	18,448,266	3,987,435	30,674	1,388,234	23,854,609	26,580,434	1.11
1997-98	13,859,985	3,028,436	28,595	31,684	16,984,700	18,339,532	1.08
1998-99	13,365,737	3,228,624	32,766	75,811	16,702,938	20,102,119	1.20
1999-00	10,960,385	2,900,783	22,445	171,502	14,055,115	18,858,460	1.34
2000-01	9,110,119	2,657,862	17,279	32,700	11,817,960	16,119,624	1.36
2001-02	6,017,163	1,820,012	13,397	0	7,850,572	9,717,479	1.24

Key Findings

Although the fishery-independent survey program did not get underway until 2001, it is now comprehensive and provides crucial data.

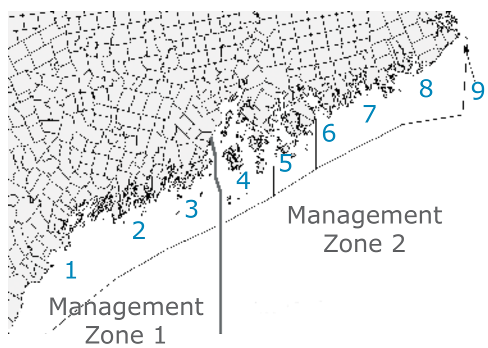
The urchin stock in Maine waters continued to decrease through 2003. After faring well compared to Zone 1, now Zone 2 shows problematic declines.

Seaweed beds, which are generally inhospitable to young urchins, increased statewide from 72 percent coverage of the seafloor in 2001 to 88 percent in 2003, at depths less than 50 feet.

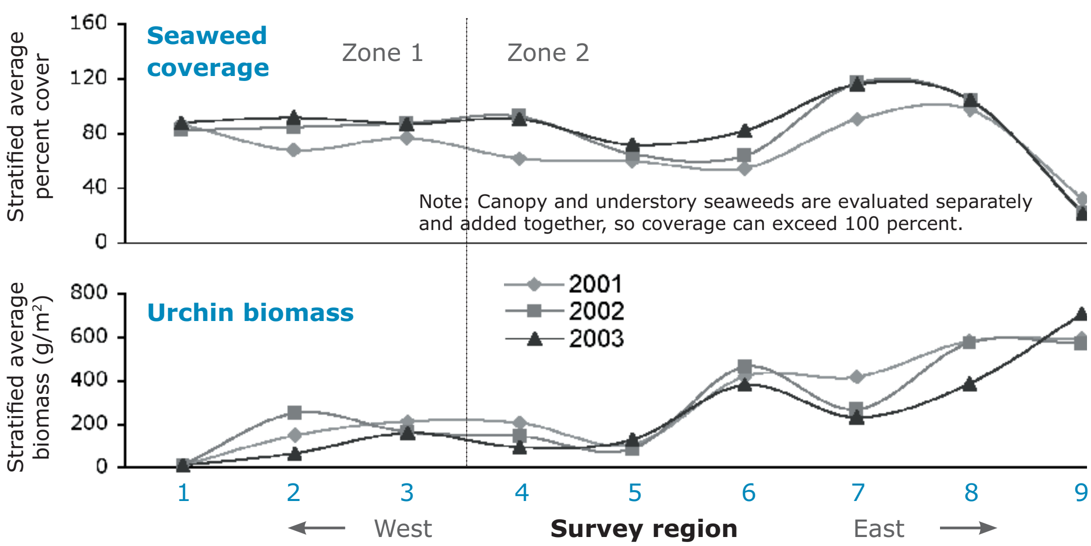
Fishery-Independent Survey of Urchin Stock and Habitat

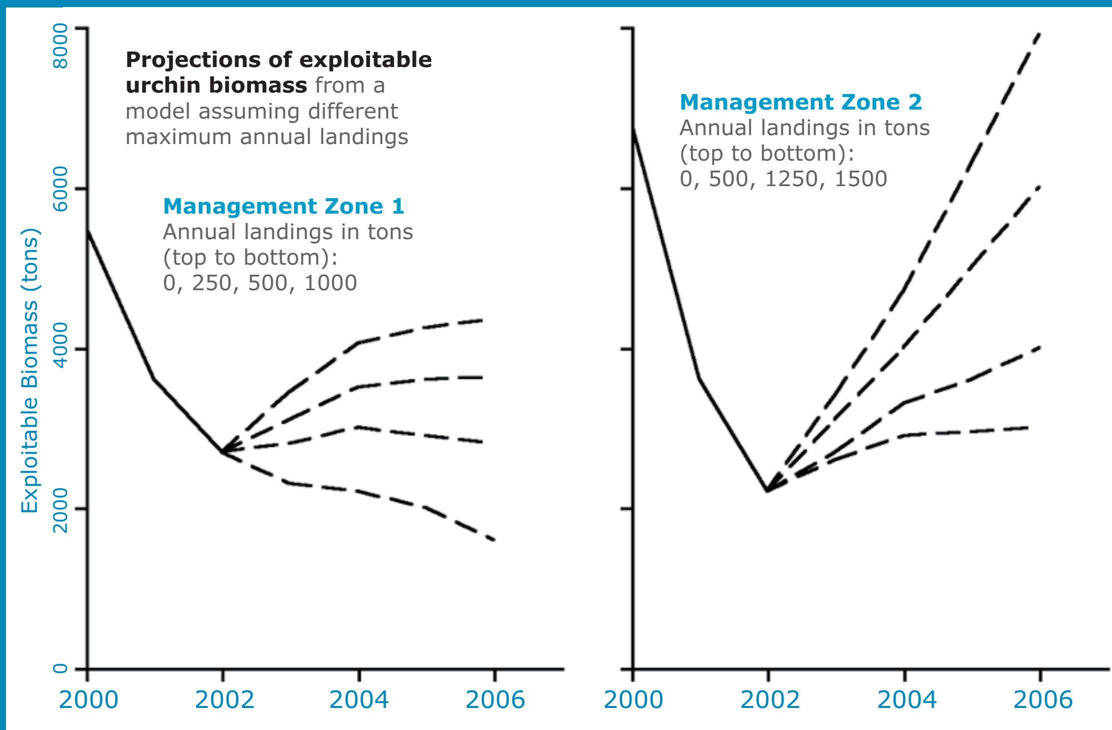
Each year, divers from the Maine Department of Marine Resources, working with industry divers, survey the number and sizes of urchins at more than two hundred sites along the Maine coast. They also document the abundance of seaweeds and crabs, both of which affect urchins. The survey includes urchins of all sizes, including those below the minimum legal size. This fishery-independent survey provides information about what's happening in the wild population of urchins. The survey data are used to track the abundance and the biomass, or total weight, of the wild urchin population. The information helps managers to understand the whole population, not just the portion targeted by harvesters. For example, if small, sub-legal urchins are scarce in the survey, it indicates that the population and the fishery may decline in coming years. Managers will use the survey data in mathematical models that simulate the ups and downs of the population.

Fishery-independent survey regions



Urchin biomass, or total weight, has been declining, and few urchins now live in western areas of the state. At the same time, seaweed coverage has been expanding.





Modeling:

Piecing It All Together

Overview

Research and monitoring studies have produced—and continue to provide—essential information about urchin biology, ecological processes, and the fishery. Putting this information together into a comprehensive mathematical model of Maine's sea urchin population allows scientists, managers, and the industry to understand causes of the urchin's decline, the overall health of the population, and the effects of management actions.

Top: Scientists used a mathematical model of Maine's sea urchin population to understand how different amounts of harvesting would affect the stock in the future, if limits were begun in 2002.

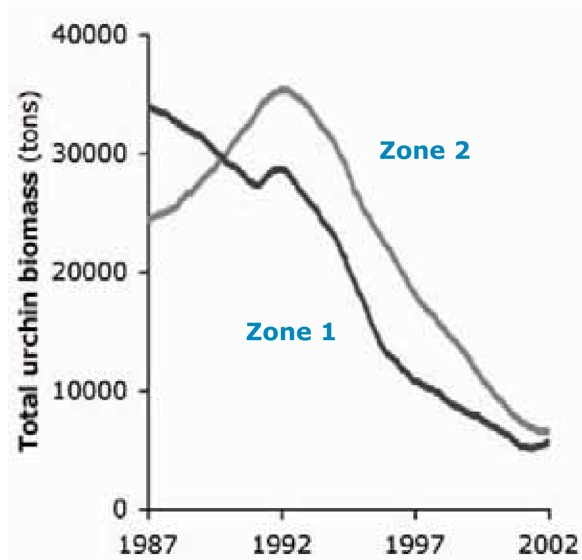
Developing and Using a Stock Assessment Model

With funding from SURF, Yong Chen (University of Maine, Orono), Margaret Hunter (Maine Department of Marine Resources), and Minoru Kanaiwa (University of Maine, Orono) are creating mathematical models that incorporate research and monitoring data on growth rates, catch per unit effort, urchin sizes and ages, reproduction, and other factors to simulate the upswings and downturns of the urchin population.

The models reveal that Maine's sea urchin stock has dropped to only 10 to 15 percent of the 1980s stock in Management Zone 1 (western Maine) and to 15 to 20 percent in Management Zone 2 (eastern Maine). In both management zones, harvest rates far exceeded sustainable levels. The combination of low stock and high harvest rates indicated that the Maine sea urchin fishery was severely overfished in both zones and that a large reduction in harvest rate was necessary.

The overexploitation in Management Zone 1 was more severe than that in Management Zone 2. The models show that if landings had been limited to 1.7 million and 3.3 million pounds per year beginning in 2002 in Management Zones 1 and 2, respectively, further declines might have been halted. Even lower limits, however, would have been needed to rebuild the stock. In the 2002–03 season, landings of 2.0 million pounds in Zone 1 and 4.7 million pounds in Zone 2 exceeded these recommended catch limits.

So far, the models do not take into account several of the important factors uncovered by research. For example, studies have shown that as urchin numbers decline the habitat tends to shift toward more extensive kelp beds, which are unfavorable to young urchins. The model also does not include the possible increase in urchin death rates due to outbreaks of predators such as the Jonah crab, or the finding that urchins probably reproduce less successfully when they become scarce. Another potentially important factor is that currents may carry larval urchins from Zone 2 to Zone 1, reducing the rate of population replenishment in Zone 2 and subsidizing Zone 1. All of these factors not included in the model would tend to make urchin populations decline. Therefore, management plans to sustain and rebuild the stock probably need to be more restrictive than indicated by these models.



Produced by a mathematical model, this graph shows the decline of the wild sea urchin population in Maine's coastal waters. The model was built using findings from basic scientific research into urchin biology and data from fishery-dependent and -independent monitoring.

Key Findings

Recent urchin landings far exceeded sustainable levels, and the urchin stock is severely depleted.

In 2002, harvests should have been capped at a maximum of 1.7 million pounds in Zone 1 and 3.3 million pounds in Zone 2—and probably less.

Other factors, not included in the model, indicate that stricter limits and complementary management strategies may be necessary to sustain the fishery.

Jim Berke

Looking to the Future: How Can We Rebuild the Fishery?

Overview

All indications from the landings data, stock assessment, basic research, and mathematical modeling—as described in the previous sections—are that Maine's sea urchin fishery has declined dramatically from its peak and will continue to do so unless key actions are taken to help. In the past, many people thought that green sea urchins were like weeds that would be resistant to and resilient from harvesting. But now we know that the urchin population suffers from:

1. low rates of young urchins arriving to join the adult population, especially in eastern Maine
2. low survival rates of juveniles in seaweed beds
3. changes in habitat with kelp beds growing more extensive from western into eastern Maine
4. low fertilization rates in low-density populations

Addressing these problems, which originate from overfishing of the urchins, could help the fishery to recover and sustain future generations of harvesters. Effective management also could restore the natural role of the green sea urchin in the Gulf of Maine ecosystem and provide an example for managing other fisheries.

Experts do not expect that Maine's fishery could return to the high levels of the early 1990s, nor would it be fair to use those levels as a benchmark. Often, before a new fishery develops and the fish stock has not been fished intensively, there has been a build up of animals, especially older animals. The new fishery may remove animals faster than they will be replaced. For a time, the population doesn't suffer because only "extra" animals are being removed. This is called "fishing-down the biomass" and is not necessarily bad. For example, improved growth rates could result if the population is thinned out. However, the challenge lies in reducing fishing effort to a sustainable level once enough thinning has occurred. Even if Maine's sea urchin population can rebuild and fishing is maintained at a sustainable level, the annual catch probably will be less than during the fishery's boom because the "build up" of urchins prior to the 1980s has been eliminated.

Basic Management Options

Adjusting Fishing Effort

Some urchin fisheries around the world appear to be sustainable. They tend to have less intense levels of fishing than in Maine. A range of options exist for adjusting fishing effort in Maine, such as closed seasons, limited entry of new harvesters into the fishery, minimum and maximum legal sizes, and daily and annual catch limits. Over the past decade, the state has implemented some of these tactics with varied success. Additional steps to adjust fishing effort in Maine could improve the long-term economic health of the urchin fishery. In the short-term, reducing fishing effort might reduce the number of people who could make a living as urchin harvesters.

Urchin Licenses by Jurisdiction: An Indicator of Potential Fishing Effort

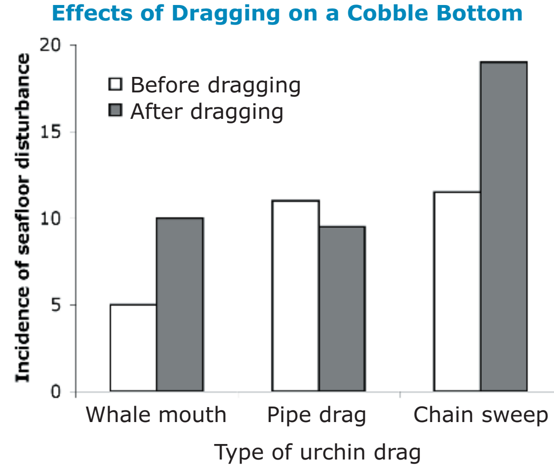
Location	No. of Urchin Licenses*
Alaska	557
British Columbia	110
Maine	1,300
Massachusetts	100
Newfoundland	58
Oregon	30; peaked at 66 in 1990
Prince Edward Island	10 permits; up to 6 divers per permit

*Data from J. Huston, 1999. Numbers approximate.

Minimizing Effects of Urchin Dragging on Seafloor

Scientific studies funded by SURF have shown that urchin drags alter seafloor habitats in ways that make it difficult for urchins and other marine creatures to thrive. The effects can be minimized by 1) not dragging in cobble areas, which serve as urchin nurseries, because the rocks are loose and easily moved, 2) restricting urchin dragging to lighter gear used only on hard bottoms, 3) improving the selectivity of drags in catching only legal-sized urchins, and 4) increasing efficiency of drags to make fewer tows necessary at any given site. Over the long term, reducing the impacts of drags on seafloor habitats could help sustain the urchin fishery. However, these restrictions might be costly for draggers over the short term.

Effects of Dragging on a Cobble Bottom



At this site, only the chain sweep caused significant disturbance to urchin habitat. At a different cobble site, however, the pipe drag did have a significant effect, apparently because the cobbles were looser.

Reducing Culling Mortality

Some fishing-related mortality of urchins happens when divers cull undersized urchins after loading their bag onto the boat. They toss the small urchins back into the water, but these urchins often do not survive. A SURF-funded study by Margaret Hunter (Department of Marine Resources) found that this problem—as well as culling time—could be reduced if divers were more selective about gathering only legal-sized urchins or if they used bags with larger mesh to allow undersized urchins to fall out. However, divers would bear the cost of new bags, the larger mesh might be more likely to snag, and the payoff from reducing this source of mortality would be minimal because of other larger problems facing the fishery. This idea of large-mesh bags has been incorporated into regulations for divers in Management Zone 2 for 2003-04. Divers in Management Zone 1 will be required to cull on the bottom and bring up no more than twenty percent undersized urchins.

Enhancement of Urchin Populations

Various possibilities exist for actively enhancing Maine's urchin population. The goal of enhancement is to improve urchins' survival rates through their early years. Adult urchins produce huge numbers of young every year in Maine's coastal waters. However, most of the offspring die long before they reach adulthood. They succumb to predators, disease, or other threats during their drifting, larval phase or after they settle onto the seabed. Few grow large enough to produce offspring of their own or to be harvested. The problem seems to be increasing as kelp beds, which contain predators of young urchins, spread along the coastline. Theoretically, it might be possible to shepherd urchins through their perilous early years to increase the number of adults. But, in practice, this approach faces substantial challenges. Experts question whether enhancement can be practiced on a scale that would produce real benefits.

Aquaculture

In Japan, the urchin industry has tried raising young urchins in land-based aquaculture facilities and then moving them into the wild after they have reached a certain size. This enables the urchins to avoid the threats they would normally face as larvae and juveniles. Yet aquaculture is extremely expensive and has met scant success in revitalizing Japan's urchin fishery, even with ongoing government subsidies. Moreover, in Maine predators in the widespread kelp beds likely would kill many urchins moved from aquaculture facilities to natural habitats.

Spat Bags

A less-expensive alternative to aquaculture is to give a helping hand to young urchins in the wild. One technique involves putting so-called spat bags into the water at sites along the coast. Made of mesh and filled with mussel shells or pieces of coralline algae, the bags offer attractive homes for juvenile urchins. The young urchins settle and live safely in the spat bags. Once they grow big enough, the animals can be placed in natural habitats. This method is attractive because it may be relatively cheap, requires little equipment, and could be handled by individual harvesters. Using spat bags for enhancement, however, might require extensive changes in the management system for Maine's urchin fishery because of ownership issues regarding the spat and older urchins. It might be possible to provide leases for urchin-growing areas to harvesters or to develop a plan based on the current management system for clam harvests, which takes place on a municipal level.


Jim Berke

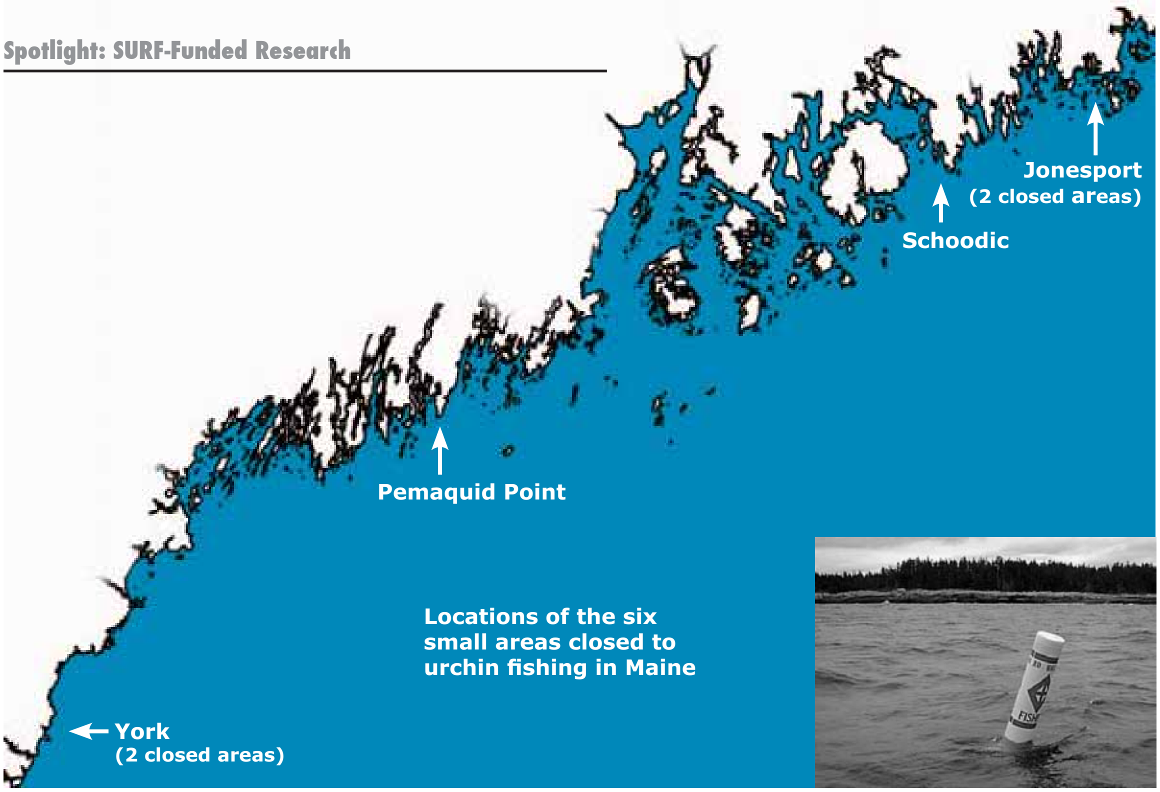
Scientists, fishermen, and other people in the urchin industry are investigating ways to grow more urchins.

Relocating Adult Urchins

SURF-funded studies show that moving adult urchins into kelp beds to enhance roe production or to mow down the seaweed is not viable. Not only are collecting and transporting the large numbers of live urchins expensive, but crabs are likely to wipe them out in their new home, at least in some locations. Moreover, the relocations would require sources of thousands of urchins.

Removal of Predatory Crabs

The number of Jonah crabs in the Gulf of Maine has exploded over the past decade. Because the crabs eat green sea urchins, harvesting them might benefit the urchin fishery. Jonah crabs currently are not fished in appreciable amounts, so markets would need to be developed. However, scientists are not certain that harvesting the crabs would result in much of an increase in urchins, and unintended side effects might harm the ecosystem or other fisheries.



John Vavrinec

To test the potential for closed areas to help rebuild the urchin stock, six small areas along the coast were closed beginning in 1999. Inset: This buoy marked one of the closed areas.

Could Closed Areas or Rotated Harvest Areas Be Useful Tools?

In 1999, six small areas along the Maine coast were closed to urchin fishing. In a SURF-funded study, scientists monitored these closed areas to assess their potential for aiding recovery of urchin populations. In contrast to traditional management methods that adjust the level of fishing effort, closed areas protect the habitat itself, as well as the urchins. And unlike enhancement, closed areas do not require large investments of money and labor. As a result, closed areas, or harvested areas that are rotated, could be useful tools.

The SURF study revealed variable outcomes among the six closed areas. After two years, two of the areas showed increases in urchin biomass. One of those sites also had increases in the number of legal-sized urchins and roe biomass. These results are expected for successful closed areas. However, some of the closed areas did not show any positive changes. Kelp beds dominated these sites at the beginning of the study. Even when protected from harvest, urchins did not reestablish themselves there because the kelp beds harbored predators. Therefore, simply allowing kelp-dominated areas to lie fallow may not lead to an increase in urchins. One of the closed areas was probably poached, which shows that closed areas would need to be supported by the industry and carefully enforced.

The findings indicate the importance of establishing closed areas before urchins disappear from a given area, allowing kelp to overtake the seafloor. These habitat shifts are not easy to reverse. To prevent them without implementing closed areas, harvesters would need to leave sufficient urchins on the bottom, rather than fishing out an area. This type of regulation would be difficult to enforce.

Key Findings

Closed areas may be helpful for sustaining the urchin population if established in areas that have not yet switched from urchin barrens to kelp bed.

Closed areas in Zone 2 may supply urchin larvae to Zone 1, if the larvae are carried west by the Eastern Maine Coastal Current.

John Vavrinec

A scientist attaches a device to monitor urchin settlement.

How Can Research Continue to Help the Urchin Fishery?

Over the past decade, research funded by SURF and organizations such as Maine Sea Grant has led to an increased understanding of urchin ecology along Maine's coast, factors affecting the success of the fishery, and possible management strategies. The information in this booklet is based largely on that research and provides a solid basis for helping the fishery. However, continued research and monitoring can further refine this understanding, improve stock assessment models, and provide essential information for management and the industry. Urchin experts have identified the following priorities for research and monitoring.

Current Research Priorities

Habitat Shifts from Urchin Barrens to Kelp Beds
The precipitous decline in kelp-eating urchins is causing habitats to change from urchin barrens to kelp beds that harbor predators, making them unfavorable to newly settled urchins. Shifts are persistent and are spreading eastward along the Maine coast. These changes can prevent urchins from becoming re-established and represent a major threat to the fishery. What are the factors that bring about the shifts, and what are appropriate preventive management strategies? Would permanently or temporarily closed areas be useful to minimize the loss of urchin barren habitats?

Few Young Urchins in Eastern Maine
The urchin stock in eastern Maine is almost all old, large individuals. Very few young urchins are joining the population. Once the existing urchins are fished out, they may be slow to replenish. How can the urchin population in eastern Maine be sustained? Do western Maine populations rely on larvae drifting from eastern Maine? Could closed areas in eastern Maine help maintain populations in western areas?

Fishing Practices
What more should be done to minimize any adverse effects of fishing on small and oversized urchins, their habitat, and other animals?

Fishery-Dependent and -Independent Monitoring
Ongoing urchin stock assessments using both fishery-dependent and -independent data provide vital information for detecting improvements or declines in the stock, planning management actions, and evaluating the outcomes.

Is Enhancement a Viable Option?
Could enhancement be practiced on a large enough scale to rebuild the urchin population? Could small trials involving the urchin industry facilitate larger-scale efforts? Is enhancement a low priority because of its costliness and the failure of past efforts?

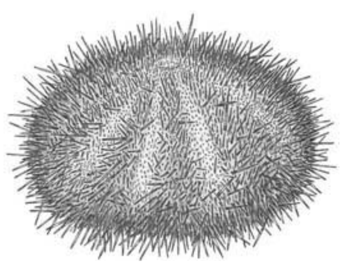
Declines in Reproduction?
When urchins become too scarce, their per capita reproductive success drops. Has the state's urchin population dwindled enough to harm reproductive success? How should stock assessment models and management actions take into account this possible factor?

Urchin Health
In Nova Scotia, disease occasionally has killed green sea urchins in large numbers. Urchin health is poorly understood, but massive die-offs could push Maine's fishery over the edge. How should management of Maine's urchin fishery account for the possible effects of disease and environmental stresses?

Jim Berke

Where Do We Go From Here?

Maine's fishery for green sea urchins has continued to decline since the early 1990s. Experts agree that the situation is likely to worsen unless appropriate steps are taken soon. Fortunately, the scientific research that has been conducted through the collaboration of the industry, scientists, and managers can enable the development and implementation of well-informed and soundly reasoned management plans. SURF-funded studies and other research programs indicate that certain management options have the potential to help rebuild Maine's urchin fishery, ensure the long-term economic viability of the industry, and maintain the role of the green sea urchin in the ecosystem.



Urchin illustration by Ethan Nedeau, biodrawversity.com

Research Projects Funded by the Sea Urchin Research Fund (SURF): 1994 through 2003

Commercial Catch Sampling
Ongoing since 1994. Annual reports available.
Researchers: Kerry Lyons, Lessie White, and Margaret Hunter (Department of Marine Resources)
Cost from fund: Approximately $30,000 annually

Commercial Landings Data from Logbooks
Ongoing since 1996. Landings data available.
Researchers: Kerry Lyons and Margaret Hunter (Department of Marine Resources)
Cost from fund: approximately $25,000 annually

An Economic Analysis of the Market for Maine Sea Urchins
Complete, 1997. Report available. 88 pp.
Researchers: Drs. James Wilen (University of California) and Cathy Wessells (University of Rhode Island)
Cost from fund: $34,465

Density-related Reproductive Trade-offs in the Green Sea Urchin and Implications to the Maine Fishery
Complete, 1998. Report available. 37 pp.
Researchers: Dr. Richard A. Wahle and Hoyt Peckham (Bigelow Laboratory for Ocean Sciences)
Cost from fund: $50,931

Temporal and Spatial Variability in the Relationships Between Adult Size, Maturity and Fecundity in Green Sea Urchins
Complete, 1999. Report available. 136 pp.
Researchers: Drs. Robert L. Vadas (University of Maine at Orono) and Brian F. Beal (University of Maine at Machias)
Cost from fund: $132,938

Settlement and Survival of the Green Sea Urchin in Maine: Effects of Algal Habitat
Complete, 1999. Report available. 59 pp.
Researchers: Douglas C. McNaught and Dr. Robert Steneck (University of Maine Darling Center)
Cost from fund: $169,534

An In Situ Study of the Impact of Sea Urchin Dragging on the Benthos
Complete, 1999. Report available. 22 pp.
Researchers: Dr. Richard A. Wahle (Bigelow Laboratory for Ocean Sciences)
Cost from fund: $91,353

Sea Urchin Drag Study
Complete, 1998. Report available. 29 pp.
Researchers: Edwin P. Creaser and Wayne Weeks (Department of Marine Resources)
Cost from fund: $41,666

Sea Urchin No-Fish Areas in Maine: Rates of Recovery, Gonad Indices, and Algal Habitats in Fished and Unfished Areas
Ongoing, interim report available. 26 pp.
Researchers: John Vavrinec (University of Maine), Dr. Susanne Meidel (University of Maine), Dr. Richard Wahle (Bigelow Laboratory for Ocean Sciences), and Dr. Robert Steneck (University of Maine)
Cost from fund: $179,018 for 1999-2001, $142,081 for 2002-2003

Reseeding the Green Sea Urchin in Depleted Habitats
Complete, 2002. Report available. 25 pp.
Researchers: Amanda Leland and Dr. Robert Steneck (University of Maine Darling Center)
Cost from fund: $95,205 for 2000, $71,809 for 2001

Cobscook Bay Sea Urchin Relocation
Complete, 2001. Report available. 16 pp.
Researchers: Robert Russell (Department of Marine Resources) and Cobscook Bay Fishermen's Association
Cost from fund: $5,000

Maine Assessment Survey for Green Sea Urchins
Ongoing since 2001. Annual reports available.
Robert Russell and Margaret Hunter (Department of Marine Resources), Dr. Yong Chen and Robert Grabowski (University of Maine)
Cost from fund: $78,000 for 2001, $31,000 for 2002

Development, Evaluation, and Application of a Stock Assessment Framework for the Maine Sea Urchin Stock
Complete, 2003. Report available. 113pp.
Researchers: Dr. Yong Chen (University of Maine), Margaret Hunter (Department of Marine Resources), and Minoru Kanaiwa (University of Maine)
Cost from fund: $39,038

Testing Two Large-Mesh Sea Urchin Diver Catch Bags
Complete, 2002. Report available. 31 pp.
Researcher: Margaret Hunter (Department of Marine Resources)
Cost from fund: $1,045

For copies of any of the reports, please contact the DMR Fishermen's Library, P.O. Box 8, West Boothbay Harbor, ME 04575; telephone (207) 633-9551; library@bigelow.org

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Yellow roe, or *uni*, in freshly cracked green sea urchins from Maine.