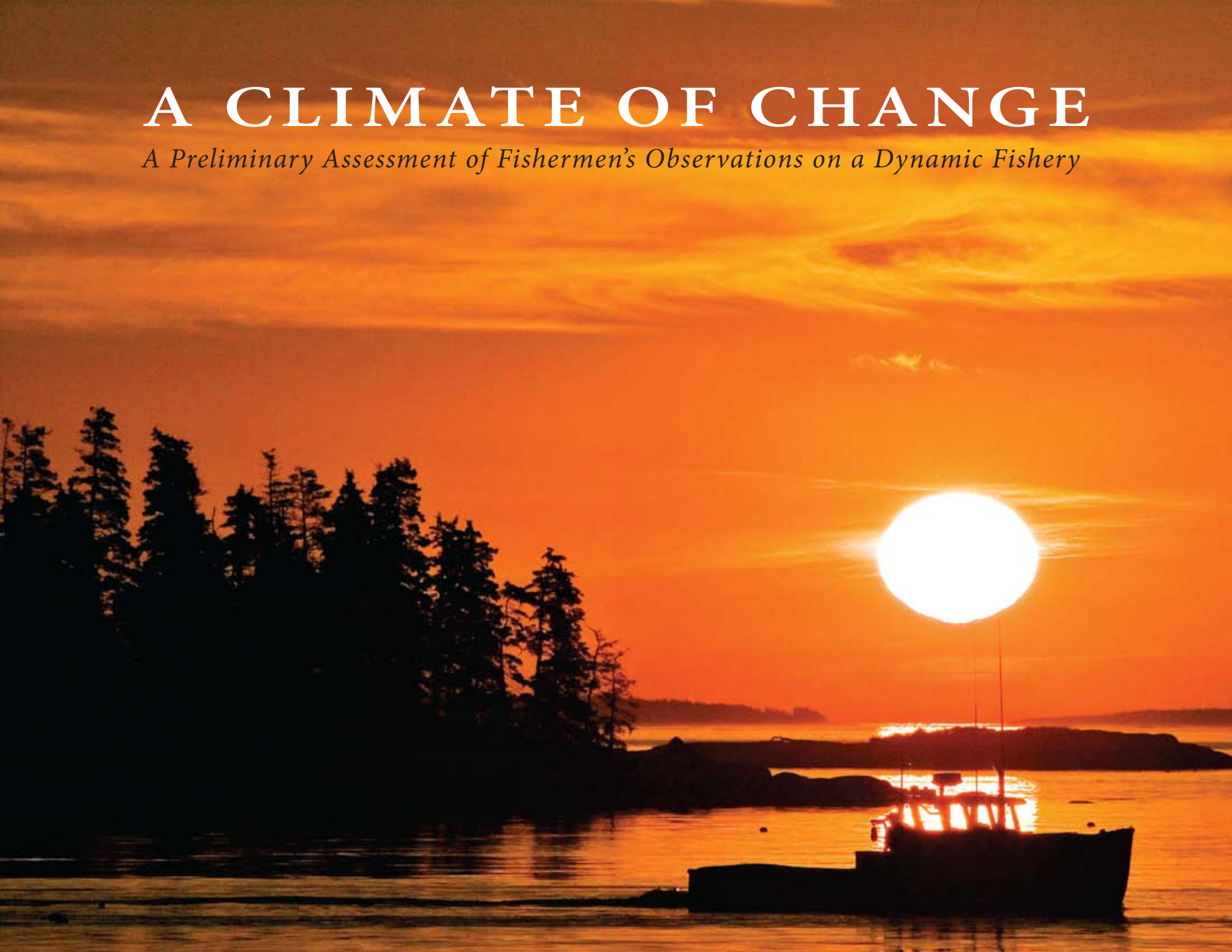
A CLIMATE OF CHANGE

A Preliminary Assessment of Fishermen's Observations on a Dynamic Fishery



ISLAND INSTITUTE
386 Main Street
Rockland, ME 04841
www.islandinstitute.org

Report prepared by Anne Hayden, Consultant, Resource Services, Brunswick, Maine
and Gillian Garratt-Reed, Marine Programs Coordinator, Island Institute

Project Director | Rob Snyder, Vice-President of Programs, Island Institute

Project Managers | Jennifer Litteral, Marine Programs Director and Gillian Garratt-Reed, Marine Programs Coordinator, Island Institute

Editors | Nancy McLeod Carter, Vice-President of Knowledge Management and David Tyler, Publications Director, Island Institute

Report Design | Bridget Leavitt, Design Coordinator, Island Institute

The Island Institute gratefully acknowledges the contributions of the following individuals without whom this report would not have been possible: Jim Acheson, Jim Alwin, John Butler, Philip Conkling, Shey Conover, Josh Conover, Gerry Cushman, Walter Day, Heather Deese, John Drouin, Janine Drouin, Peter Eaton, Bruce Fernald, Anne Henshaw, DeWitt John, Tom MacVane, Tom Marr, Dan Morris, Dana Morse, Andrew Pershing, Kelly Pitts, Paul Rozeff, Tom Shyka, Sonny Sprague, Bob Steneck, Dave Thomas, Elliott Thomas, Mike Tillotson, Michael Tlusty, Rick Wahle, Carl Wilson, Jim Wotton, and Justin Wright.

We would like to thank Maine SeaGrant for supporting the publication of this document and members of the Island Institute for supporting the research captured herein.

A CLIMATE OF CHANGE

A Preliminary Assessment of Fishermen's Observations on a Dynamic Fishery

FOREWORD BY ELLIOT THOMAS, LOBSTERMAN FROM YARMOUTH

"Whenever a group of fishermen get together and talk, you always learn something because lobstermen tend to be keen observers of what is happening in their area. When asked to attend the first session of the project, I jumped at the chance to see if others had noticed trends similar to those I had observed. Although the two sessions I have attended can only be the start of observations of a long-term process like climate change, similar observations of change along the Maine coast by other fishermen seem to suggest that something is happening. As more observations are collected from other fishermen, we will be able to see more clearly how trends are changing over time and we will be better prepared to adapt to any resulting changes in the fishery. My hope is that our observations can and will be used by scientists to help document these trends. I encourage all fishermen to read this publication and share their own observations with the rest of the industry."

EXECUTIVE SUMMARY

The Island Institute has launched a program to assess the potential effects of climate change on Maine's lobster fishery; this report presents preliminary findings.

It is difficult for climate scientists to distinguish the effects of climate change from the naturally occurring variability that characterizes climate in our region. Nevertheless, based on the interviews with scientists in this preliminary assessment, there is consensus that:

- The Gulf of Maine is warming and it is extremely likely that greenhouse gas emissions are the cause.
- It is even more certain that the warming trend will continue.
- Warming due to existing levels of CO_2 in the atmosphere will continue for decades, if not longer.

The goal of the program is to link information from fishermen and scientists in a collaborative process that will broaden our understanding of climate change and contribute to the ability of lobstermen, who depend on Maine's most valuable fishery, to adapt to its changing conditions.

Fishermen have very detailed data about the patch of ocean they fish. Often, this information is supplemented by knowledge passed down from previous generations who fished the same area. Fishermen compare trends in landings and shifts in abundance of juvenile, over-sized and reproductive lobsters with weather events, temperature trends, and other environmental factors they deem to be important. A focus of the program to date has been to identify trends observed by fishermen over the past few years, and discuss whether such trends might be related to increases in temperature and other climate factors.

Preliminary findings, based on roundtables held with fishermen in 2007 and 2008, telephone interviews, and survey results, indicate that fishermen are noticing significant changes in the annual pattern of the fishery:

- Lobsters no longer shed in a predictable fashion;

- Lobsters are moving into deeper water much earlier in the fishing season;
- Fishermen are harvesting the bulk of their catch later in the year.

This information is complementary to data collected by scientists. Comparison of fishermen's observations with scientifically collected data yields insights into the effects of climate change, both current and potential, on lobster stocks and coastal communities — as well as new opportunities for collaborative research.

Preliminary results from the first two years of the program indicate that linking scientific and real-world knowledge is a useful approach to improving our understanding of the potential impacts of climate change. Much work, however, lies ahead if we are to capture the collective knowledge of fishermen and scientists regarding climate change.

We know, for example, that we need to continue these roundtable discussions and expand them to a broad range of fisheries. We also need to drill down deeper into fishermen's vast knowledge base through individual interviews and surveys. Another critical strategy is to give fishermen and their families a greater variety of opportunities to participate in scientific data collection, and to work with oceanographers to analyze existing temperature records in the context of lobster-landings data, trawl-survey data and other information on lobster abundance.

This information will also prove useful in efforts to research the effects of temperature on lobster molt and movement to better understand the impacts temperature change may have on the fishery. Further, by gathering historical information on lobster landings, we can also link data to what we know about storm events, freshwater runoff and the lunar cycle, in order to gather information on how such phenomena may impact lobsters. Finally, we intend to create opportunities for K-12 students to contribute data and analysis regarding the effect of storm events and other climatological factors on their communities.

CRITICAL NEXT STEPS

- Continue roundtable discussions with fishermen and expand them to a broad range of fisheries;
- Drill down deeper into fishermen's vast knowledge base through individual interviews and surveys;
- Give fishermen and their families a greater variety of opportunities to participate in scientific data collection;
- Assist lobstermen in working with scientists to analyze existing temperature records in the context of lobster-landings data, trawl-survey data and other information on lobster abundance;
- Use relevant data to research the effects of temperature on lobster molt and movement to better understand the impacts that temperature change may have on the fishery;
- Link data containing historical information on lobster landings to what is known about storm events, freshwater runoff and the lunar cycle, in order to gather information on how such phenomena may impact lobsters;
- Create opportunities for K-12 students to gather data and contribute analyses regarding the effect of storm events and other climatological factors on their communities.

CLIMATE CHANGE IN THE GULF OF MAINE

The Gulf of Maine is warming and it is extremely likely that greenhouse gas emissions are the cause. It is even more certain that the warming trend will continue. Due to the lag effect in the earth's climate system, warming due to existing levels of CO_2 in the atmosphere will continue for decades, if not longer.

In Maine, fishermen and scientists alike are concerned about the possible effects of climate change on the Gulf's flora and fauna. The Island Institute is bringing fishermen and scientists together in a collaborative process that will expand, if not transform, our ability to respond to the effects of climate change. Fishermen from up and down the coast and a panel of highly respected marine scientists have joined this exciting enterprise in mutual learning and exploration.

"I do believe global warming is happening because this year Hancock County supposedly was the top dog in lobsters and the top dog most of the time has been Spruce Head and Vinalhaven. Now it's shifted a little bit eastwards. Before long they're going to be by us; they'll be in Nova Scotia."

SONNY SPRAGUE, SWAN'S ISLAND

Our goal in this publication is to put the observations of fishermen in context with what is known about the impacts of climate change on the Gulf of Maine. Our next step is to identify the potential effects of climate change on lobster populations and fishermen in order to prepare coastal communities for upcoming changes. Scientists are now confident that models of atmospheric warming at a global scale are reliable. They are less sure about what such warming means for the oceans or for regional ecosystems such as the Gulf of Maine, to say nothing of the local impacts in Casco Bay, Penobscot Bay or Down East

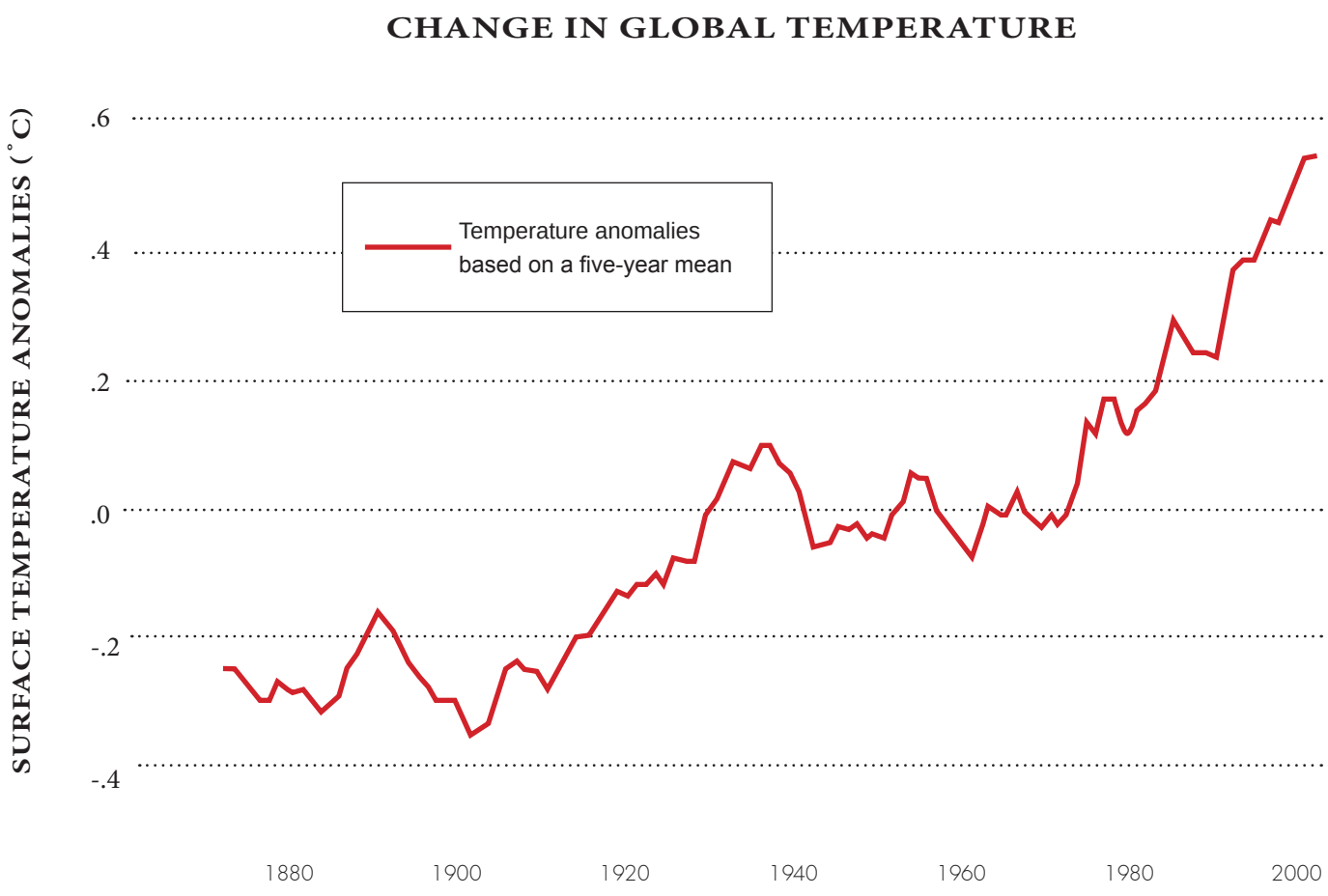
near the mouth of the Bay of Fundy. Nevertheless, current research identifies sea-level rise, shifts in plant and animal populations, changes in nutrient cycles, and an increase in ocean acidity as possible consequences.

Fishermen have much to offer such investigations. Their knowledge of ecosystem change is local and richly detailed. Unlike scientists' measurements, which are relatively recent, their knowledge incorporates historical information. By bringing the two sources of know-how together, we may be able to predict what climate change will mean for Maine's lobster-fishing communities. The findings described below are not sufficient to identify any current effects of climate change on Maine's lobster fishery; much more work needs to be done before it would be possible to determine if any such impacts are currently in play. These findings, however, represent an important source of environmental information that should be incorporated in future climate assessments.

Are lobster fishermen like the canary in the coal mine? Hardly. Unlike the helpless bird, they are exceptionally resilient. Lobster fishermen have adapted to a great many changes over the 100-plus years of the industry. They constantly monitor their environment in order to adjust to changes they detect. The success of the fishery, in stark contrast to other fisheries worldwide, is due in no small part to the collective efforts of Maine's lobstermen to ensure the sustainability of their resource. In addition to gaining valuable data about the Gulf of Maine's response to global warming, working with fishermen holds many lessons for the rest of society regarding how best to prepare for the effects of climate change.

"I have a thermometer that I keep in one of my traps and, if I see it's 47 degrees, I slam everything into the water because 48 is when they start moving."

ELLIOT THOMAS, YARMOUTH



[Fig. 1] Five-year mean of annual surface temperature anomalies relative to the 1951-1980 mean, based on surface air measurements at meteorological stations and ship and satellite measurements of sea-surface temperature.
Adapted from http://data.giss.nasa.gov/gistemp/2007/.

CLIMATE SCIENCE

Much of what we know about climate change relates to global averages. "Business as usual" projections by the International Panel on Climate Change forecast an increase of as much as 10 degrees Fahrenheit in the earth's atmosphere over the next 100 years (IPCC 2007). As made clear by the scientists advising the Island Institute, translating that prediction to the Gulf of Maine is not a simple task. For one thing, warming is not uniform; the poles are warming faster than the rest of the earth (ACIA 2004). For another, the transfer of heat from the atmosphere to the ocean is complicated by flows in the atmosphere, such as the jet stream, as well as ocean currents. The Gulf Stream, Labrador Current, and currents and tides within the Gulf of Maine alter the distribution of heat from the air to the water.

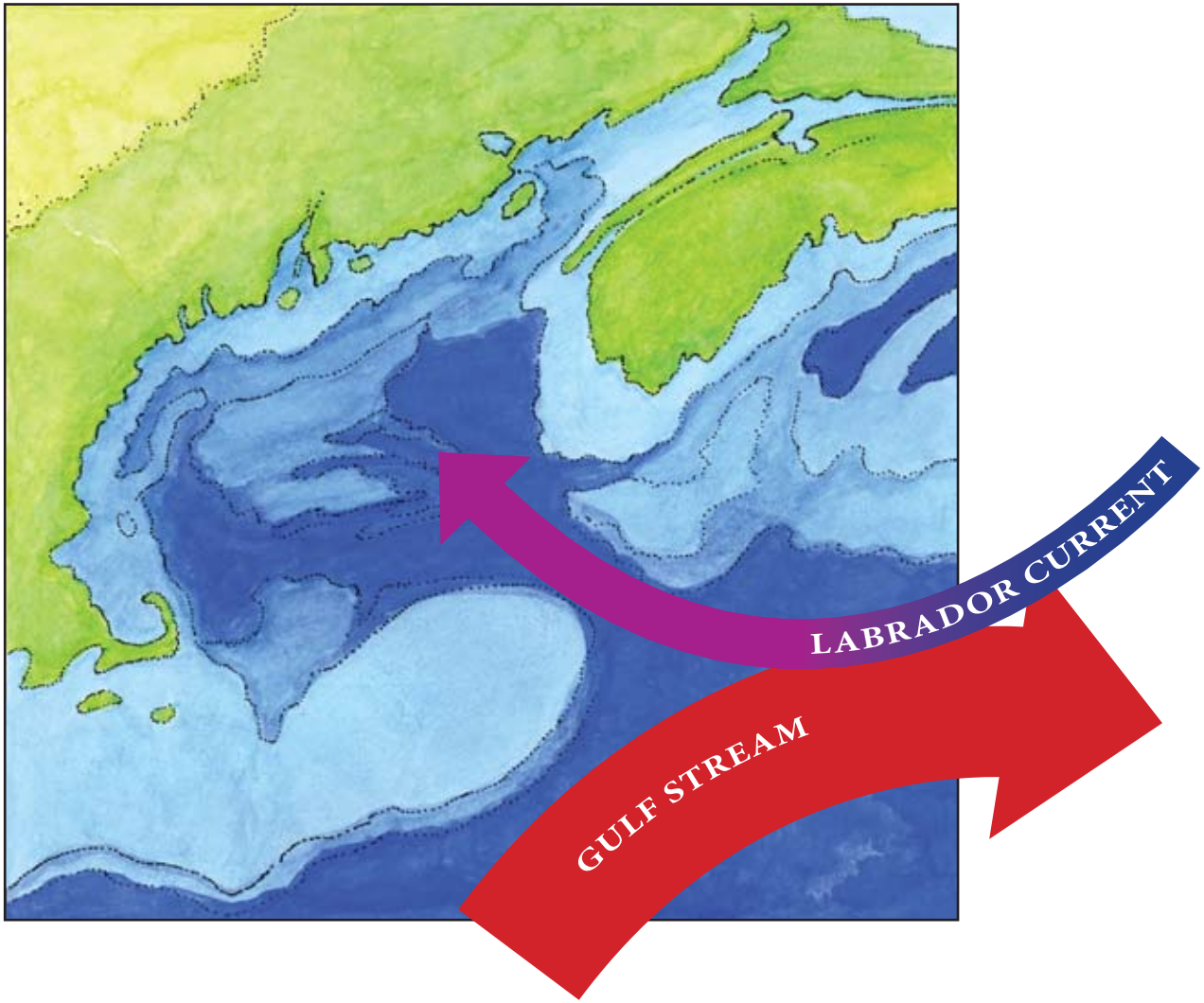
While we do know that climate change is well underway, it can be difficult to distinguish the incremental increase in average temperature due to climate change from a naturally occurring variation in temperature [Fig. 1]. The average range in temperatures we experience in the course of a year is much greater, and therefore more noticeable, than the increase due to climate change. Sea-surface temperature recorded in Boothbay Harbor has increased about five degrees Fahrenheit in the last 20 years. As recently as the 1950s, however, the same record shows that water temperature was even warmer than it is today. While warming at that time was likely a function of climate variability, scientists believe that current conditions reflect this ongoing decade-to-decade inconsistency combined with human-induced climate change.

Water temperature in the Gulf of Maine is driven by several factors. The temperature of the air in the region is a major driver; water temperature will increase as climate change increases air temperatures. The second driver is the inflow of currents from the Northwest Atlantic Ocean, including the Labrador Current and the Gulf Stream. The Labrador Current, flowing south from the Arctic, mixes with waters

"I have always thought that the cold water protected us. I think the warmer the water, the greater the chances of something bad happening."

DAN MORRIS
PORT CLYDE

DEEP WATER FLOW INTO THE GULF OF MAINE



[Fig. 2] Representation of the deep-water flow from the Labrador Current and the Gulf Stream into the Gulf of Maine through the Northeast Channel.

from the northern edge of the Gulf Stream. Some of this mixture enters the Gulf of Maine through the Northeast Channel [Fig. 2].

How much gets into the Gulf of Maine is affected by climate-driven changes in atmospheric pressure over the North Atlantic as well as the effect of warming on the cycle of water movement, distribution and quality in the region. Warming air temperature is increasing the rate of evaporation from surface waters in the tropics, which, in turn, is increasing rates of precipitation, particularly in northern latitudes where air temperatures are lower. Oceanographers believe that changes in the density of Arctic waters, due to their freshening, will tend to increase the relative amount of cool, fresh Labrador Current water entering the Gulf of Maine. This shift will likely be further enhanced by the rapid melting of Greenland's glaciers.

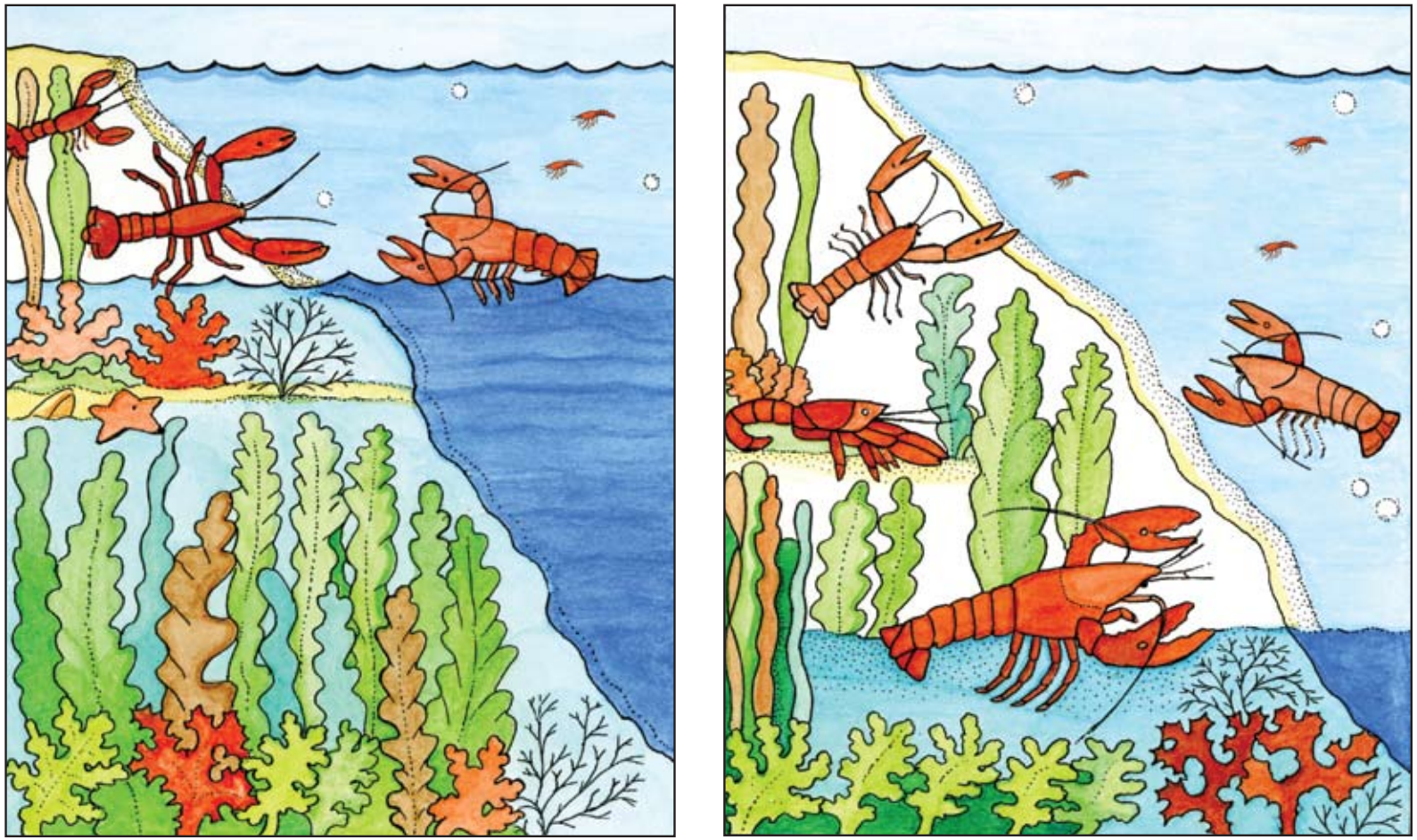
Scientists who consider the complex interaction of these atmospheric and oceanic forces predict that atmospheric warming will ultimately overshadow cooling due to shifting oceanographic currents. But their prediction comes with a caveat: it is possible that the freshening of Arctic currents could slow the Gulf Stream and its delivery of moderating temperatures to northern latitudes. It is not clear what conditions would lead to such an event or what it would mean for the Gulf of Maine. In any case, due to the mixing effect of large tides in the eastern Gulf of Maine, it will likely continue to be cooler than the western Gulf of Maine.

Assuming that the Gulf Stream continues to flow at its present rate, scientists project that surface temperatures along the Northeast coast of the United States, including the Gulf of Maine, are likely to warm five to eight degrees Fahrenheit over the next century (Frumhoff et al. 2007). What this will mean for the Gulf ecosystem is a challenging question. Species at the southern edge of their range may be forced out of the Gulf by warming temperatures. Similarly, species

"I agree there's climate change and polar ice caps are probably melting but they have been for 10,000 years or more."

JIM WOTTON
FRIENDSHIP

POTENTIAL IMPACTS ON LARVAL HABITATS



[Fig. 3] In the summer months, warmer air temperatures lead to formation of a warm surface in the Gulf of Maine. With climate change, this layer will deepen. As a result, more habitat will be available for settlement by larval lobsters that require higher temperatures than adults.

at the northern edge of their range may find the Gulf more hospitable. Warming may be good for lobsters in the Gulf; warmer temperatures will speed their development and growth rates. Lobsters to the south of Cape Cod may not fare as well as temperatures rise above their levels of tolerance; unusually high temperatures contributed to a die-off of lobsters in Long Island Sound in 1999 (Howell et al. 2005). Warming waters in the Gulf may also benefit lobsters by increasing the habitat available to larval lobsters looking for the right mix of temperature and habitat type in which to settle (Fogarty et al. 2007) [Fig. 3]. On the downside, warming waters may open the Gulf to a new host of invasive species. Warmer temperatures may also increase the incidence of shell disease in the Gulf; an outbreak of shell disease south of Cape Cod in the 1990s may have been triggered, in part, by warmer temperatures (Glenn et al. 2006).

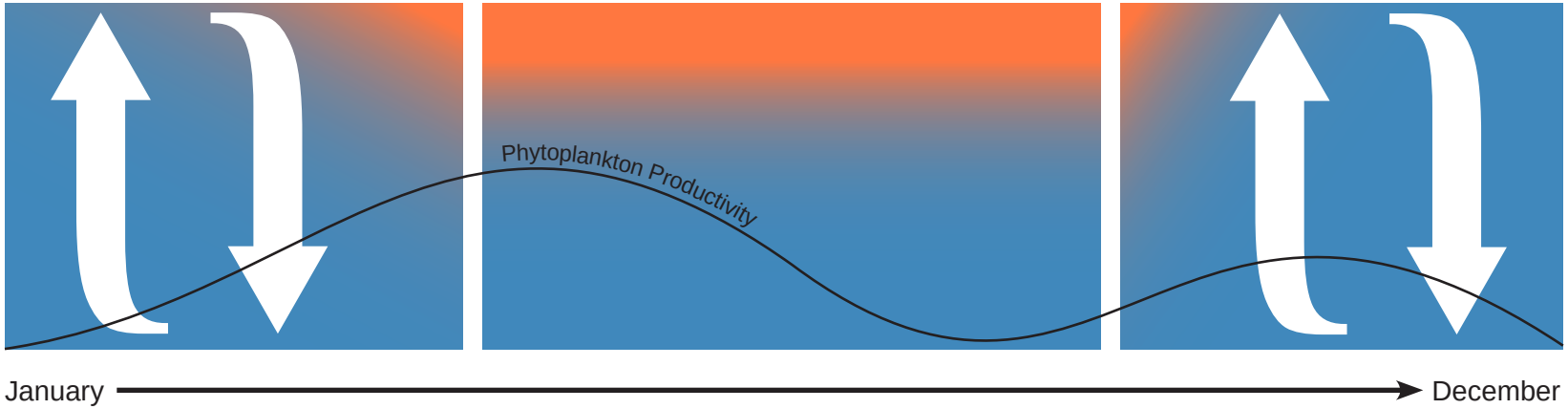
Warming waters will have an effect on the Gulf's weather: northeasters and hurricanes will increase in intensity as warmer waters feed extra energy to these cyclones as they spin across the Gulf. While it is not clear what impacts, if any, such storms have on lobsters; the threat for fishermen, boats, wharves and gear is clear.

Increased precipitation will influence the Gulf of Maine, as it does the Arctic, by amplifying the volume of fresh water flowing into the Gulf from its many rivers. This in turn will increase the layering effect, or stratification, that occurs in the Gulf each summer when warmer, less saline waters create a surface layer distinct from the cooler, saltier and nutrient-rich waters at depth. Increased stratification should initially benefit phytoplankton by trapping them near the surface where there is more light. However, if stratification is too strong, it could reduce the cycling of nutrients from ocean depths to the surface, possibly decreasing productivity [Fig. 4]. Changes in precipitation will also affect the flow of water out of rivers and into the Gulf, an

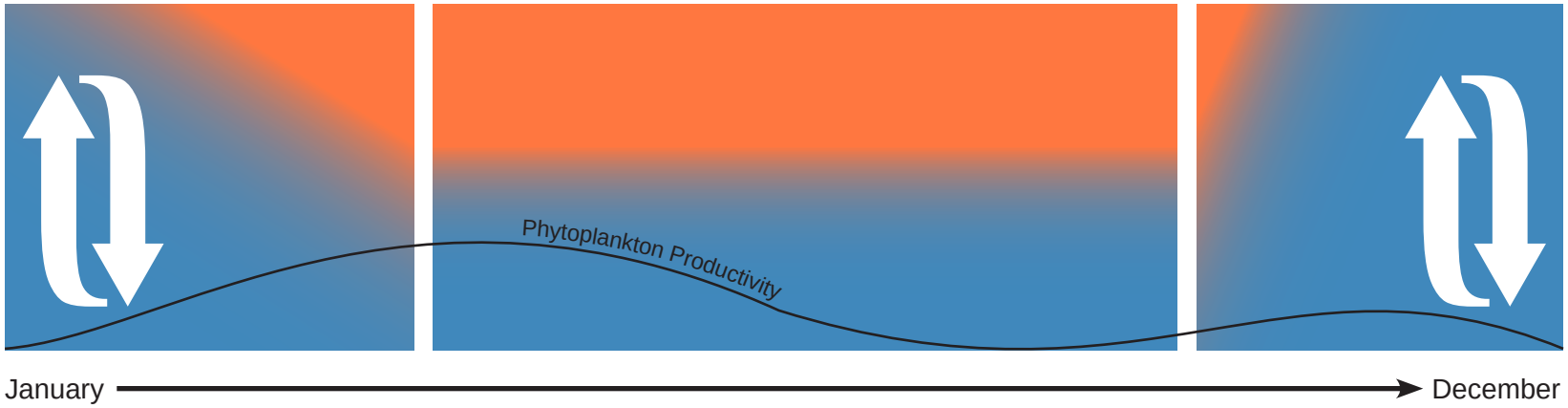
"In our bay, way up in the head of it, the fishing has been very poor and I say it's because of the amount of fresh water. As the lobsters were going in there, they got a taste of it, they turned around and they've gone back out."

JOHN DROUIN
CUTLER

PRE-CLIMATE CHANGE



POST-CLIMATE CHANGE

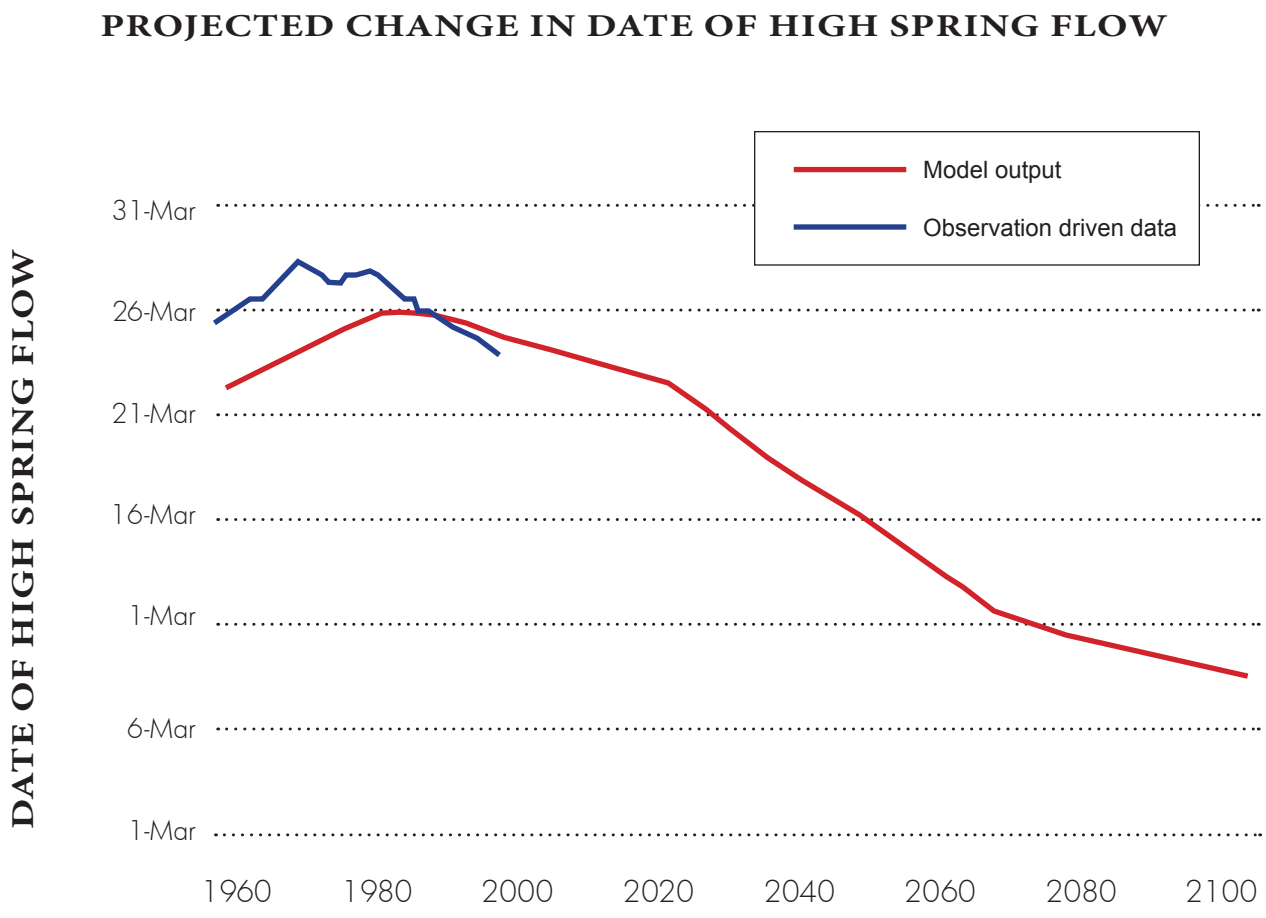


[Fig. 4] The spring phytoplankton bloom in the Gulf of Maine is much of the basis of the Gulf's food web. The bloom declines after several weeks as nutrients in the surface layer are depleted. As air temperatures cool through the fall, surface waters become colder and sink. As they sink, the water column becomes well mixed. Nutrient-rich bottom waters are brought to the surface and support a smaller fall bloom. Climate change may result in the formation of a warm surface layer that begins earlier in the summer, lasts longer into the fall, is deeper and more distinct. Such changes would limit the mixing of nutrients into surface waters and might result in a decline in phytoplankton productivity.

important process that affects nearshore currents and the distribution of plankton. Despite the fact that precipitation will increase overall, the spring freshet (run-off due to snow melt) will be smaller — because precipitation will be less in the form of snow and more in rain.

The freshet will also be earlier in the year, affecting those organisms attuned to a different relationship between the spring bloom and run-off [Fig. 5]. Changes in phytoplankton productivity, which forms the basis of the Gulf's food chain, are possible, but it's unclear what their effects on the rest of the ecosystem, including lobsters, would be.

A decrease in the pH of the world's oceans, or acidification, has a direct effect of the increase of CO_2 in the atmosphere, and represents another threat to the Gulf ecosystem. As more molecules of CO_2 dissolve in the ocean, the pH of the water becomes less alkaline. The Gulf of Maine may be particularly vulnerable to acidification because its concentration of carbonate ions is low relative to other parts of the world's oceans. Increased acidity puts stress on those organisms, such as lobsters, that must now exert more energy to extract calcium carbonate from the water in order to build their shells. Ocean acidifica-



[Fig. 5] Projected change in date of high spring flow based on the United Kingdom Meteorological Office's Hadley Centre Climate Model version 3 (HadCM3) adapted from Northeast Climate Impact Assessment.

POSSIBLE EFFECTS OF CLIMATE CHANGE ON LOBSTERS AND LOBSTER FISHING

Likely Environmental Change	*Positive*	*Negative*
Increased water temperature	More larval habitat	Temperature stress in shallow waters
	Increased growth rates	
Increased precipitation		Decline in catches near rivers
Increased storm intensity		Trap losses
Increased acidification		Increased stress on lobsters
		Lobster shell disease

tion and warming temperatures may have a cumulative impact on lobsters, increasing their vulnerability to disease and other stressors. Lobster abundance is very high, resulting in an increase in the density of these animals on the bottom. This concentration of lobsters further contributes to the risk of a devastating outbreak of disease (Steneck 2008). The possible effects of climate change are summarized in the above table.

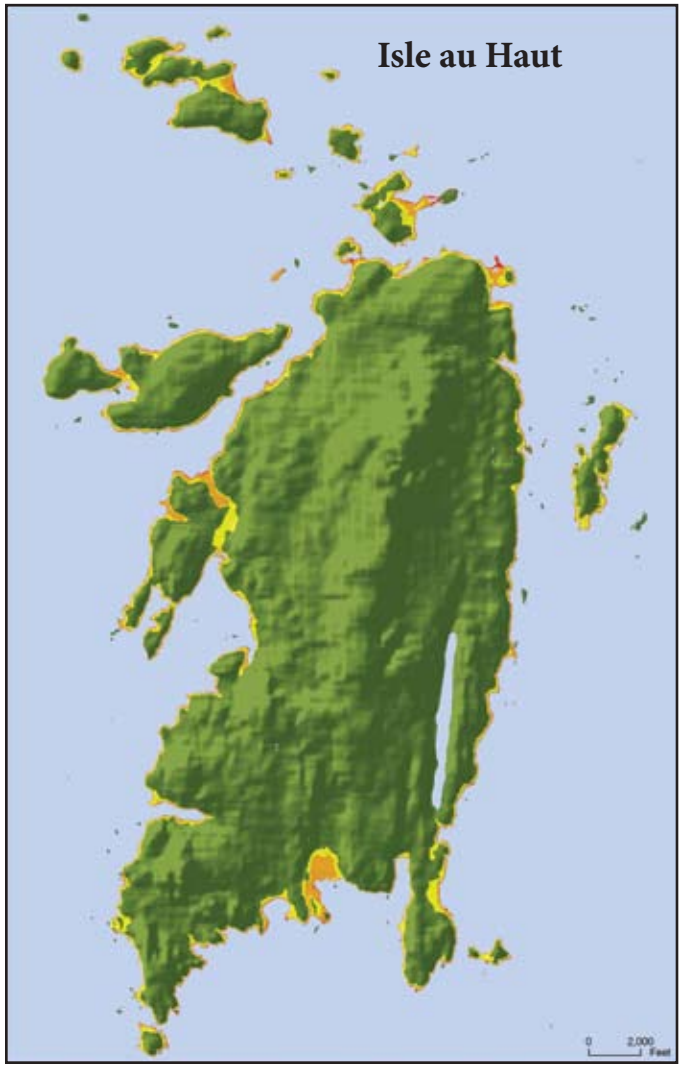
Sea-level rise is another likely effect of our warming climate. Conservative projections call for a rise in sea level in the Northeast of 7 to 23 inches in the next century (Frumhoff et al. 2007). The potential effects of sea-level rise on coastal communities include loss of shore-side infrastructure such as docks and wharves, impacts on storm drains and sewage treatment plants, flooding of low-lying areas, increased erosion, and increased risk of storm damage.

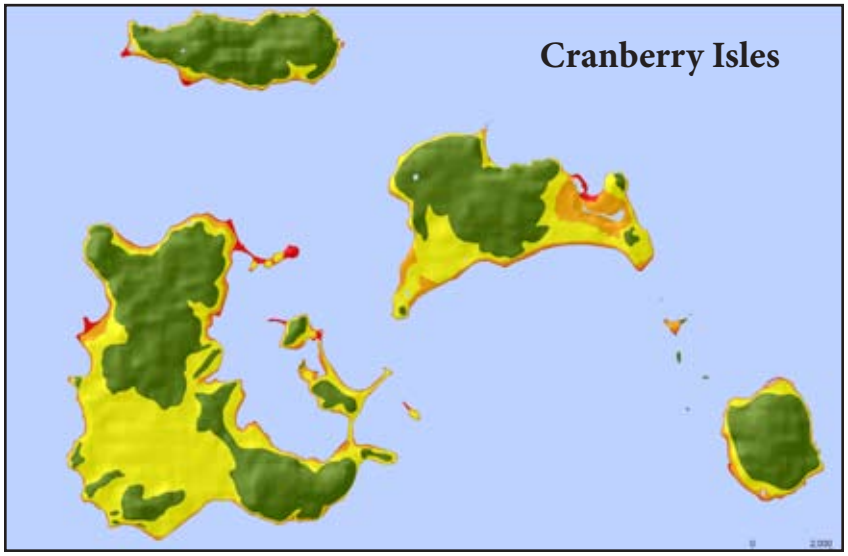
Fig. 6 illustrates the potential effect of a two-foot rise in sea level on the Cranberry Isles and Isle au Haut. The low-lying Cranberry Isles will be flooded to a much greater extent than Isle au Haut with its steep slopes.

Lobster with shell disease. Photo: Michael Tlusty, New England Aquarium

There is much to learn about what all this means for lobsters, lobster fishermen and their communities. Predictions about what climate change will mean for the Gulf of Maine are far from certain — and do not yet take into account variations within the Gulf. Fishermen don't fish in the Gulf so much as they fish a bay, a bottom, an edge, a rise or a gully. Their fishing areas are ecosystems in their own right, responding uniquely to a warming atmosphere as well as to currents, tides, storms, bottom types and nutrient cycles. These details are as important as the generalities in sorting out what climate change means for Maine's lobster fishermen.

SEA LEVEL RISE IMPACT ON ISLE AU HAUT AND THE CRANBERRY ISLES





2-foot rise in sea level

10-foot rise in sea level

20-foot rise in sea level

[Fig. 6] Land inundated by sea-level rise on the Cranberry Isles and Isle au Haut. Red areas indicate land inundated by a 2-foot rise in sea level, orange indicates land inundated by a 10-foot rise, and yellow indicates land inundated by a 20-foot rise in sea level. Images from “Sea Level Rise Impacting Maine’s Island Communities” Island Institute: March 2007.

"An old timer always used to say that the best place to catch lobsters was around no one else—and it only makes sense."

JOSH CONOVER
ISLESBORO

LOCAL KNOWLEDGE

A key objective of our work is to identify trends observed by fishermen over the past few years; trends that might be related to increases in temperature and other climate factors. Maine's lobster fishery provides a rich context for examining the perceptions of fishermen regarding climate change. Established over 100 years ago, the fishery has been dominated by the passage of entry rights, local knowledge, and a concern for sustainability in the fishery from one generation to the next. As a result, the local knowledge of fishermen passed from one generation to the next has built a collective understanding of the fishery as one that follows natural cycles.

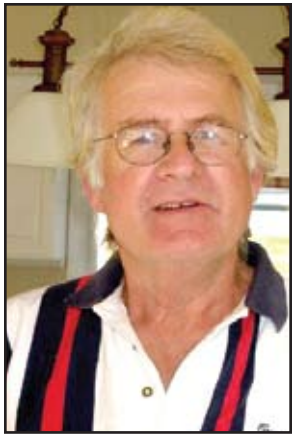
Fishermen are keen observers of trends in the fishery and have historically adjusted their behavior to make it through the downtimes. At the same time, fishermen have devised rules to restrain overharvesting of the lobster population so that it may provide a livelihood for their descendants. The history of the fishery is one of continual adjustment of fishing behavior. The establishment of informal fishing territories that restricted access to the fishery was followed by use of the so-called "double gauge", which limits the harvest to lobsters within a narrow size range, protecting juveniles and oversized, reproductive lobsters. The fishery was limited to owner-operators to ensure that knowledge of the rules stayed with the boat and dragging for lobsters was banned. The V-notching of egg-bearing or "berried" females, to protect those animals known to be breeders, and a requirement for escape vents on traps, and the protection of small lobsters came later. Most recently, the establishment of seven zones along the coast has enabled trap limits, suited to the local ecology of each zone, to be applied by zone councils. While each new rule benefited some fishermen at the expense of others, the overall effect has been to sustain the fishery.

A bust occurred in the fishery in the 1920s, when landings dropped significantly for several years. Contemporary fishermen are well aware of the event;

they ascribe it to natural cycles in the fishery, among other causes. Some fishermen, including Walter Day of Vinalhaven, wonder whether changes in climate contributed to the decline. Although the reasons for the bust are not clear, it appears to have contributed to an incentive to conserve: fishermen do not take lobster abundance for granted.

Without stock assessments or limits on landings, the fishery sustained a harvest of roughly 20,000,000 pounds annually from the 1930s until the late 1980s. At that point, landings began to climb, only recently reaching an apparent peak of over 70,000,000 pounds. The causes of this tremendous increase are the subject of ongoing debate. Scientists do agree that a convergence of a variety of factors most likely explains the increase (Acheson 2003). The elimination of nearshore stocks of groundfish removed a major predator of the lobster. The over-harvesting of urchins allowed kelp forests, a favorite nursery habitat for juvenile lobsters, to flourish. Water temperatures increased, promoting lobster growth and development. Fishing effort increased dramatically during this time, as huge landings convinced many part-timers to join the fishery full-time. Fishermen added many more traps, switching from wood to wire construction, which can be fished longer and harder. Boats and engines got bigger, allowing more area to be fished, particularly areas vacated by groundfishermen. Certainly, the efforts of the fishermen to sustain their fishery have also contributed to the increase in landings. As Dan Morris of Port Clyde noted regarding the number of legal-sized lobsters he finds in his traps, "You will come up with a trap that will look like it has eight or ten counters in it and you'll end up taking one." Currently, the fishery is characterized by declining landings and excess effort.

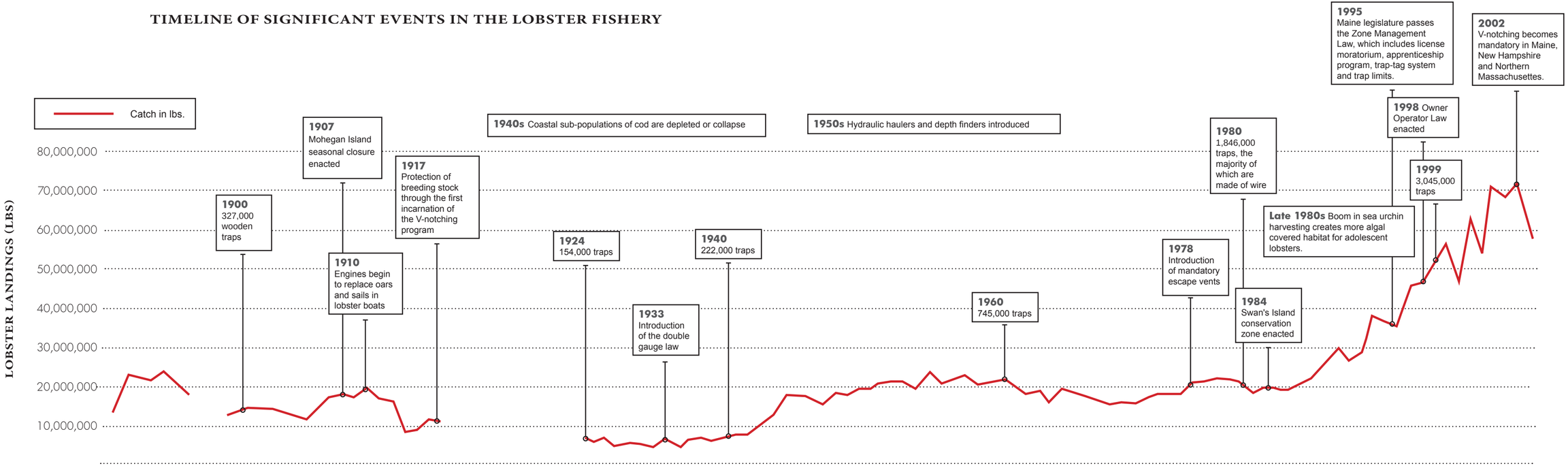
[Fig. 7 on page 20-21 and Fig. 8 on page 23 provide additional information on lobster-fishery events and trends.]



"The catch may not have gone down but my share of it sure has."

TOM MACVANE
LONG ISLAND

TIMELINE OF SIGNIFICANT EVENTS IN THE LOBSTER FISHERY



[Fig. 7] Timeline of significant events in the lobster fishery. *Sources: Acheson 2003.; Ames 2004.; Maine Department of Marine Resources*

"I liked [the roundtable discussion;] I learned a few things and I liked hearing how things are different yet the same for all of us."

JIM WOTTON
FRIENDSHIP

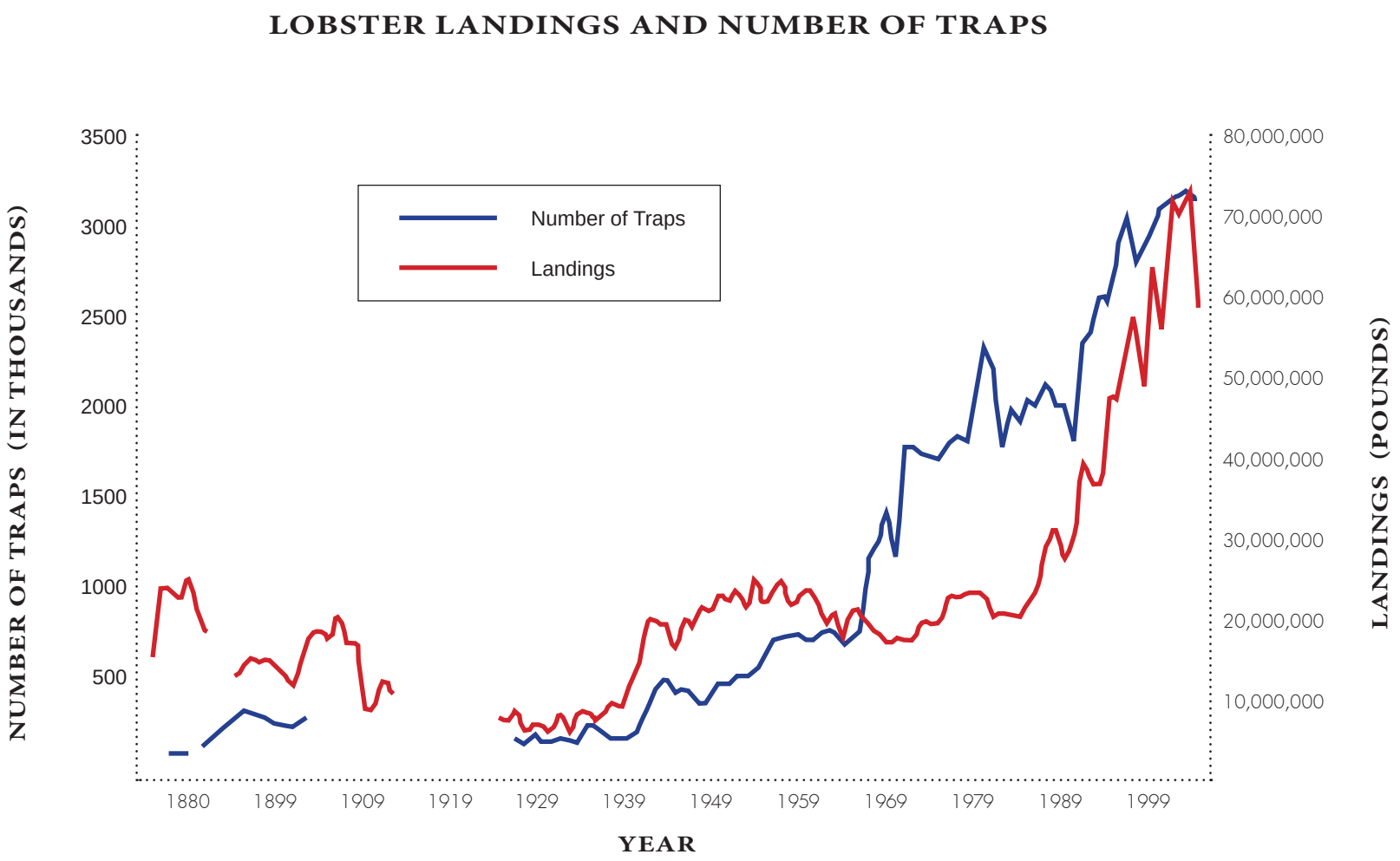
CAPTURING LOCAL KNOWLEDGE

We have employed a variety of methods to capture the observations of fishermen. Trained facilitators convened roundtable discussions in February of 2007 and 2008. A dozen or so fishermen volunteered to participate in each roundtable. Facilitators designed the meetings to give fishermen the opportunity to respond to a series of questions, to ask their own questions, and to compare notes with other fishermen. Fishermen expressed their thoughts regarding the seasonal cycle of the fishery: when do the lobsters start crawling in the spring, when does the shed occur, when do landings peak and when does the fishery dry up in the fall? Has this cycle changed from any historical norm? Have they observed any unusual creatures in their traps? Have storms affected fishing? Do they have any observations regarding sea-level rise?

Information from the roundtables was synthesized and presented at the Maine Fishermen's Forum in 2007 and 2008 and additional input was solicited from fishermen. As a follow-up to comments made by Walter Day of Vinalhaven, who compared current conditions to those of the 1950s, we also conducted an in-depth interview with Walter in order to capture his perspective, based on over five decades of fishing.

During the 2007 fishing year, Institute staff surveyed additional fishermen by telephone regarding the impact of the Patriots' Day storm as well as northeasters that hit the region later in early fall.

In 2008, we developed a survey to expand the reach of the project, distributed it at the Fishermen's Forum and the Canadian-American Lobster Town Meeting, held in Portland, Maine in March, and then mailed it to all 5,677 commercial license holders in July 2008. We expect to have preliminary findings in the winter of 2008.



[Fig. 8] Maine lobster landings and number of traps 1880 to 2007. Data from the Maine Department of Marine Resources. Dealer reporting became mandatory in 2004. 2007 data is preliminary.

FINDINGS

The findings of the project to date provide insights into the current and potential effects of climate change on the lobster fishery. Perhaps just as importantly, the project has shed light on how the fishery functions — and how it has evolved to be highly adaptive.

Information provided by fishermen is complementary to data collected by scientists. Fishermen and scientists collect data on water temperature and other oceanographic features at different scales. As reported by our panel of marine experts, scientists tend to work at a large spatial scale; fishermen are more concerned with the much smaller area in which they fish. Since the 1970s, National Oceanographic Atmospheric Administrative (NOAA) buoys have been collecting temperature data from several points in the Gulf. Oceanographic surveys have also contributed to the historical temperature record. The Gulf of Maine Ocean Observing System (GoMOOS) was implemented in 2001, augmenting the NOAA buoys with an array of sophisticated sensors deployed throughout the Gulf.

Prior to the 1970s, however, limited long-term data is available. Researchers have measured surface-water temperature for over 100 years at Boothbay Harbor, and they have measured temperatures at the surface and at depth off of Grand Manan for over 80 years. Fishermen, on the other hand, have information on water temperature that describes the dynamics of a bay or cove in great detail. In some cases, it also stretches back several decades.

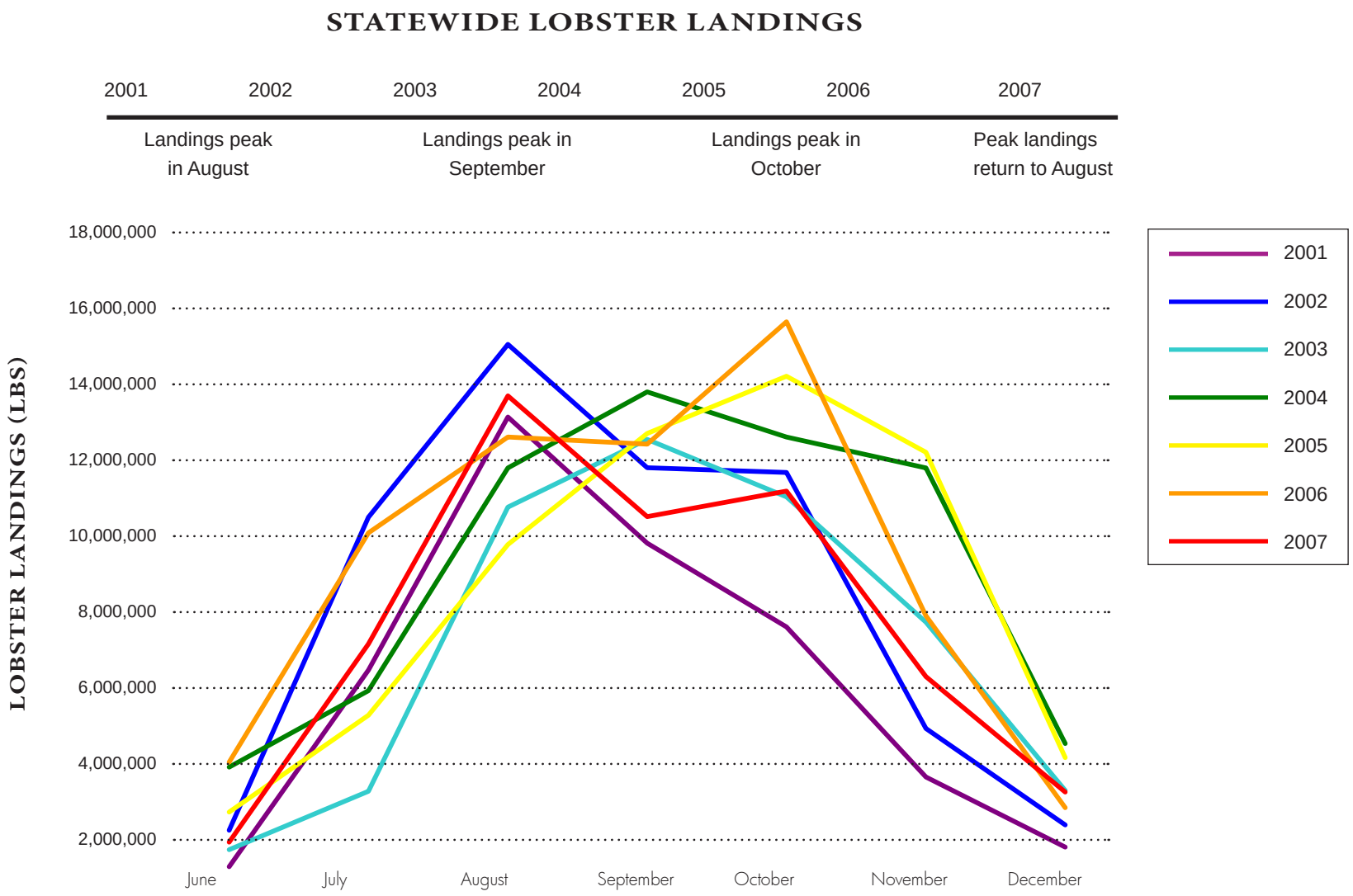
Patterns in the fishery are changing. Fishermen from Schoodic Point west, who shift their gear during the season to follow the seasonal migration of the lobsters, are shifting gear to deeper water earlier in the season than they used to. "The places I fish in August are the places we used to fish in October — and now everyone is starting to do it," said Jim Wotton of Friendship. Whether this phenomenon is related to changing oceanographic factors — or

"The shed just started so early. A lot of the gear went into the bay without the buoys being painted."

ELLIOT THOMAS
YARMOUTH

to the fact that inshore populations are being fished down by all the gear in the water — is unclear. Other causes could also be at work that complicate analysis of patterns in the seasonal movement of gear. For example, the cost of fuel may influence some fishermen to delay moving their traps offshore. On the other hand, fishermen from areas popular with recreational boaters often like to move their gear offshore to avoid congestion and the likely loss of traps due to entanglement in propellers.

Fishermen also agree that the pattern of molting by lobsters, known as "the shed", is changing. Lobsters molt as they grow, shedding a shell that is too small in order to grow a larger one. The rate of molting depends on the age and growth rate of the lobster but the majority of legal-sized lobsters molt once or twice during the warmer months of the year. Lobsters with new shells appear in lobstermen's traps in a wave, or series of waves, each summer. Until a few years ago, the timing of sheds was very predictable. While following a different schedule in different parts of the coast, the arrival of shedders was something that fishermen could count on. In the past six-to-eight years, however, the timing of sheds has become much more variable, with an apparent shift earlier in the season. Jim Wotton of Friendship remarked that he thinks the warmer temperatures are "making them shed a little earlier than usual." He, like some fishermen, tracks water temperature carefully when planning his fishing. "I've got temperature on my fathometer. I like to see 58 degrees when I start up the river. When I get 56, 57, 58 degrees, it's time to start setting shedder pots." Sometimes, the shed seems to occur hardly at all; at other times, it stretches over several weeks rather than coming in what the fishermen call a "spurt". Landings data [Fig. 8], which reflect increased feeding activity of post-shed lobsters, demonstrate changes in the nature of sheds. Distinct peaks in the shed occurred in most years; in 2003 and 2004, the shed took the form of a large plateau.



[Fig. 8] Lobster landings by month for years 2001 through 2007. Until 2007, the peak in landings shifted later in the year. (Source: Maine Department of Marine Resource)

"You've always got to think about storms and hurricanes when you start fishing around the shore."

BRUCE FERNALD
ISLESFORD

Fishermen also noted that the point of highest landings along the coast has been gradually shifting to the east over the past few years. Sonny Sprague of Swan's Island attributes the shift to warming temperatures: "I do believe global warming is happening because this year Hancock County supposedly was the top dog in lobsters and the top dog most of the time has been Spruce Head and Vinalhaven. Now it's shifted a little bit eastwards. Before long they're going to be by us; they'll be in Nova Scotia." The shift eastward follows a similar shift, several years earlier, in the settlement of larval lobsters. If climate change is behind the shift in landings, then its effect is most likely on the larval rather than the adult stage of the lobster (Wahle 2007).

Storms affect lobsters — and fishermen. Fishermen are keenly aware of heavy weather. For one thing, they can't fish when it's blowing too hard. But storms can also damage or destroy gear; it can get dragged and tangled. Fishermen also note the effect of storms on the lobsters. Spring storms that dump a lot of fresh water into the ocean can stop the movement of lobsters and, therefore, the ability to harvest them, for several days. These severe weather disturbances also pose a risk for fishermen trying to catch "groundkeepers", the hard-shell lobsters that have overwintered in shallow water. Gear set in shallow water on hard bottom is most at risk of storm damage.

Fall storms are another story. They are generally seen as a good thing: catches tend to rise after a storm — unless it's a big one. The mixing of the water from top to bottom that occurs during a big storm tends to cause the lobsters to stop crawling into traps — and marks the end of the inshore fishing season.

Many factors, besides climate change, affect landings. As mentioned previously, many environmental factors affect lobsters. Conservation measures have also most likely had a major impact on landings. Fishermen from York to Washington counties reported large numbers of juveniles, V-notched females, and

ANDREW PERSHING, PH.D.

Andy Pershing, an oceanographer at Gulf of Maine Research Institute, uses computer models to explore the potential effects of climate change on the Gulf of Maine. He and other scientists are in the early stages of determining what precise changes will result in the Gulf from warming water, increased ice melt, and more intense storms. Because of the limits in predicting marine response to warming conditions, Pershing says that "climate change is a form of uncertainty that must be factored in the lobster industry". Andy notes that there has been a shift in climate research away from the possible range of global temperature increases and towards thinking about local and regional-scale impacts. Pershing sees a positive shift towards ecosystem-based research, but warns that "our management structures do not incorporate ecosystem climate changes yet."

WALTER DAY, VINALHAVEN

Walter remembers fishing in the 1950s, when his mother would take him out to haul his ten traps; he brought his catch back in a peach basket and sold shedders for 35 cents. He notes that the bulk of the landings came later in the year — just as it does now. According to Walter, "the fishermen are always blamed" — unfairly — for the bust of the 1920s. He says that the decline was part of a natural cycle but wonders if a change in climate might have played a role. Walter has noticed other changes in the fishery. Beginning in the late 1980s, lobsters could be caught on mud as well as hard bottom, expanding the availability of productive fishing area. More recently, Walter has seen the fishing improve in deeper waters. Now, "it's not worth the aggravation" to fish in shoal water thick with gear. Walter has temperature probes in two traps and watches bottom temperature closely by checking the GoMOOS website.

over-sized lobsters — all illegal to harvest — in their traps. As Peter Eaton of Kennebunkport said, "the V-notch is what's kept us going. The V-notch is one of the best laws we've got, I don't care what anyone says." External factors, such as the advent of refrigeration in the 1920s, the development of international markets at the end of the 20th century, and the difficulties that fishermen face — due to increased regulations — in switching fisheries have also had an impact. Dramatic rises in the cost of bait and fuel — and concerns about the availability of bait — appear to be having an effect on lobstermen. They are changing their practices to keep their expenses low. Such efforts include running at a lower speed, hauling less often, waiting until later in the spring to put traps in the water, planning routes to shorten fishing trips, and reusing bait.

V-notched, egg-bearing female lobster.

REACTIONS TO CLIMATE CHANGE

Concerns regarding climate change include fears for future generations of lobstermen rather than impacts on this generation. Fishermen have questions regarding an increase in invasive species, the possibility of freshwater runoff shutting off the fishing, and the trend in peak landings moving into Canada. For the most part, however, fishermen see the effects of climate change as just another thing they'll have to deal with; they are confident that they can adapt, just as they have adapted to trap limits, gauge increases, bait shortages, seal predation, etc. This view comes from the fact that fishermen have always had to be adaptive; under the best of circumstances, when landings were growing and the shed occurred at the same time every year, lobsters have been unpredictable. As Dan Morris of Port Clyde put it, "if we never took a lobster by a lobster trap, the population of lobsters would probably go up and down."

"We've been catching lobsters in June - which is wrong."

TOM MARR, LONG ISLAND, CASCO BAY

A traditional approach to fishing is to find a place to fish where no one else is fishing. This practice has a two-part logic. First, it allows fishermen to test the bottom for the presence or absence of lobsters. Second, if lobsters are found, the fisherman doesn't have to share them with others. East of Schoodic, strong currents and tides make it impractical for fishermen to move their gear. To the west, however, they are continually moving traps, testing the bottom for lobsters. Gerry Cushman, of Port Clyde, said, "There isn't a day that I go fishing that I don't move 40 or 50 traps." As much as it is a given that lobsters move inshore and off with the seasons, it is unclear exactly where to find them at any given time. Even


MISS WHITNEY

during the times when, according to John Drouin of Cutler, you "could set your clock" by the timing of the shed, fishermen still did not know exactly where the lobsters would be. Adaptive by nature, fishermen plan to adjust to climate impacts by working harder. During the boom years of the 1990s, it was easier to catch lobsters when, as Jim Alwin of Biddeford Pool said, "you could do no wrong. Now we need to go back to fishing and not just trap-hauling."

Fishermen were unconcerned regarding the prospect of sea-level rise; in fact, they see it as potentially increasing the amount of fishable bottom along the coast. Josh Conover of Islesboro identified another potential benefit: sea-level rise "is going to turn Islesboro into two islands…we'll save on fuel, because we won't have to go all the way around." Another speculated about the effect of sea-level rise on the tides.

"We'll roll with the climate changes."

JOHN DROUIN, CUTLER

The process itself was useful to fishermen and scientists. Fishermen who have participated in our project are very enthusiastic about the opportunity to work with other fishermen in making sense of what they see on the water day in and day out, year after year. As Jim Wotton of Friendship commented, "I liked it; I learned a few things and I like hearing how things are different yet the same for all of us." While the fishery is comprised of individuals owning their own boats and working their gear on their own or with a sternman, the fishermen trade information regularly. By these means, they keep track of trends in landings along the coast, follow ups and downs in the market, and learn about innovations such as alternative bait or fuel-saving techniques. The roundtable discussions were particularly beneficial, according

to fishermen who participated, because they were able to trade information with fishermen from other areas of the coast. Compliance with V-notch regulations, dynamics of the shed, strategies for getting the most out of gear and keeping costs down, tactics for finding hot spots, and relative numbers of juveniles, V-notched, berried and oversized lobsters were common themes among roundtable participants.

Scientists also appreciated the opportunity to learn about the information that fishermen collect. They were quick to identify ways in which this information complemented their own knowledge. They also made suggestions for structuring input from fishermen so that it could be more easily linked with more traditional forms of scientific data. In particular, the panel recommended that, in addition to participating in roundtable discussions, fishermen be surveyed to collect quantitative as well as qualitative information regarding their observations on the dynamics of the marine environment.

Fishermen have important information regarding fine-scale changes in their environment and in lobster population dynamics. This information can be linked with larger-scale climate data and forecasts of scientists to provide a much fuller picture of the potential impacts of climate change on lobsters and the Gulf of Maine ecosystem.

Our goal in launching this project was to take the first step in developing real-world recommendations for the lobster fishery and for all of the coastal and island communities that depend on it for their continued survival.

Our hope is that, with this initial research and the work to follow, we will not only create a model for adapting to climate change along Maine's coast but also one that proves useful for natural resource based communities around the world.

"Why are we catching shedders in March, April, May and June?"

GERRY CUSHMAN
PORT CLYDE

REFERENCES

Acheson, J.M. 2003. *Capturing the Commons: Devising Institutions to Manage the* Maine Lobster Industry. University of New England Press. Hanover, NH.

Ames, E. 2004. Atlantic cod stock structure in the Gulf of Maine. Fisheries, 29(1): 10-29.

Conkling, P. and Hayden A. 2002. Lobsters Great & Small. Island Institute. Rockland, ME.

Fogarty, M., L. Incze, R. Wahle, D. Mountain, A. Robinson, A. Pershing, K. Hayhoe, A. Richards, and J. Manning. 2007. Potential climate change impacts on marine resources of the Northeastern United States. Northeast Climate Impacts Assessment (NECIA). Cambridge, MA; Union of Concerned Scientists. http://www.northeastclimateimpacts.org/pdf/miti/fogarty_et_al.pdf.

Frumhoff, P.C., J.J. McCarthy, J.M. Melillo, S.C. Moser, and D.J. Wuebbles. 2007. Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Synthesis Report of the Northeast Climate Impacts Assessment (NECIA). Cambridge, MA; Union of Concerned Scientists. http://www.northeastclimateimpacts.org.

Glenn, R.P. and T.L. Pugh. 2006. Epizootic shell disease in American Lobster (Homerus americanus) in Massachusetts coastal waters: Interactions of temperature, maturity, and intermolt duraction. Journal of Crustacean Biology, 26(4): 639–645.

Goddard Institute for Space Studies (GISS). 2007. GISS Surface Temperature Analysis. Global Temperature Trends: 2007 Summation. http://data.giss.nasa.gov/gistemp/2007/

Howell, P., J. Benway, C. Giannini, K. McKown, R. Burgess, J. Hayden. 2005. Long-term population trends in American lobster (Homarus americanus) and their relation to temperature in Long Island Sound. Journal Of Shellfish Research, 24(3): 849-857

IPCC. 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, 104 pp. http://www.ipcc.ch/ipccreports/ar4-syr.htm.

Maine Department of Marine Resources http://www.maine.gov/dmr/index.htm

Steneck, R. 2008. Climate Change and the Gulf of Maine's Marine Ecosystem. In prep.

Wahle, R. 2007. New England Lobster Settlement Index. Bigelow Laboratory for Ocean Sciences. Boothbay Harbor, ME. http://www.bigelow.org/docs/wahle_crab_lobster/ne_lobster_update2007.pdf

ADDITIONAL READING ON CLIMATE CHANGE IN THE GULF OF MAINE

Wake, C., L. Burokowski, G. Lines, K. McKenzie, and T. Huntington. Undated. Cross Border Indicators of Climate Change over the Past Century: Northeastern United States and Canadian Maritime Region. Gulf of Maine Council.

http://www.gulfofmaine.org/council/publications/cross-border-indicators-of-climate-change.pdf.

Edgecomb, M. 2006. Our changing world: understanding the science of climate change. *Bangor Daily News*. Thursday, January 12, 2006.

http://www.climatechange.umaine.edu/Research/news/whatisclimchange.html.

ISLAND INSTITUTE

386 Main Street • Rockland, Maine 04841

www.islandinstitute.org (207) 594-9209