HOT TOPICS IN MARINE BIOLOGY 2.1

Warming of Marginal Seas and Estuaries: Has It Occurred and What Does It Mean?

We have discussed a century-long global trend of increasing surface temperatures. Some of the larger-scale changes are very striking, including very rapid warming of the Arctic Ocean and a general increase of temperature in the western Pacific relative to the eastern Pacific. But these changes are operating also in marginal seas and within bays and estuaries.

Let's examine some coastal regions. Box Figure 2.1a shows temperature change on the southern coast of Vancouver Island, British Columbia, Canada, in the northwest Pacific, and Box Figure 2.1b shows Woods Hole on Cape Cod, Massachusetts, in the northeast Atlantic. Temperature was stable for a few decades in the early twentieth century but has rapidly increased at both locations over the past few decades. There are many reasons that temperature might change in a nonlinear trend in a given region, so we can only speculate as to whether these changes are local or part of a worldwide trend. We can at least conclude that the increase may be hemisphere-wide because the same temperature increases in the northeastern Pacific have occurred on the eastern side of the North Atlantic. In the North Sea, temperatures have increased an average of 0.6°C between 1962 and 2001.* In the Baltic Sea, which has very low salinity, there is a record of irregular but ever-increasing sea-surface temperature from 1,860 to 2,007† (Box Figure 2.1c). So we have now documented a trend for inshore waters of the western and eastern North Atlantic oceans. What will this mean?

There is no global answer to what the warming trend will bring to any specific coastal water body, but we can list a series of effects that are already known, likely to occur, or can be speculated to occur.

1. Temperature change may bring some species beyond their ability to function because all marine species have an upper temperature limit beyond which they will not grow, reproduce, or perhaps even survive.
2. Temperature increase may cause the geographic ranges of mobile species to shift to higher latitudes to stay within their optimal range of temperature. Different species might therefore move northward to different degrees. This might result in different combinations of species and therefore different sets of interactions between predators and prey and between species that compete for the same resources of food and habitat. What if a breeding oceanic bird must nest on an island, but its food supply such as a fish species moves northward and out of flight range, because of local warming?
3. Increased temperature might change local climate and therefore affect other factors such as rainfall. The rainfall might change the amount of water flow in estuaries and might change salt content of inshore bodies of water.
4. Increased temperature might cause local extinction but also might allow the immigration of species from other areas that are tolerant of higher temperatures.

We are only beginning to understand the implications of climate change, but temperature increases in the North Sea have already caused modest northward shifts in the distribution of cod, which is a very important fishery species. Perry and colleagues conclude that, with further warming, some abundant species may shift northward, which would greatly impact North Sea fisheries. In a place such as the Hudson River, estuarine species such as the tomcod, *Microgadus tomcod*, are trapped at the southern end of their geographic range. If temperature increased, then local extinctions might be expected. Though never proven, mass mortality of a large western Long Island Sound population of the American lobster, *Homarus americanus*, may have been caused by high temperature.‡ Like the tomcod, western Long Island Sound lobsters are in the warmest waters of their range. Temperature increase also may bring on an increase of oyster disease in New York waters. Keser and colleagues documented a rapid increase of temperature in Long Island Sound and predicted that a very common and ecologically important seaweed may disappear in a few decades. On the other hand, warming might bring more southerly species such as blue crabs, *Callinectes sapidus*, into the Hudson. These crabs have been on the rise in this estuary in the past few years. Higher temperatures and higher salinity may also bring saltier water further up the Hudson estuary, creating more oyster habitat.

In the Baltic Sea, a predicted indirect outcome of regional temperature increase is an increase in precipitation. The Baltic Sea already has low salt content because of the large amount of freshwater input from coastal drainage and rivers in Scandinavia and northern Europe. MacKenzie and others report that the salinity will decline further. While this may increase the abundance of certain freshwater fish species, it will probably cause the local extinction of fish such as cod, herring, and plaice, which will exert major economic stress on the large regional fishing fleets.

Most interesting and alarming is the role of temperature as an influence on the success of invasive species. We discuss invasive species in Chapter 17, but increased temperature might enhance opportunities for warm-adapted species to invade warming coastal waters and estuaries. Because of the ability of many species to hitchhike on oceangoing ships in ballast water, the arrival of invasives is frequent. But warming has allowed a number of colonial sea squirts to invade Long Island Sound rocks and displace native species.§ Two important species of invaders arrive and spread more frequently when temperatures are warmer than average. By means of controlled experiments, Stachowicz and colleagues‖ demonstrated that the native sea squirt species tended to win in competition with the invaders but lost when temperature was elevated.

The examples given show that a general regional trend, oceanic warming, may have a variety of major ecological effects on inshore waters and estuaries, but it will not always be predictable which effects matter the most. Thus, although there is a predictability to the overall climate change, the biological factors must be studied carefully and individually in different local water bodies.

*See Perry and others, 2005, in Further Reading.
†See MacKenzie and others, 2007, in Further Reading.
‡See Wilson and Swanson, 2005, in Further Reading.
§See Stachowicz and others, 2002, in Further Reading.
‖See Stachowicz and others, 2002, in Further Reading.

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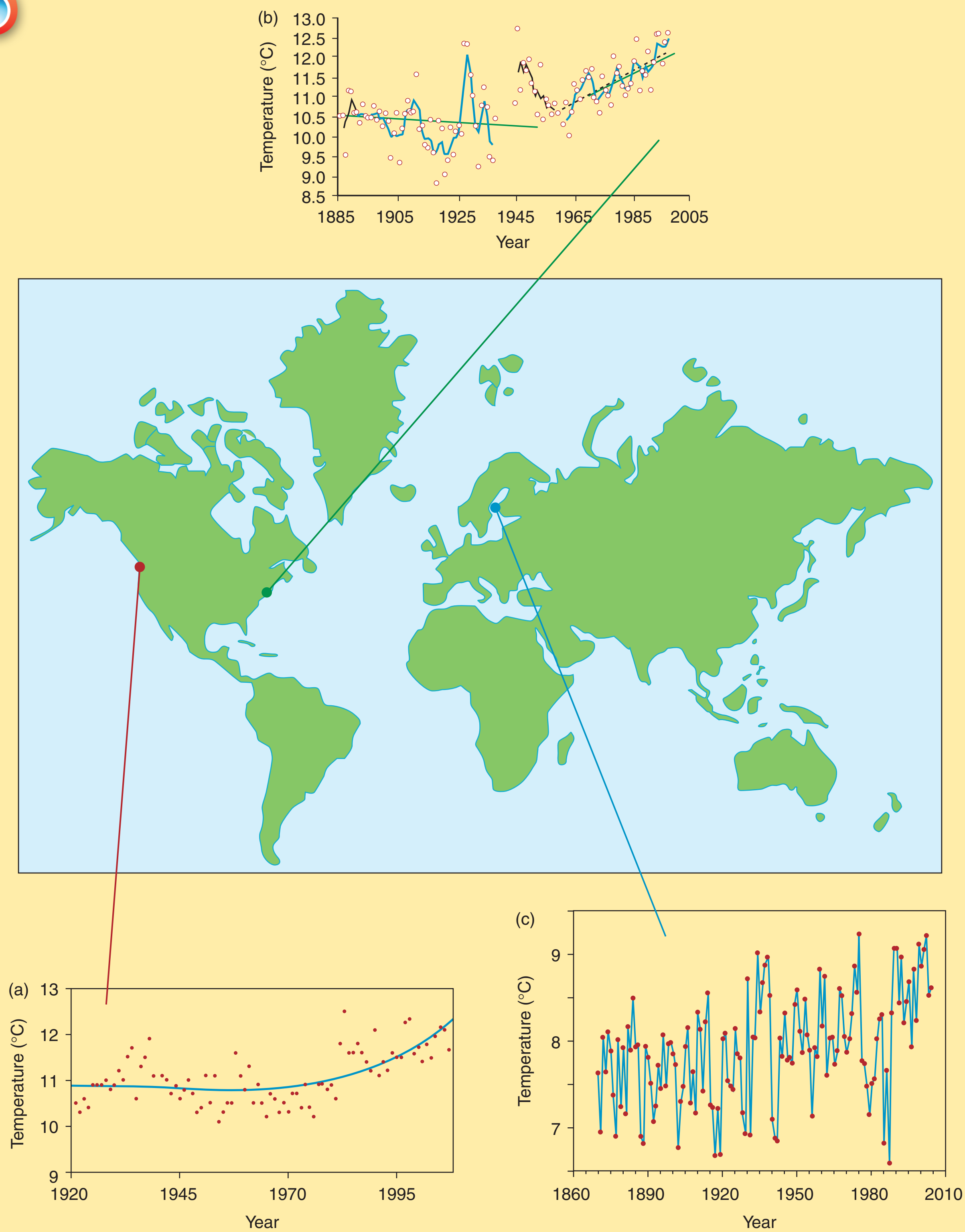

BOX FIGURE 2.1 Changes in sea-surface temperature at three nearshore localities: (a) Race Rocks, NE Pacific, on the southern tip of Vancouver Island, British Columbia, Canada (data from www.racerocks.com). (b) Sea-surface temperatures at Woods Hole, Cape Cod, Massachusetts, NW Atlantic (from Nixon et al., 2004). (c) Sea-surface temperatures in the Baltic Sea, northern Europe, measured from ships since the 1860s (after MacKenzie et al., 2007).