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# Hands-on Materials for Teaching about Global Climate Change through Graph Interpretation

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## Abstract

Teachers need to address global climate change with students in their classrooms as evidence for consequences from these environmental changes mounts. One way to approach global climate change is through examination of authentic data. Mathematics and science may be integrated by interpreting graphs from the professional literature. This study examined the types of errors 72 preservice elementary teachers made in producing hands-on materials for teaching graph interpretation skills through graphed evidence of global climate change from the literature. The teaching materials consisted of a graph electronically manipulated on a colored background and enhanced with clip art related to the graph's topic that was then printed and mounted on colored cardboard. The graph was accompanied by six graph interpretation statements printed on cards that were to be sorted as true or false. Additionally, a topic-related object was provided for each graph for an initial activity that focused student attention and aroused interest. Four graphs with their accompanying statements and four related objects were combined into one box of materials to be used by a small group of students.

Preservice teachers practiced with example sets of materials made by the course instructor and then worked to each create a new, unique set. An appendix of many sets of correct materials is provided in this ERIC document. About half of the teaching materials produced were error-free. The most common errors preservice teachers made were misuse of vocabulary and over generalizing a graph's information. Other frequent errors included not supplying enough specific information in a statement to allow its verification and misinterpreting a major trend on a graph. These problems can be attributed to preservice teachers' lack of sufficient experience in graph interpretation. Therefore, the authors conclude that the materials-making exercise was beneficial to preservice teachers and the resulting materials (with any errors corrected) can effectively be used with upper elementary and secondary students. [1 Table, 1 Appendix containing 18 graphs accompanied by interpretation statements.]

## Introduction

The American Geophysical Union (2007) in their recent position statement has documented that the Earth's climate is clearly warming. To bring life to this global climate change situation in the classroom, our teachers must have a solid understanding of the magnitude of the problem and be prepared to deliver engaging instruction concerning these concepts. While some materials are currently available to help students understand the significance of global warming, school budgets are often stretched to their limits and teachers will need to develop their own materials for classroom use.

This project was undertaken to raise preservice teachers' awareness of global warming through the examination of scientific literature, and to help them develop research and technology skills needed to prepare appropriate teaching materials. The materials developed by preservice teachers in this study were graph interpretation object boxes. These boxes were chosen

because they can be used to meet middle school national mathematics and sciences standards for graph reading skills and standards for authentic learning activities set in real world contexts (ISTI, 2005; NCTM, 2000; NSTA, 1998).

## Method

*Participants*

The study participants consisted of seventy-two (61F, 11M; 69W, 1B, 1H, 1A) preservice elementary teachers who were of predominantly middle-class European heritage and who were enrolled in three sections of a mathematics methods course at a mid-sized college in central New York State.

*Design*

Preservice teachers practiced with several sets of global warming graph interpretation materials made by the first author. Then they participated in a class session held at the college library co-led by a librarian to learn how to find scientific or other scholarly works that contained graphed evidence concerning global warming. They worked independently to each create a set of materials. Every set of materials consisted of: 1) a graph related to global warming set on a colored background and enhanced with clipart; 2) an object (toy, handmade model, or other small item) related to the theme of the graph; 3) two heading cards for sorting statements that were labeled "true statements" and "false statements;" and 4) six graph statements that represented three correct interpretations of the graph and three incorrect interpretations. The graph, heading cards, and graph interpretation statements were printed in color and mounted on mat board (the colored cardboard used in matting and framing pictures) for attractiveness, durability, and ease of handling.

When the sets of materials were complete, each small group of four preservice teachers combined their four sets of materials into a plastic shoebox to make an "object box." They exchanged materials with other small groups of preservice teachers during class and tried out each other's teaching materials. Then the instructor collected and graded the materials. This document reports the most common errors that preservice teachers made in making materials, to help others prepare students to avoid these mistakes. More importantly, this documents presents (in Appendix A) corrected teaching materials that may be used in integrated mathematics-science lessons to teach concepts of global climate change through graph analysis.

## Using the Teaching Materials

Four sets of materials – four objects, 4 graphs, four pairs of heading cards, and four sets of six graph interpretation statements (three correct or "true" and three incorrect or "false") should be combined into a plastic shoebox to make a global warming graph interpretation object box. The four objects should be placed on top of the other materials so that they are readily accessible. This lesson forms a Learning Cycle of three phases (exploration, explanation, and expansion, along with evaluation) that address constructivist learning strategies (Atkin and Karplus, 1962; Karplus and Lawson, 1974). This Learning Cycle lesson format is a widely used teaching model based on Constructivist Learning Theory, which holds that that learning is not the result of passively listening to a teacher, but results from interacting with objects to construct knowledge. This activity provides knowledge of those objects (Sigel and Cocking, 1977). National science teaching organizations such as the American Association for the Advancement of Science (1993), the National Research Council (1996) and the National Council of Mathematics Teachers (2000) recognize Constructivist teaching methods as best practice.

*Exploration Phase of the Lesson*

The group of four students begins by removing the four objects from the box without peeking at the graphs. They hypothesize what each of these four objects has to do with global climate change. This phase of the lesson activates prior knowledge and focuses student attention on the lesson. The teacher finds out what students already know about the lesson topics as students report their ideas to the class. Students may experience disequilibrium as they consider possible connections between objects (toy animals, silk plants, home-made models) and global climate change. This uncomfortable feeling of being unsure of how it all fits together motivates students to learn.

*Explanation Phase of the Lesson*

This phase of the lesson leads students to discover new understandings and explanations of the topic. After students have considered the objects and reported their possible ideas to the class, they remove the other items from the object box. Each student places one of the graphs before him/her. The student examines the graph and tells the group members the main idea of the graph, identifying the object to which the graph is connected. At

this point, students will reach equilibrium concerning the relationships of the objects to global warming.

Next, each student takes two of the heading cards ("true statements," "false statements") and places them below the graph that he/she has. Heading cards in the sets presented here are color-coded to the graph backgrounds, but matching the heading cards to the graphs is not really necessary. Then students in the group read the graph interpretation statements and attempt to sort them to the graphs to which they pertain, making inferences from clues in the wording of statements. For example, a statement may mention the fact that there are two graphs together on the graph card or may name the animal on which a graph focuses, thereby identifying the corresponding graph. After all statements have been sorted, students take turns reading a graph statement and determining if this is a true or false interpretation of the graph. One or more other group members may give their ideas about the correctness or incorrectness of the statement and the evidence for this assertion, thereby helping others attain graph interpretation skills. This group work corresponds to Vygotsky's (1989) social learning theory and the concept of the Zone of Proximal Development, which states that learners can learn more from working with knowledgeable peers than they can learn independently.

The teacher may decide to mark the backs of the graph interpretation statements with the name of the graph to which each corresponds with "true" or "false" so that students can self-check their work. This is particularly useful when students are expected to work independently with the materials. Alternatively, the teacher might print out the entire pages of graphs as shown here and use these as answer keys because the graph interpretation statements have been sorted under the correct headings in Appendix A. This would allow the teacher to present the answers after students had struggled with the graph interpretations for an optimal amount of time.

*Expansion Phase of the Lesson*

In the expansion phase, students practice their new learning in a different way, thereby creating more memory connections for their freshly acquired understandings. There are several ways the teacher may accomplish this. In our college lessons with preservice teachers reported here, we asked them to create their own sets of materials. This can also be done in elementary or middle school classes, especially if the teacher provides the graphs and students work on finding appropriate

objects (or pictures of objects) and true/false interpretations of these graphs.

A teacher may also have students practice their new graphing interpretation knowledge by focusing on mathematics exercises involving graph generation or interpretation. Alternatively, students may focus more on the science of global climate change and reinforce their learning with science readings or activities.

After students have practiced, their new learning should be evaluated with a test or a graded project.

## Results and Conclusion

In general, the preservice elementary teachers in our study were able to produce effective global warming graph interpretation materials. Thirty-five of the seventy-two sets of materials were error-free. Table 1 presents the types of errors preservice teachers made. The most common type of error preservice teachers made was misuse of vocabulary. Words such as "frequency," "endangered," "fluctuation," "negative correlation," and "baseline" were incorrectly used, probably because of preservice teachers' lack of familiarity with the definitions of these terms. The second most common error was over-generalizing information followed by not including enough specific information in a graph interpretation statement to allow it to be verified, and incorrectly interpreting major trends.

Table 1. Types of errors made by preservice teachers in creating global warming graph interpretation materials

| Type of Error | Frequency |
|---|---|
| Misuse of vocabulary | 13 |
| Over-generalizing information presented on the graph | 13 |
| Not including enough specifics in a statement to allow its verification | 10 |
| Incorrect interpretation of a major trend | 6 |
| Not labeling units on the graph or in a statement | 4 |
| Not explaining the main point of the graph | 3 |
| Choosing a graph not related to global warming | 3 |
| Misinterpreting a data point | 2 |
| Repeating the same idea in slightly different ways on statements | 1 |
| Total Errors | 55 |

All of these problems can be attributed to preservice teachers' lack of experience in graph interpretation. The remaining errors of not labeling units, not explaining the main point of the graph, choosing an

inappropriate graph, misinterpreting a data point and repeating ideas in statements are probably more closely tied to carelessness.

These findings indicate that preservice teachers might benefit from more practice, particularly in finding errors and interpreting major trends. Instructors should spend time explaining vocabulary and thinking out loud about their reasoning in graph interpretation.

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**Appendix A**

Figure 1. Effects of climate change on the Emperor Penguin population [Materials designed by Nichole McDonald].



## Emperor Penguins and Climate Change
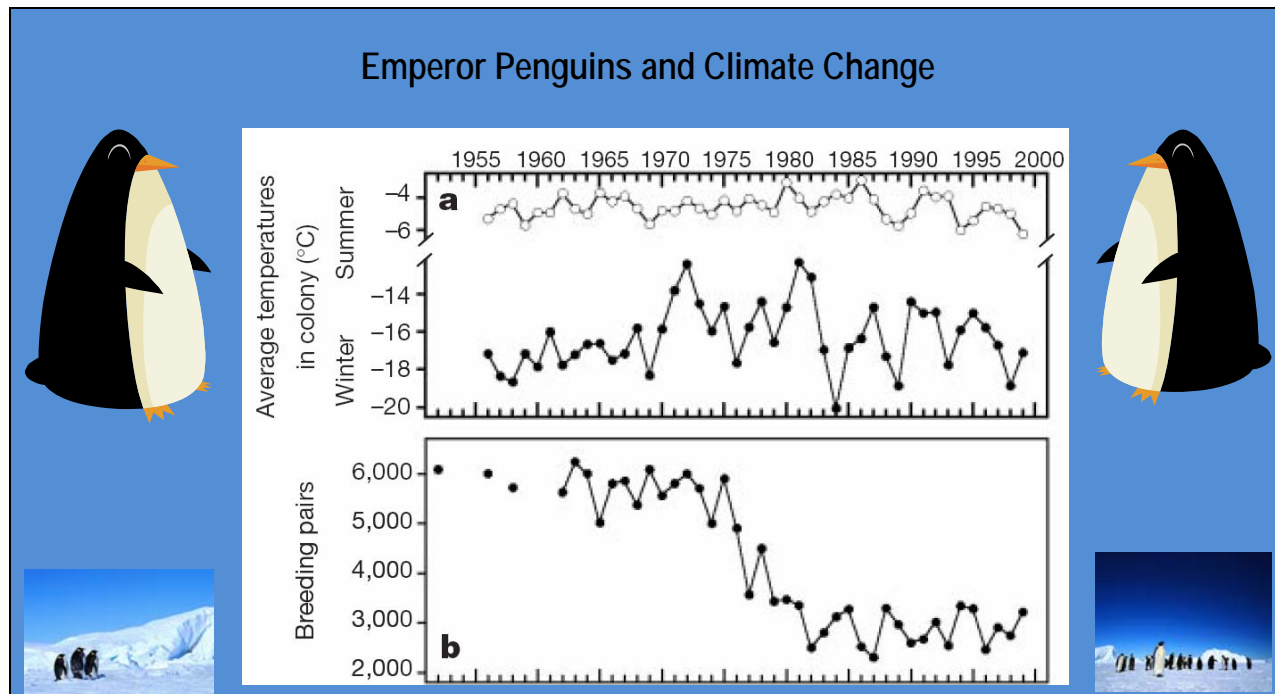
Climate and population changes. a. Summer and winter average temperatures recorded at Dumont D'Urville meteorological station (1956±1999). b. Number of breeding pairs of emperor penguins at Pointe GeÂ ologie archipelago, Terre AdeÂ lie (1952 ± 1999).

Adapted from Figure 1, page 184 of:
Barbraud, C., & Weimerskirch, H. (2001). Emperor penguins and climate change. *Nature, 411* (6834), 183-185.

| True Statements | False Statements |
|---|---|
| The number of breeding penguin pairs has declined greatly from 1960 to 2000. | The number of penguin pairs has stayed pretty constant through the years on the graph. |
| Average Antarctic temperatures in the winter generally show more variation than summer temperatures. | There were about 4500 penguin breeding pairs in 1980. |
| The number of penguin pairs has decreased in size to almost half for the years shown on the graph. | The loss of many pairs of penguins appears to be correlated to much warmer summer temperatures. |

Figure 2. Effects of climate change on the elk population [Materials designed by Patrick Grennell].

## Elk Population in Rocky Mountain National Park
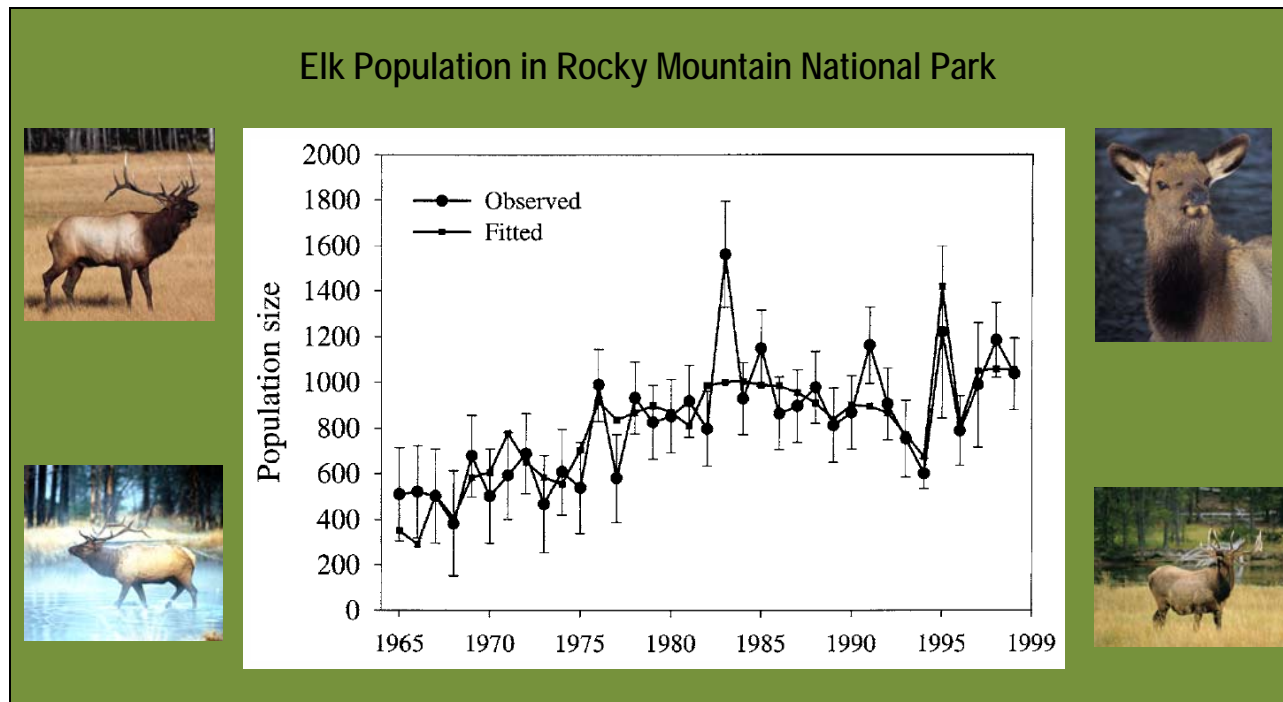


Observed and the best discrete logistic model – fitted population sizes of elk at Rocky Mountain National Park from 1965 to 1999.

Adapted from Figure 2, page 214 of:
Wang, G., Hobbs, N. T., Singer, F. J., Ojima, D. S., & Lubow, B. C. (2002). Impacts of climate changes on elk population dynamics in Rocky Mountain National Park, Colorado, U.S.A. *Climatic Change, 54*, 205-223.

| True Statements | False Statements |
|---|---|
| The elk population shows an upward trend of increasing numbers over the years shown on the graph. | The last year of elk data presented on the graph is 1995. |
| There have never been more than 2000 elk recorded in one year. | The elk data collection spans more than 50 years. |
| There were less elk in the park in 1970 than in 1995. | The graph shows elk ages. |

Figure 3. Temperature effects on turtle eggs [Materials designed by Kenda Simmons].



## Effect of Temperature on Eggs of the Red-Eared Slider Turtles from Stump Lake in Jersey County, Illinois
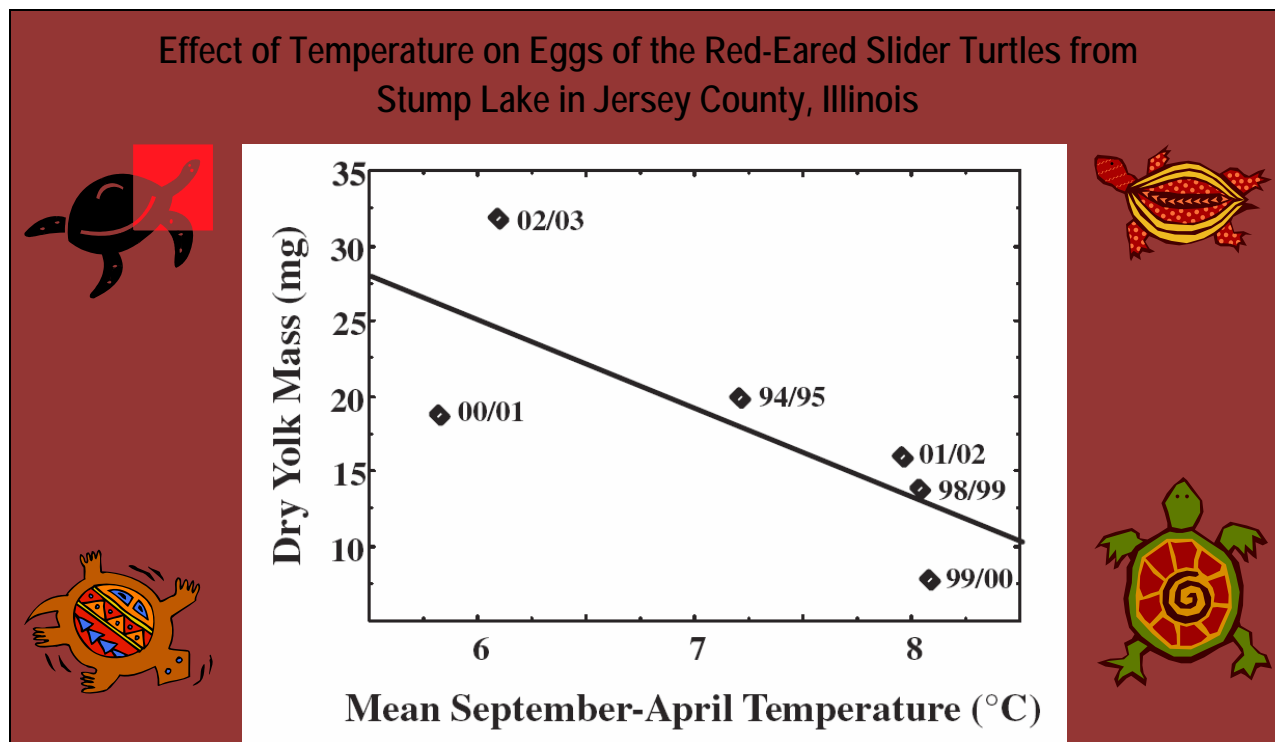
Six-year relationship between mean ambient temperature from 1 September to 30 April and dry residual yolk mass of cohorts of neonatal red-eared slider turtles, *Trachemys script elegans*, captured in a natural population near the northern edge of the geographic range.

Adapted from Figure 1, page 848 of:
Willette, A. S., Tucker, J. K., & Janzen, F. J. (2005). Linking climate and physiology at the population level for a key life-history stage of turtles. *Canadian Journal of Zoology, 83,* 845-850.

| True Statements | False Statements |
|---|---|
| Turtle eggs contained less yolk mass in 1998/1999 than in 2000/2001. | The graph shows that warmer temperature result in larger yolk of turtle eggs. |
| Cooler temperatures appear to be correlated with larger dry yolk mass. | The graph shows data on turtle eggs collected during all 12 months of the year. |
| The graph shows that at 7 degrees Centigrade, the dry yolk mass was approximately 20 mg. | The years in which turtle eggs had the largest yolk mass were the most recent years. |

Figure 4. Temperature effects on turtle eggs [Materials designed by Audrey Rule].

## Increase in Diseased Coral as Reported in the Literature



Percent of literature reporting disease over time in the coral taxonomic group. Coral bleaching and disease (closed square); coral disease including infectious bleaching (open circle); coral bleaching (asterisk).

Adapted from Part B of Figure 1, page 544 of:
Ward, J. R., & Lafferty, K. D. (2004). The elusive baseline of marine disease: Are diseases in ocean ecosystems increasing? *PLoS Biology, 2* (4), 542-547.

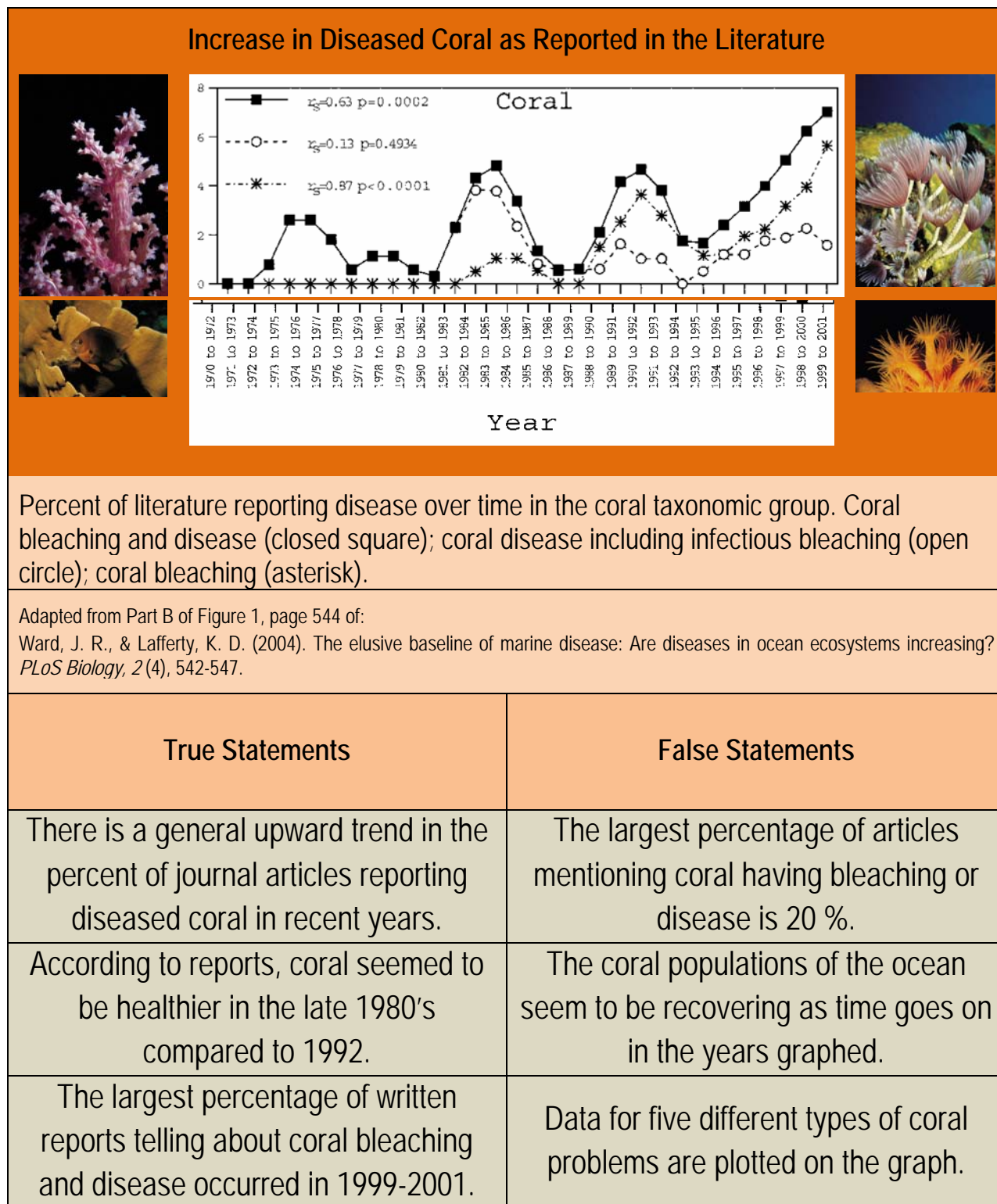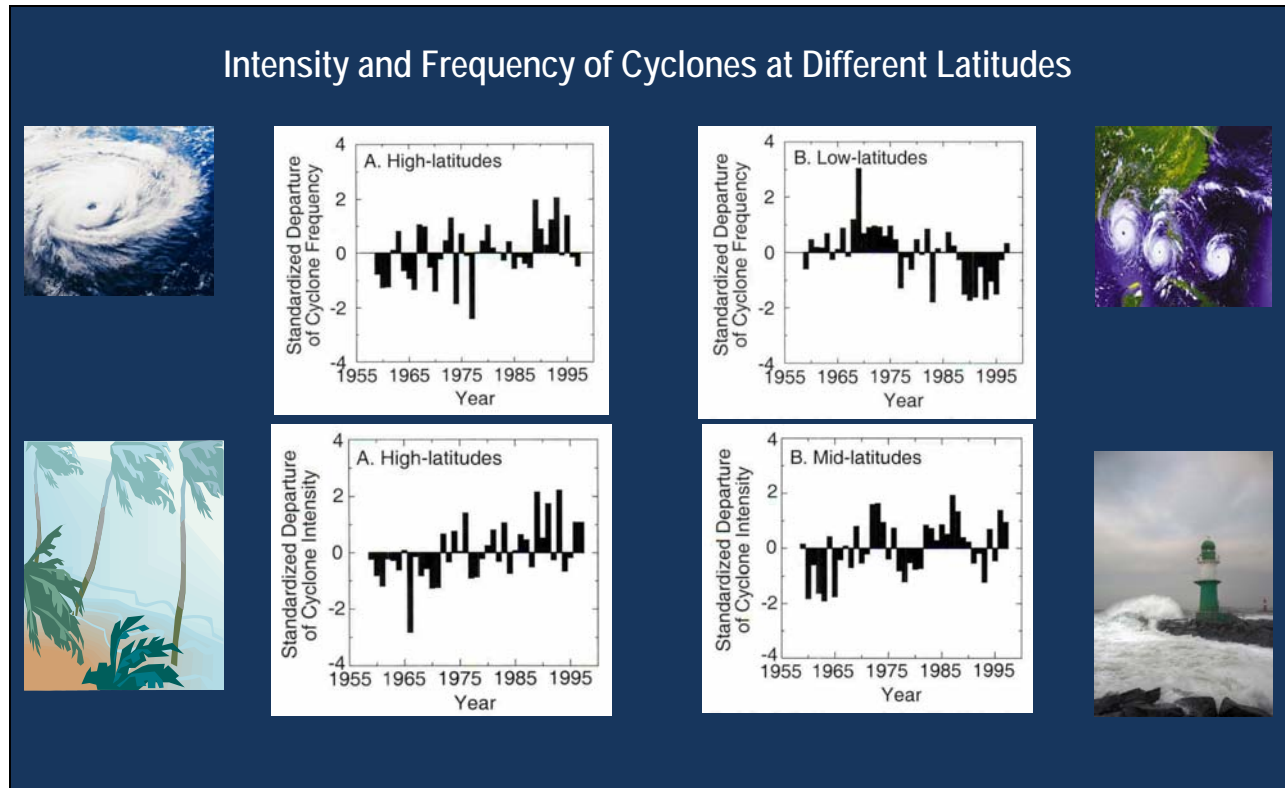| True Statements | False Statements |
|---|---|
| There is a general upward trend in the percent of journal articles reporting diseased coral in recent years. | The largest percentage of articles mentioning coral having bleaching or disease is 20 %. |
| According to reports, coral seemed to be healthier in the late 1980's compared to 1992. | The coral populations of the ocean seem to be recovering as time goes on in the years graphed. |
| The largest percentage of written reports telling about coral bleaching and disease occurred in 1999-2001. | Data for five different types of coral problems are plotted on the graph. |

Figure 5. Temperature effects on turtle eggs [Materials designed by Kara Nicholas].



Northern hemisphere standardized departures of winter (November– March) cyclone counts at (A) high latitudes and (B) mid-latitudes, as well as for intensity (C) high latitudes and (D) midlatitudes.

Adapted from Figure 2, page 2765, and Figure 4, page 2767, of:
McCabe, G.J., Clark, M.P., & Serreze, M.C. (2001). Trends in Northern Hemisphere surface cyclone frequency and intensity. *Journal of Climate 14,* 2763– 2768.

| True Statements | False Statements |
|---|---|
| The top left graph shows that 1978 had the lowest standardized cyclone frequency in high latitudes, | The number of cyclones for high latitudes is increasing, but their intensity is lessening. |
| The top graphs show that cyclones are more frequent in high, but less frequent in low latitudes in recent years. | 1989 was a year showing the very lowest intensity cyclones in the high-latitudes. |
| Cyclone intensity seems to be increasing in high and mid latitudes in recent years. | The intensity of cyclones in the mid-latitudes reached a peak in 1993. |

Figure 6. Natural disasters in Australia [Materials designed by Ryan Scott].



Natural Disasters in Australia from 1967 to 1999
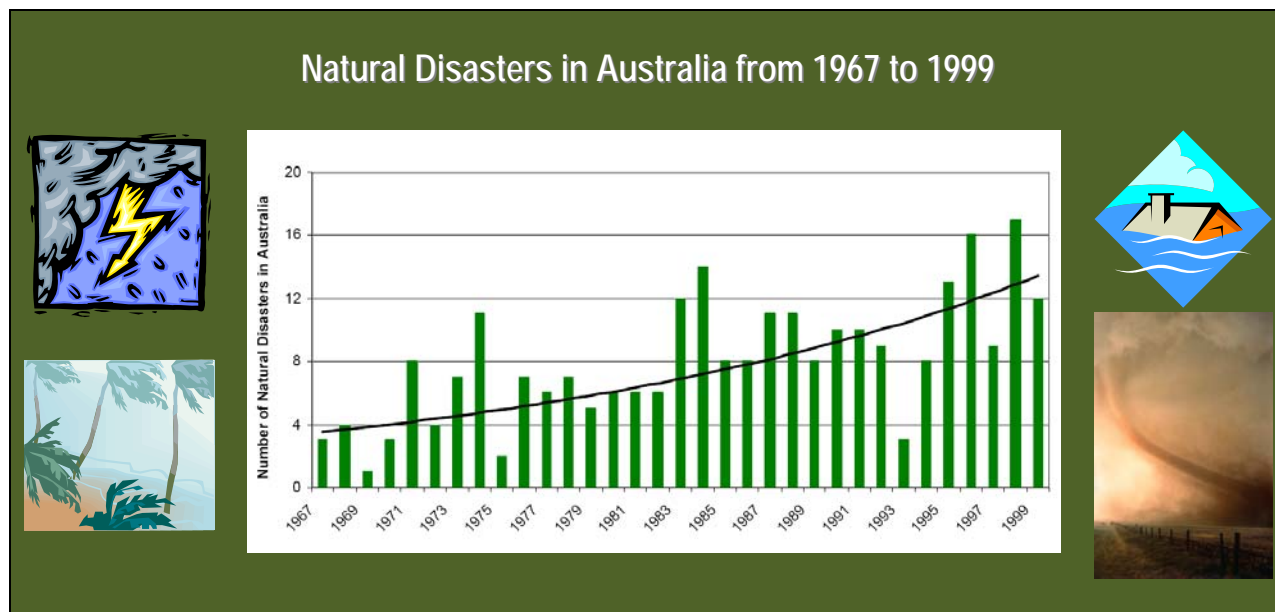
Reconstructed from the Bureau Transport Economics analysis of Emergency Management Australia. {Note: Definition of Natural Disaster: Economic costs greater than $10m (in 1999 prices, Includes costs of deaths and injuries).}

Adapted from Figure 6, page 9 of:
Coleman, T. (2003). The impact of climate change on insurance against catastrophes. Presentation to the Institute of Actuaries of Australia, 2003 Biennial Convention, "Shaping the future in a world of uncertainty. Retrieved May 30, 2008 from: http://svc012.wic020p.server-web.com/PublicSite/pdf/conv03papercoleman.pdf

| True Statements | False Statements |
|---|---|
| The graph shows an increasing trend in the number of natural disasters in Australia. | Disaster data are shown only for every other year on the graph. |
| A natural disaster is defined as an event with an economic cost of greater than ten million dollars. | According to the graph, the fewest disasters happened between the years 1977 and 1978. |
| The time between 1983 and 1985 saw many disasters but not as many as 1996-1997 or 1998-1999. | The graph shows economic growth in Australia as a result of natural disasters. |

Figure 7. Climate change in the Great Lakes region [Materials designed by Jenn Haas].



## Climate Change in the Great Lakes Region
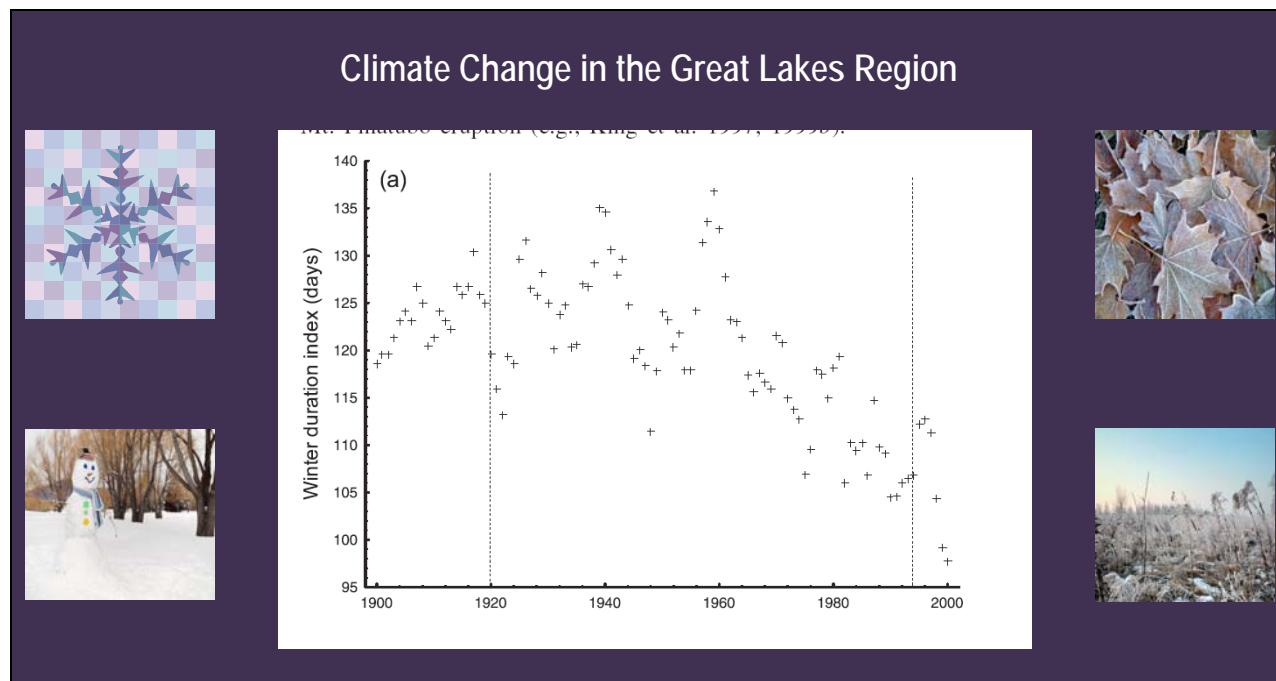
Number of days that winter lasts determined by Lake Erie temperature measurements.
Variation in index of winter duration: the number of days between the last day in fall when the surface water temperature is above 4 °C and the last day in the following spring when the surface water temperature is below 4 °C.

Adapted from Figure 2, page 461 of:
Jones, M. L., Shuter, B. J., Zhao, Y/, & Stockwell, J. D. (2006). Forecasting effects of climate change on Great Lakes fisheries: Models that link habitat supply to population dynamics can help. *Canadian Journal of Fisheries and Aquatic Sciences, 63*, 457-468.

| True Statements | False Statements |
|---|---|
| The graph shows that the number of cold winter days for a year are becoming fewer. | The graph shows the number of winter days each year is increasing. |
| In the year 2000, there were less than 100 days of winter. | 1960 saw a decrease in the number of winter days; it was a warm year. |
| There were less winter days in the year 2000 than in the year 1900. | The year 1940 was warmer and had fewer winter days than 1980. |

Figure 8. Changes in mean global temperatures [Materials designed by Sara Loiacono and Kyle Percy].

## Global Annual Mean Surface Air Temperature Change
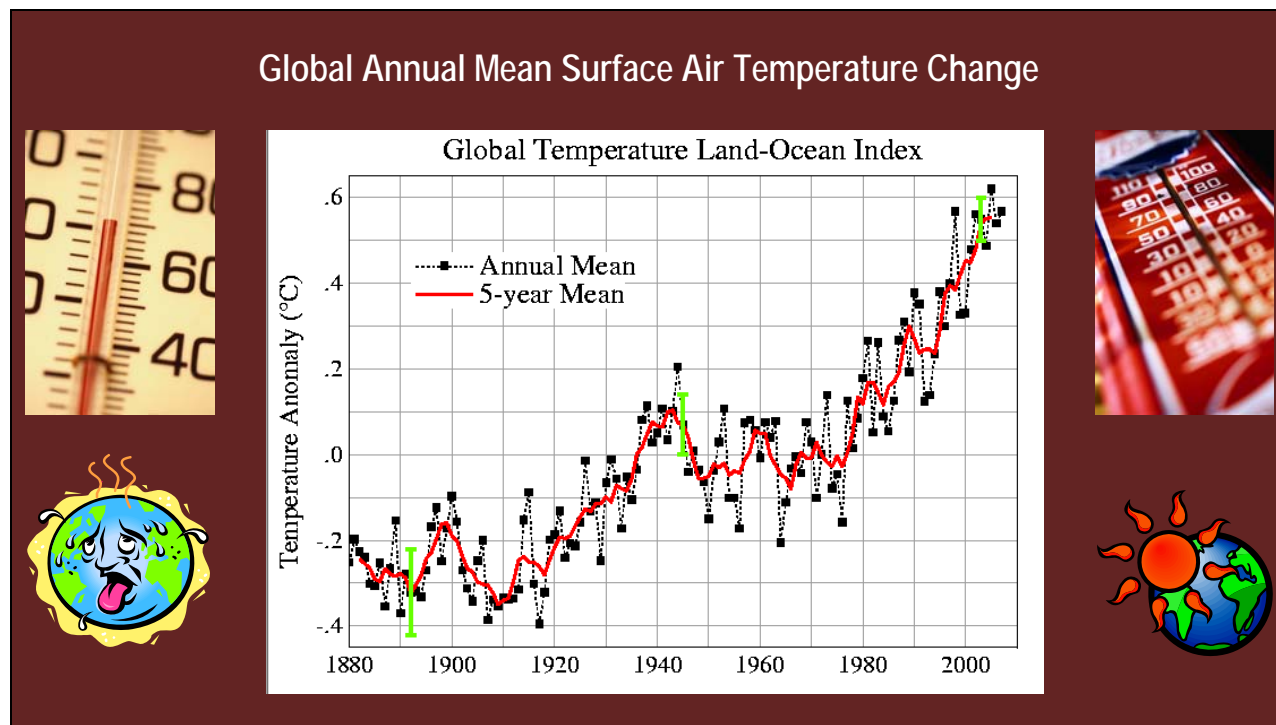


Line plot of global mean land-ocean temperature index, 1880 to present. The dotted black line is the annual mean and the solid red line is the five-year mean. The green bars show uncertainty estimates.

| True Statements | False Statements |
| --- | --- |
| This graph shows an increase in the annual temperature anomaly between 1920 and 1940. | All of the annual temperatures from the 1950's on to 2000 have been warmer than temperatures during the 1930's. |
| Temperatures seemed to have leveled off during the 50's, 60's and early 70's. | 1944 was the warmest year shown on the graph. |
| The graph shows that temperatures over the past 30 years have been steadily trending warmer. | The graph shows so much temperature variation that no general trend can be seen. |

Figure 9. Ice mass loss in Greenland [Materials designed by Phineas Stevens].



## Ice Mass Loss in Greenland

-162+/- 22 km³/yr
~0.4 +/- 0.1 mm/yr sea level rise

Velicogna and Wahr, 2005
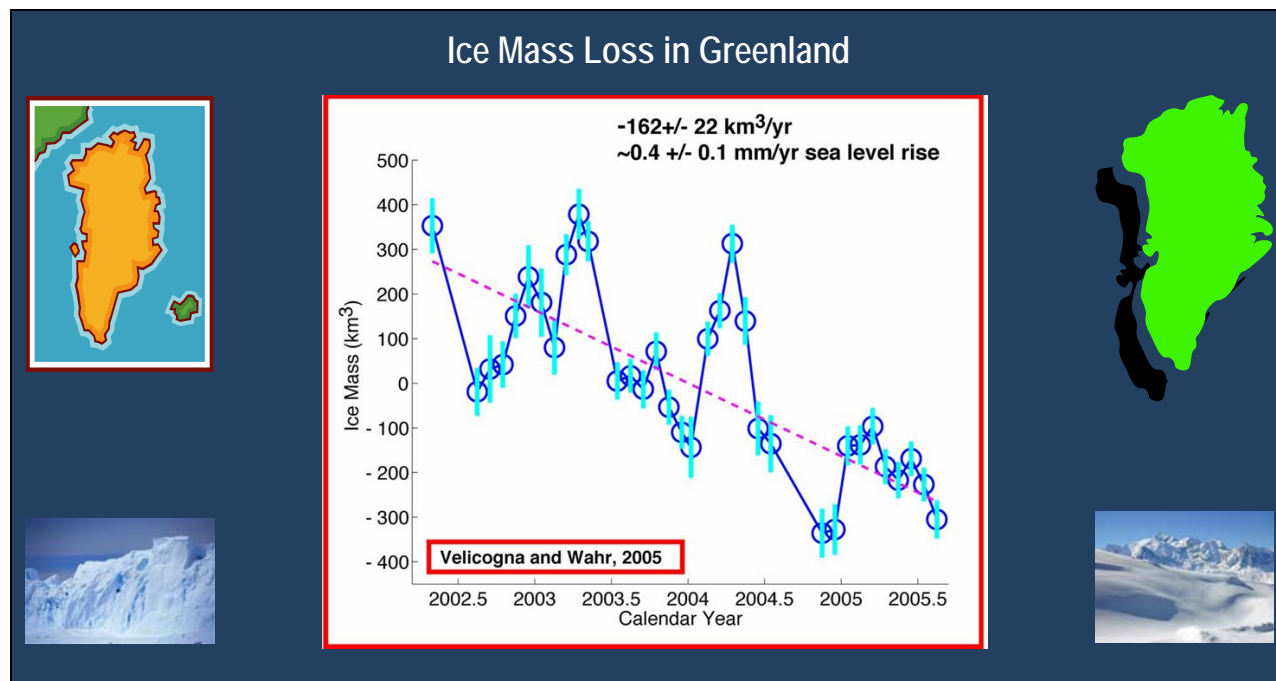
This figure shows the ice mass loss in Greenland as observed by Grace over the period 2002-2005 measured in cubic kilometers per year. The ice mass loss observed contributes about 0.4 millimeters (.016 inches) per year to global sea level rise. Image credit: NASA/JPL/University of Colorado.

Adapted from Figure in "NASA's Grace Finds Greenland Melting Faster" of:
NASA (2005). Mission news. retrieved May 30, 2008 from: http://www.nasa.gov/vision/earth/lookingatearth/grace-20051220.html
Velicogna, I., & Wahr, J. (2005). Greenland mass balance from GRACE. *Geophysical Research Letters, 32,* LI1805, 1-4.

| True Statements | False Statements |
|---|---|
| The ice mass data on the graph span three years. | The last year that ice mass accumulated rather than was lost was 2003. |
| The trend line shows a steady loss of ice mass over the years of the data. | An ice mass data point was recorded every half-year. |
| In general, early data points showed an accumulation of ice, but later data points showed loss of ice. | The graph shows how many centimeters thick the ice is at a certain place in Greenland. |

Figure 10.  Loss of sea ice in northern hemisphere [Materials developed by Vicki Roth].



## Twenty-five Year Decrease in Northern Hemisphere Sea-Ice Extent

25-Year Decrease in Northern Hemisphere Sea-Ice Extent

Legend:
- Parkinson.et.al.
- Chapman...Walsh
- Bjorgo......et.al.
- Ropelewski
- Zakharov

y-axis: Sea-Ice Extent: Millions of Sq. Km. (11.0 to 13.0)
x-axis: 1970, 1975, 1980, 1985, 1990, 1995, 2000
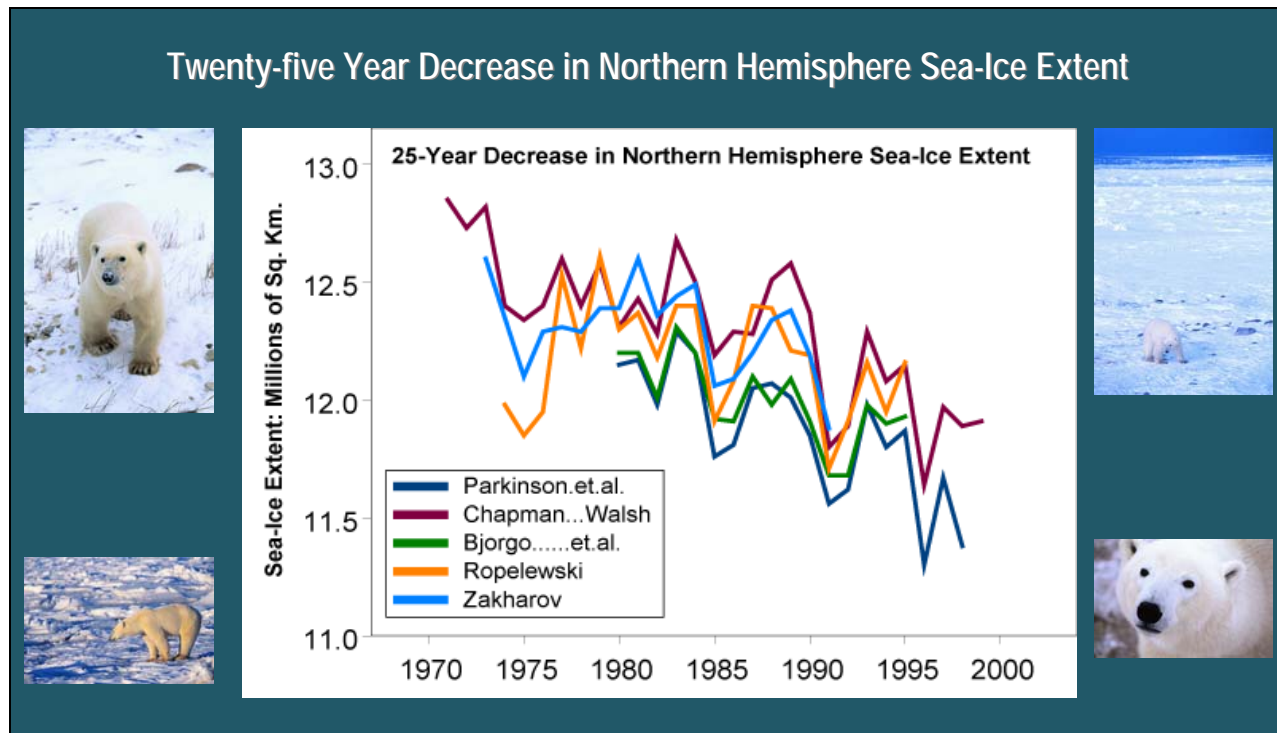
Polar bears depend upon seals as a main food source. Loss of sea ice means seals lose their snow dens for birthing pups and therefore the seal population declines. Loss of sea ice means polar bears spend more time on land and use their stored fat. This affects their ability to give birth to more cubs. Loss of ice and snow means fewer snow dens for polar bears. All of these changes put pressure on polar bears.

Adapted from Figure in:
Schliebe, S. L. (2000). What has been happening to polar bears in recent decades? NOAA Arctic theme page essay. Retrieved May 30, 2008 from: http://www.arctic.noaa.gov/essay_schliebe.html

| True Statements | False Statements |
|---|---|
| The graph shows that the arctic region is experiencing loss of sea ice. | The horizontal x axis shows the amount of water lost when sea ice melts. |
| The graphed data plots in general show the same trends of loss of sea ice. | The graph shows the number of polar bears that have died because of loss of sea ice. |
| 1988-89 data points show that the temperatures were cold enough for sea ice to begin accumulating. | The vertical y axis shows the amount of ice present in cubic miles of ice. |

Figure 11. Loggerhead turtle nesting [Materials developed by Katie Meyer].



## Loggerhead Turtle Nesting is Earlier because of Global Warming
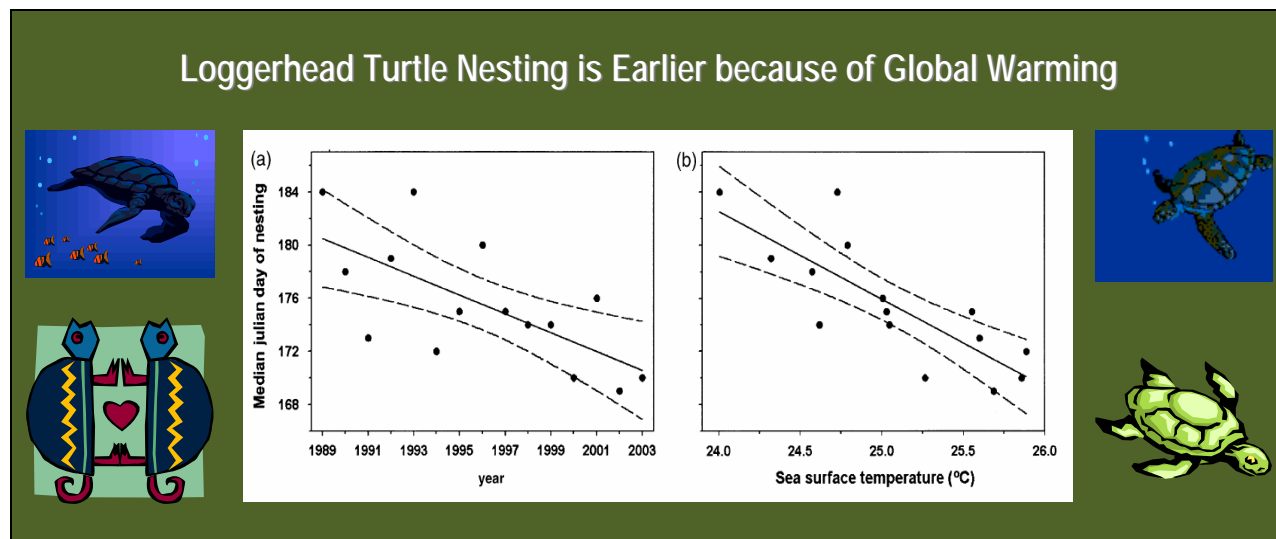
(a) Temporal change and trend in the annual median nesting date within the 10 May–30 August window (r250.46, P50.006) from 1989 to 2003. (b) Relationship between May sea surface temperature derived from a nearby NOAA buoy and annual median nesting date (r250.65, Po0.001) from 1989 to 2003. Dashed lines represent 95% confidence envelopes.

Adapted from Figure 2, page 1426 in:
Weishampel, J. F., Bagley, D. A., & Ehrhart, L. M. (2004). Earlier nesting by loggerhead sea turtles following sea surface warming. *Global Change Biology, 10,* 1424-1427.

| True Statements | False Statements |
| --- | --- |
| The median turtle nesting date occurred about 14 days earlier over the span of 15 years. | The dotted lines on the two graphs show the layers of sea water that affect the turtles. |
| Turtles tend to nest earlier in the 2000's than they did in the late 1980's because of the warmer water. | Sea surface temperatures cooled by an average of two degrees during the years shown on the 2nd graph. |
| Sea surface temperature is shown as degrees Centigrade on the second graph. | The two graphs indicate that there is no relationship between reptile behavior and global warming. |

Figure 12. Jellyfish population biomass increase [Materials developed by Heather DeCare].
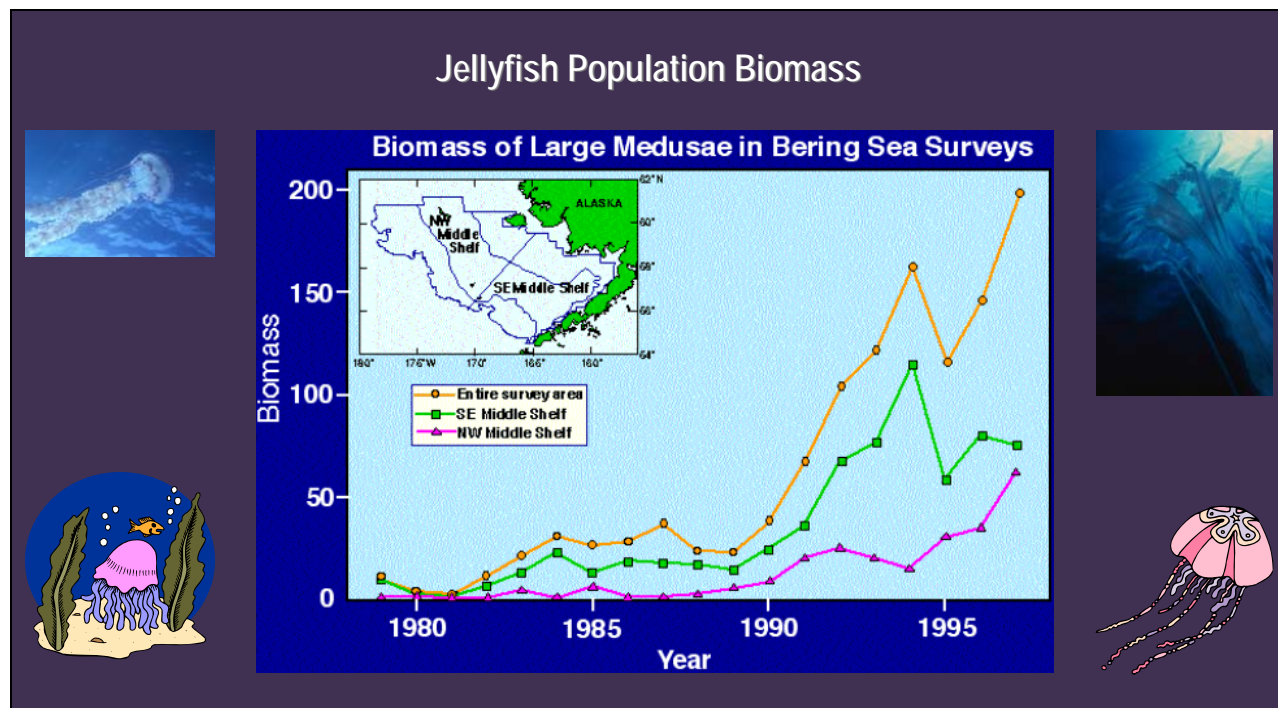


As the ocean warms, the biomass of populations of jellyfish changes.

Adapted from Slide 7of:
Macklin, A. (2000, June). Fisheries-Oceanography Coordinated Investigations (FOCI). Increase in jellyfish abundance. Retrieved May 30, 2008 from: http://www.pmel.noaa.gov/foci/info/foci_tour/slide7.html

| True Statements | False Statements |
|---|---|
| Both continental shelf areas show an increase in jellyfish biomass as time goes on. | The graph shows exactly 15 years of jellyfish data. |
| The biomass of jellyfish appears to explode (rise rapidly) beginning in 1991. | The orange line (top line) shows jellyfish data from the Gulf of Mexico. |
| The data come from an ocean shelf area near Alaska. | The largest amount of jellyfish biomass occurred in 1987. |

Figure 13. North Sea cod [Materials developed by Kirby Lodovice].
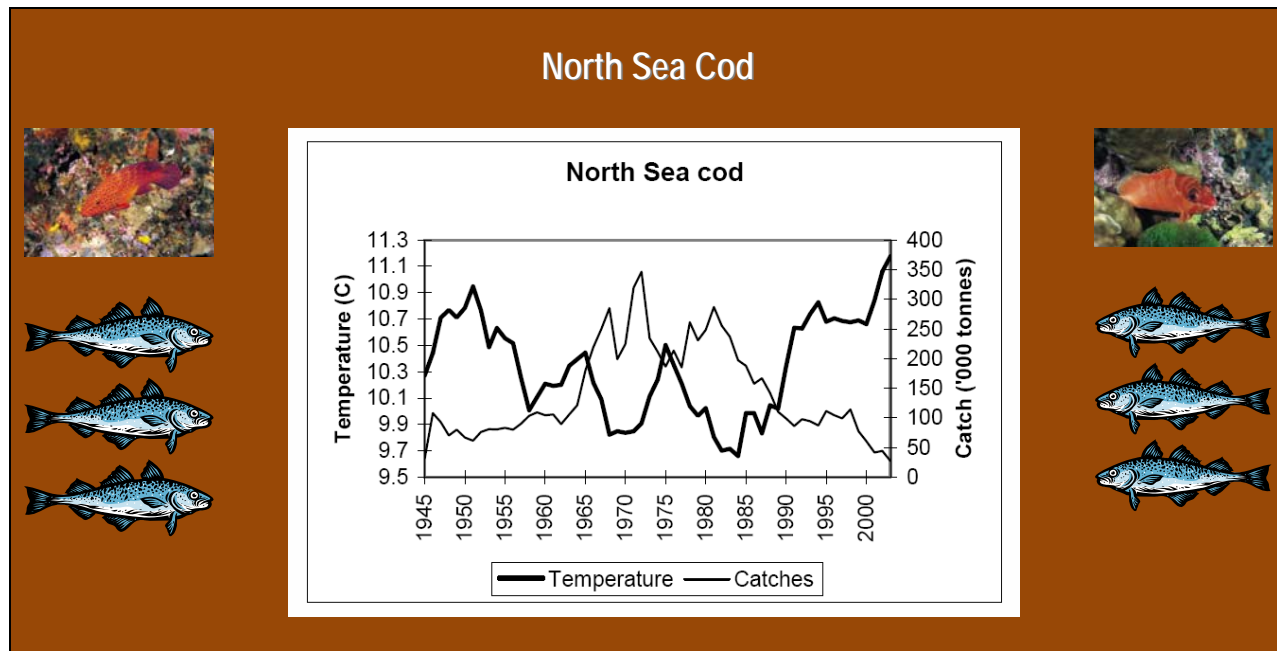


## North Sea Cod

Catches of North Sea Cod and 7-year running average of temperatures in Sognesjøen.

Adapted from Figure 5, page 8, of:
Hannesson, R. (2006). Geographical distribution of fish catches and temperature variations in the Northeast Atlantic since 1945. SNF Working Paper No. 01/06.  Retrieved May 30, 2008 from: http://bora.nhh.no/bitstream/2330/92/1/A01_06.pdf

| True Statements | False Statements |
|---|---|
| The graph shows an inverse relationship between temperature and fish catches. | There is no relationship between temperature and fish catches. |
| When the water is cooler, the fish catch is larger. | The thinner line on the graph represents temperature; the thicker line represents fish catches. |
| Since 1984/1985, temperature has increased and fish catches have decreased. | The fish catches in 1985 and 2005 were similar in tonnage. |

Figure 14. Natural catastrophes and economic losses in Canada [Materials developed by Tharath Som].



## Natural Catastrophes and Economic Losses in Canada

ECONOMIC LOSSES FROM NATURAL CATASTROPHES, 1965–1994

Source: Adapted from Munich Re (1996)
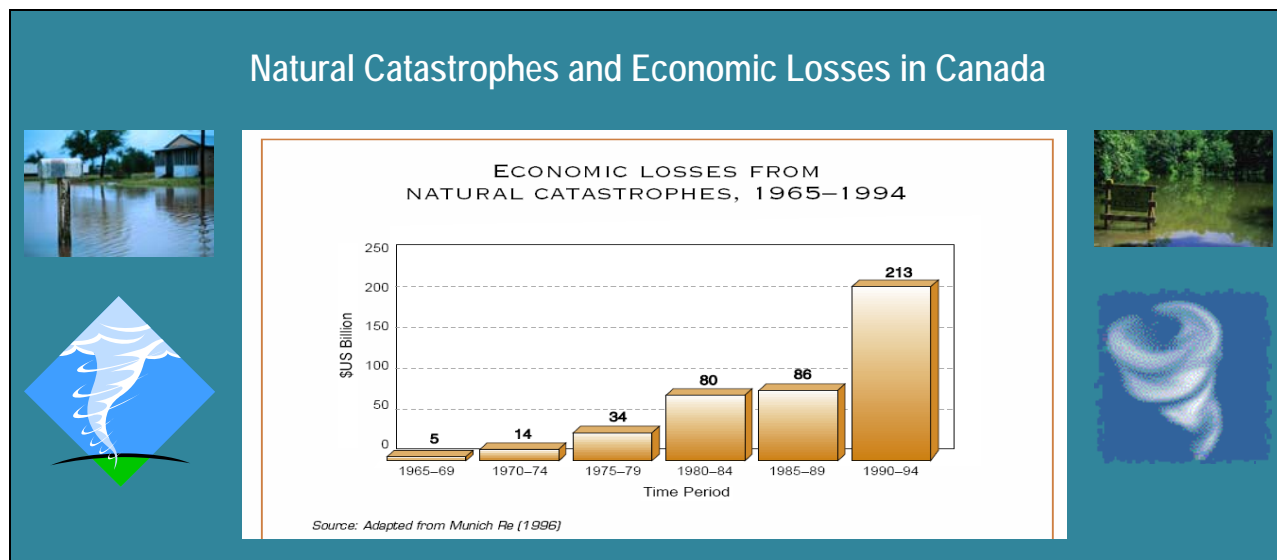
Dramatic increases in economic losses from natural catastrophes, most of them weather-related, imply an increase in weather extremes.

Adapted from unnumbered figure, page 3, of:
Francis, D., & Hengeveld, H. (1998). Extreme weather and climate change. Environment of Canada. Retrieved June 30, 2008 from: http://www.msc-smc.ec.gc.ca/saib/climate/Climatechange/ccd_9801_e.pdf

| True Statements | False Statements |
|---|---|
| The largest economic loss on the graph occurred in 1990-94. | The lowest economic loss shown on the graph is 14 billion dollars. |
| Between 1970-74, Canada lost 14 billion dollars to natural catastrophes. | Between the years 1985-89, the dollar loss was 70 billion. |
| The time period of this graph showing Canadian data ranges from 1965-1994. | As time advances on the graph, the economic losses decrease. |

Figure 15. Frequency of winter storms [Materials developed by Audrey Rule].



This graph, from an analysis of severe winter storms in the extratropical Atlantic and Pacific by Steven Lambert of Environment Canada, shows a striking change in storm activity.

Adapted from unnumbered figure, page 6, of:
Francis, D., & Hengeveld, H. (1998). Extreme weather and climate change. Environment of Canada. Retrieved June 30, 2008 from: http://www.msc-smc.ec.gc.ca/saib/climate/Climatechange/ccd_9801_e.pdf

| True Statements | False Statements |
|---|---|
| The number of winter storms each year has been increasing. | There is so much scatter in the winter storm data, no trend can be seen. |
| After 1970, winter storms appear to increase dramatically. | The graph shows the severity of winter storms. |
| The number of storms between 1900 and 1920 was lower than most other years. | Some years on the graph have had several hundred winter storms. |

Figure 16. South Atlantic Ocean sea surface temperatures [Materials developed by Karl Budkevics].
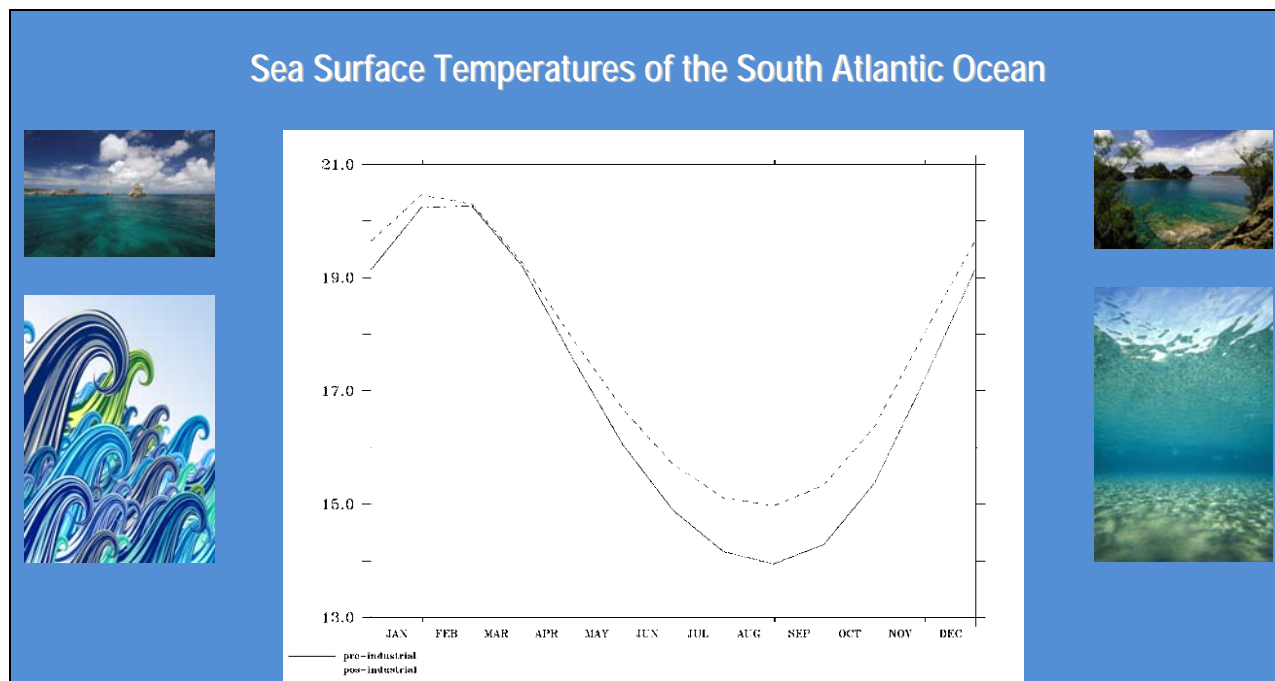


Annual cycle of sea surface temperature (SST) averaged for the whole South Atlantic domain in degrees C. Black curve represents the pre-industrial simulation results while the dashed curve represents the present day results.

Adapted from Figure 3, page 169, of:
Nainer, I. (2004). A numerical study of the impact of greenhouse gases on the South Atlantic Ocean climatology. *Journal of Climatology, 66* (1/2), 163-189.

| True Statements | False Statements |
| --- | --- |
| January-February were the months with the highest ocean surface temperatures recorded. | The water temperature for both eras was highest in November. |
| Post industrial water temperatures are always equal to or greater than pre-industrial temperatures. | The recorded sea surface temperature in February was 22 degrees C. |
| The lowest recorded water temperature recorded for the pre-industrial era was 14 degrees C. | The water temperatures in August are higher than those in February. |

Figure 17. Population size of Australian rainforest birds [Materials developed by Jen Schotts].

## Rainforest Bird Population Size Related to Temperature



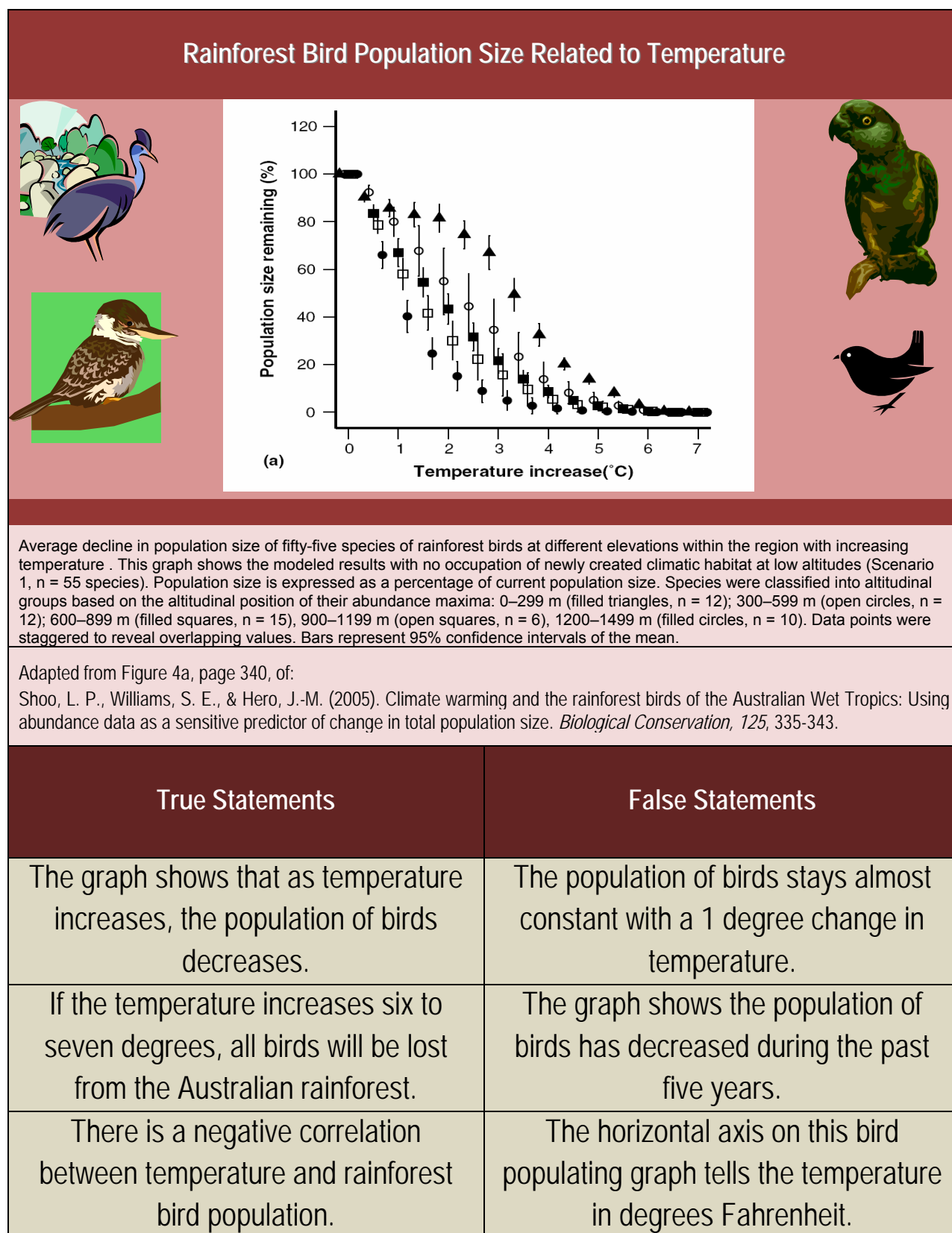Average decline in population size of fifty-five species of rainforest birds at different elevations within the region with increasing temperature . This graph shows the modeled results with no occupation of newly created climatic habitat at low altitudes (Scenario 1, n = 55 species). Population size is expressed as a percentage of current population size. Species were classified into altitudinal groups based on the altitudinal position of their abundance maxima: 0–299 m (filled triangles, n = 12); 300–599 m (open circles, n = 12); 600–899 m (filled squares, n = 15), 900–1199 m (open squares, n = 6), 1200–1499 m (filled circles, n = 10). Data points were staggered to reveal overlapping values. Bars represent 95% confidence intervals of the mean.

Adapted from Figure 4a, page 340, of:

Shoo, L. P., Williams, S. E., & Hero, J.-M. (2005). Climate warming and the rainforest birds of the Australian Wet Tropics: Using abundance data as a sensitive predictor of change in total population size. *Biological Conservation, 125*, 335-343.

| True Statements | False Statements |
|---|---|
| The graph shows that as temperature increases, the population of birds decreases. | The population of birds stays almost constant with a 1 degree change in temperature. |
| If the temperature increases six to seven degrees, all birds will be lost from the Australian rainforest. | The graph shows the population of birds has decreased during the past five years. |
| There is a negative correlation between temperature and rainforest bird population. | The horizontal axis on this bird populating graph tells the temperature in degrees Fahrenheit. |

Figure 18. Bird egg size related to temperature [Materials developed by Natasha Mapes].



## Lapland Flycatcher Bird Egg Size Related to Temperature
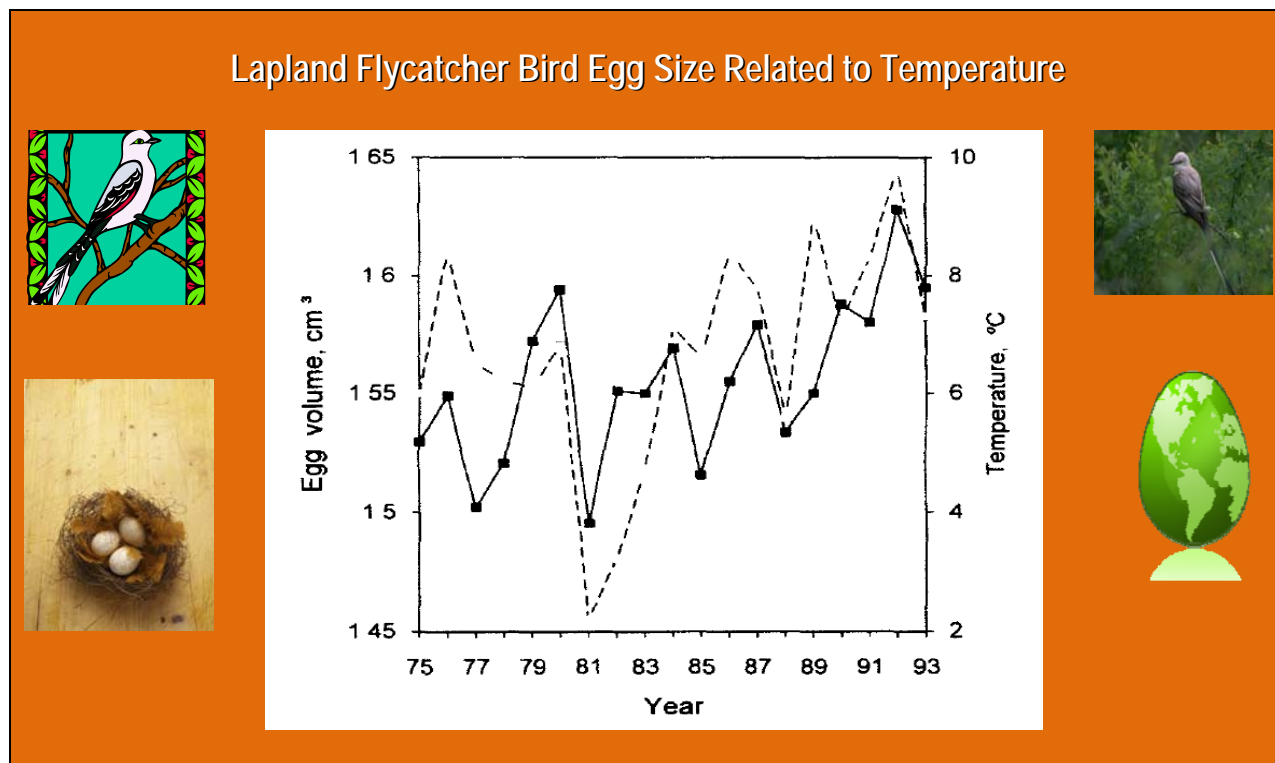
Mean egg volume (cubic centimeters, continuous line) of pied flycatcher population and mean air temperature (°C, broken line) during the main egg-laying period of the species at Kilpisjaryi in Northern Lapland in Sweden in 1975-1993.

Adapted from Figure 1, page 109, of:
Járvinen, A. (1994). Global warming and egg size of birds. *Ecography, 17*(1), 108-110.

| True Statements | False Statements |
|---|---|
| In general, the peaks and dips of the solid egg size line follow the shape of the dotted temperature line. | The largest egg volume or egg size shown on the graph occurred in 1980. |
| Temperatures increased from 1981 to 1993; egg volume increased also. | The graph shows that 1981 was a good year for birds: eggs were large that year. |
| There is a positive correlation between temperature and egg size. | When the temperatures are cooler, birds tend to lay larger eggs. |