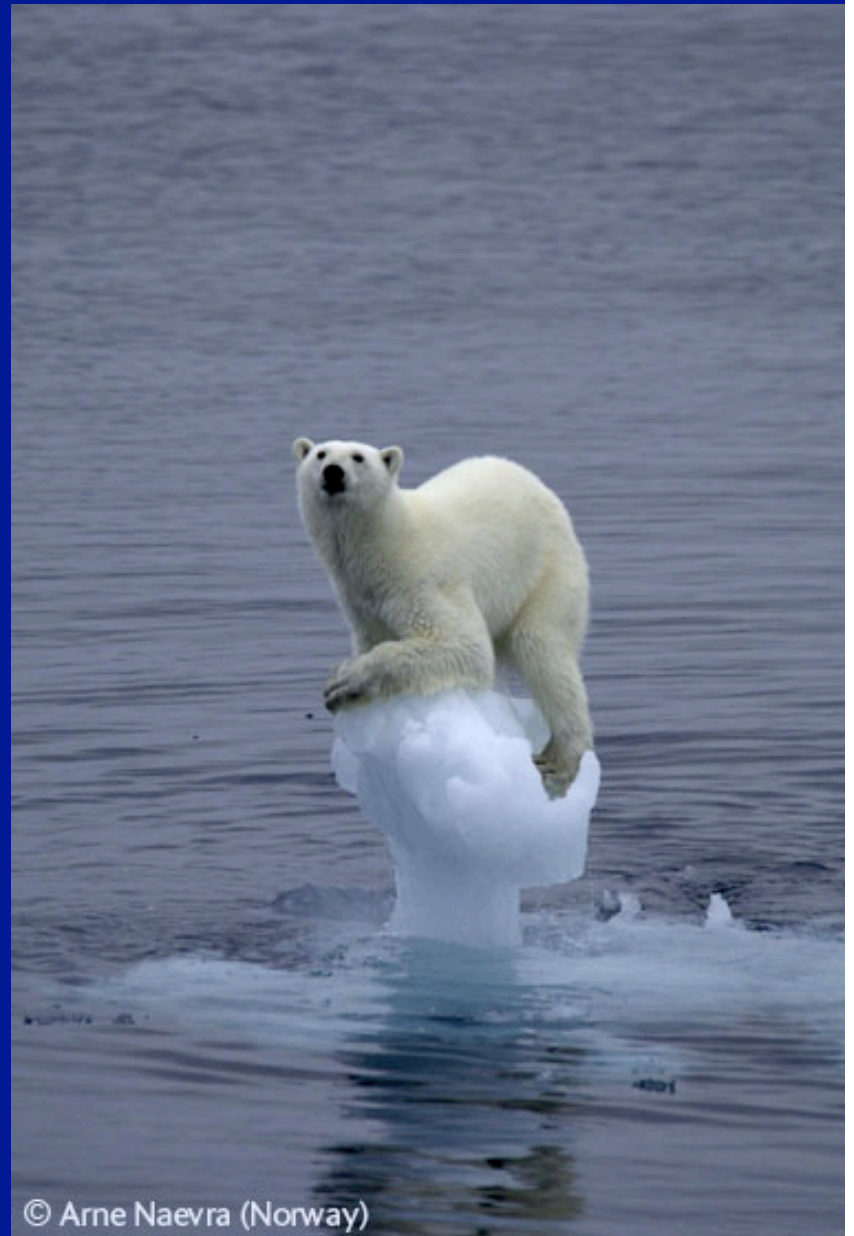
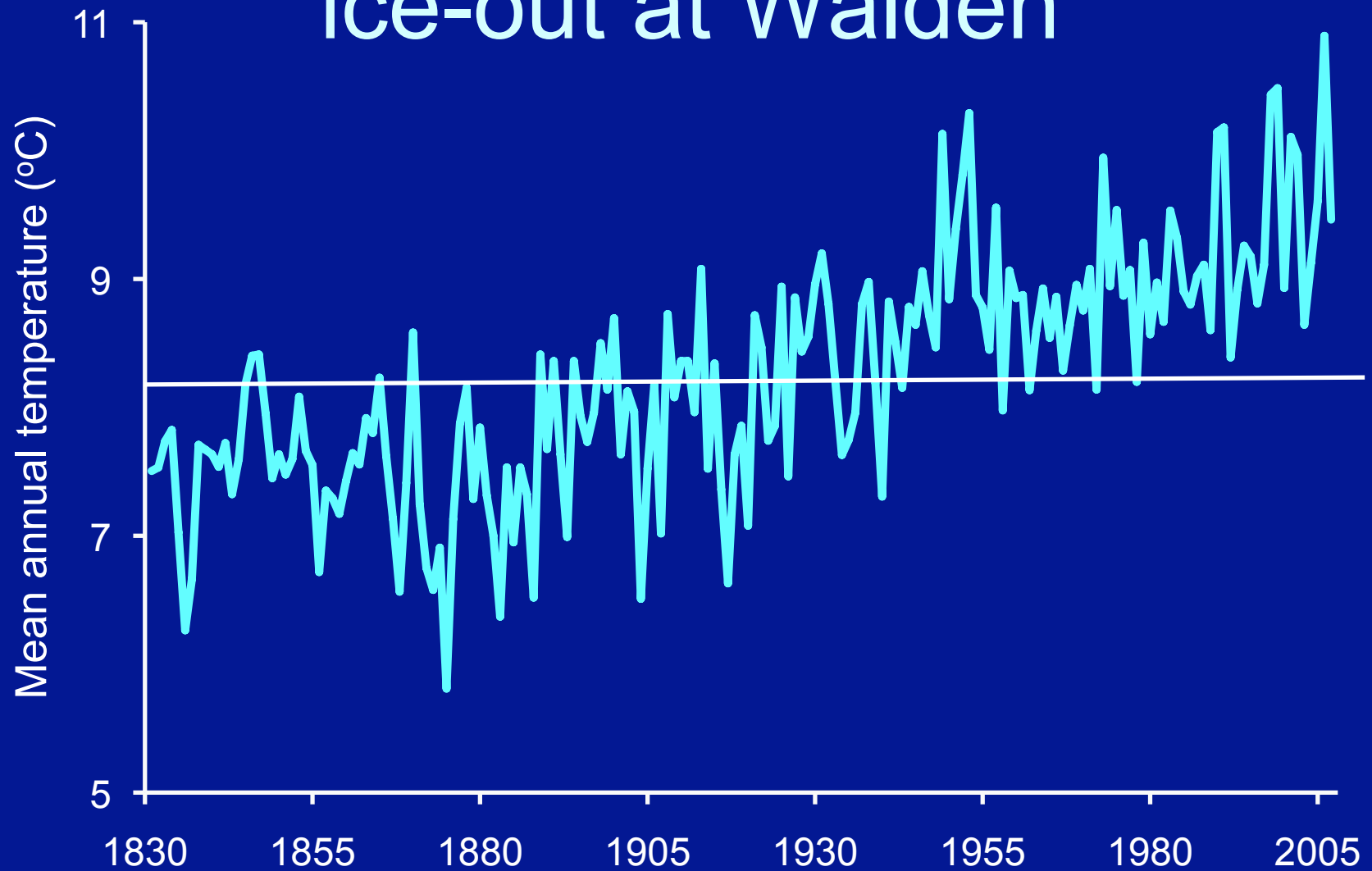


- Can we see the effects of climate change in Massachusetts?
- Richard Primack



Warming temperatures; and ice-out at Walden



Data from Blue Hill Meteorological Observatory



Large-flowered trillium
(*Trillium grandiflorum*)

- What is happening in Massachusetts?
- Why should we care?



English oak
(*Quercus robur*)

EARLIER

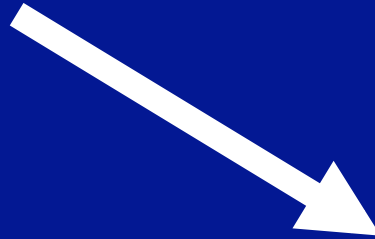
Phenology matters!

From Both et al.
2006. *Nature*.



English oak
(*Quercus robur*)

EARLIER



Winter moth
(*Operophtera brumata*)

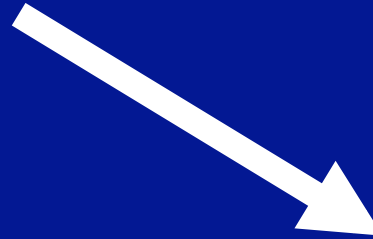
EARLIER

From Both et al.
2006. *Nature*.



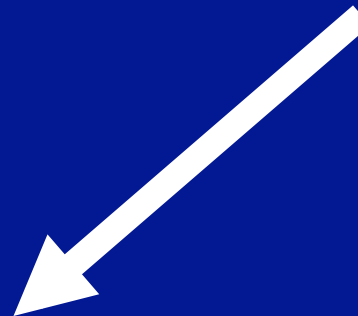
English oak
(*Quercus robur*)

EARLIER



Winter moth
(*Operophtera brumata*)

EARLIER



Pied flycatcher
(*Ficedula hypoleuca*)

SAME TIME
EACH YEAR

From Both et al.
2006. *Nature*.



Finding old records

Henry David Thoreau kept detailed records

“I want to go away soon
and live away by the pond...
But my friends ask what I
will do when I get there?
Will it not be employment
enough to watch the
progress of the seasons?”
- Thoreau, 1841



Flowering times in Concord; Thoreau, Hosmer, Miller-Rushing & Primack

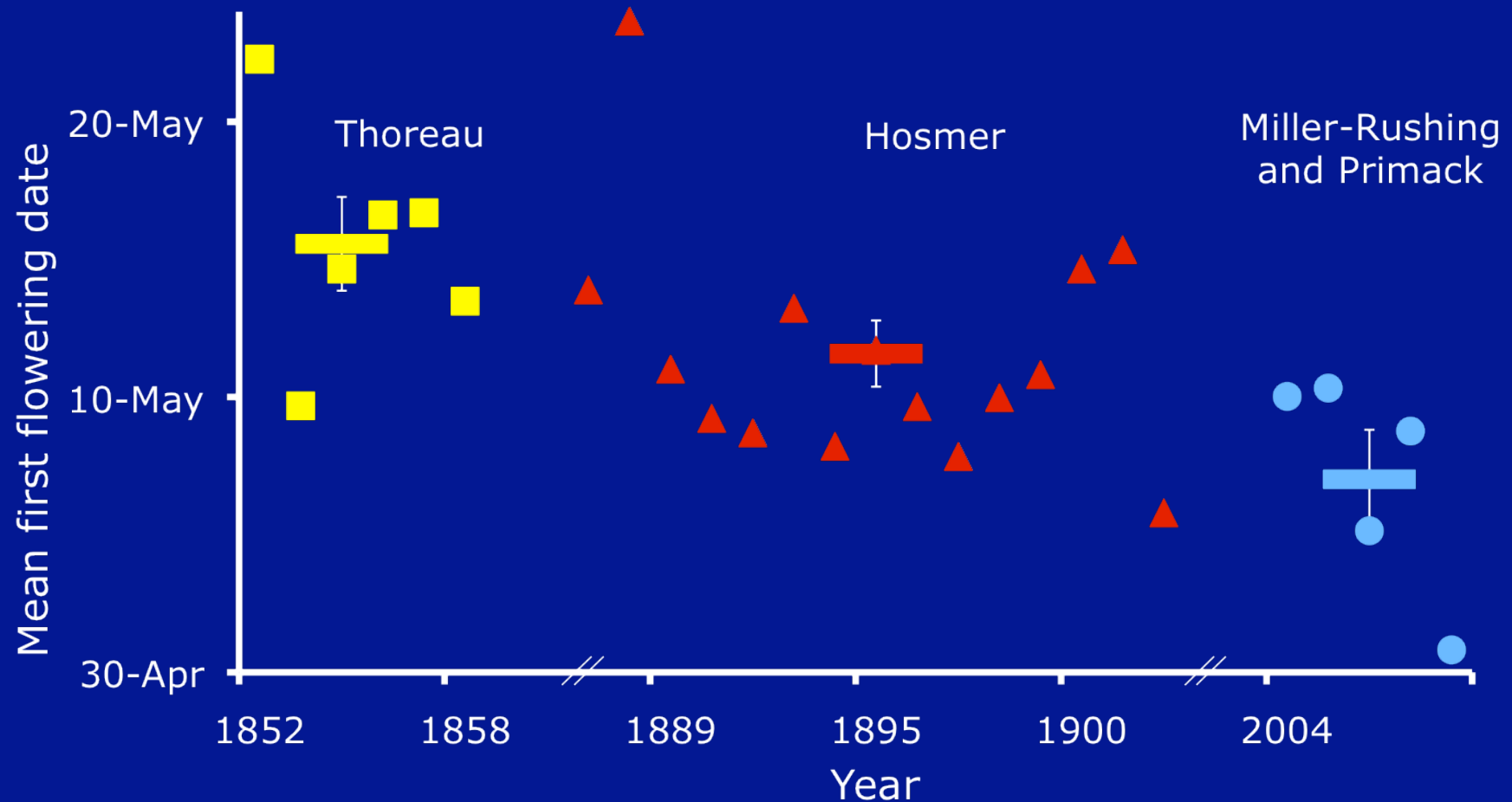


Rhodora



Bird's foot violet

Earlier flowering times



Miller-Rushing and Primack. 2008. *Ecology*

Photographs and climate change

Example: Fringe tree



20 June 1926



American Fringe Tree
Chionanthus virginicus

7 May 2003

Miller-Rushing et al. 2006. Amer. J. Bot.

Photographs from Lowell Cemetery



30 May 1868



22 May 2010

Miller-Rushing et al. 2006

New Sources of Data; Herbarium specimens



Primack et al. 2004.

Intensive search for bird data



Are the birds responding
to climate change?

Is their response similar
to that of plants?



Insects are the missing link!

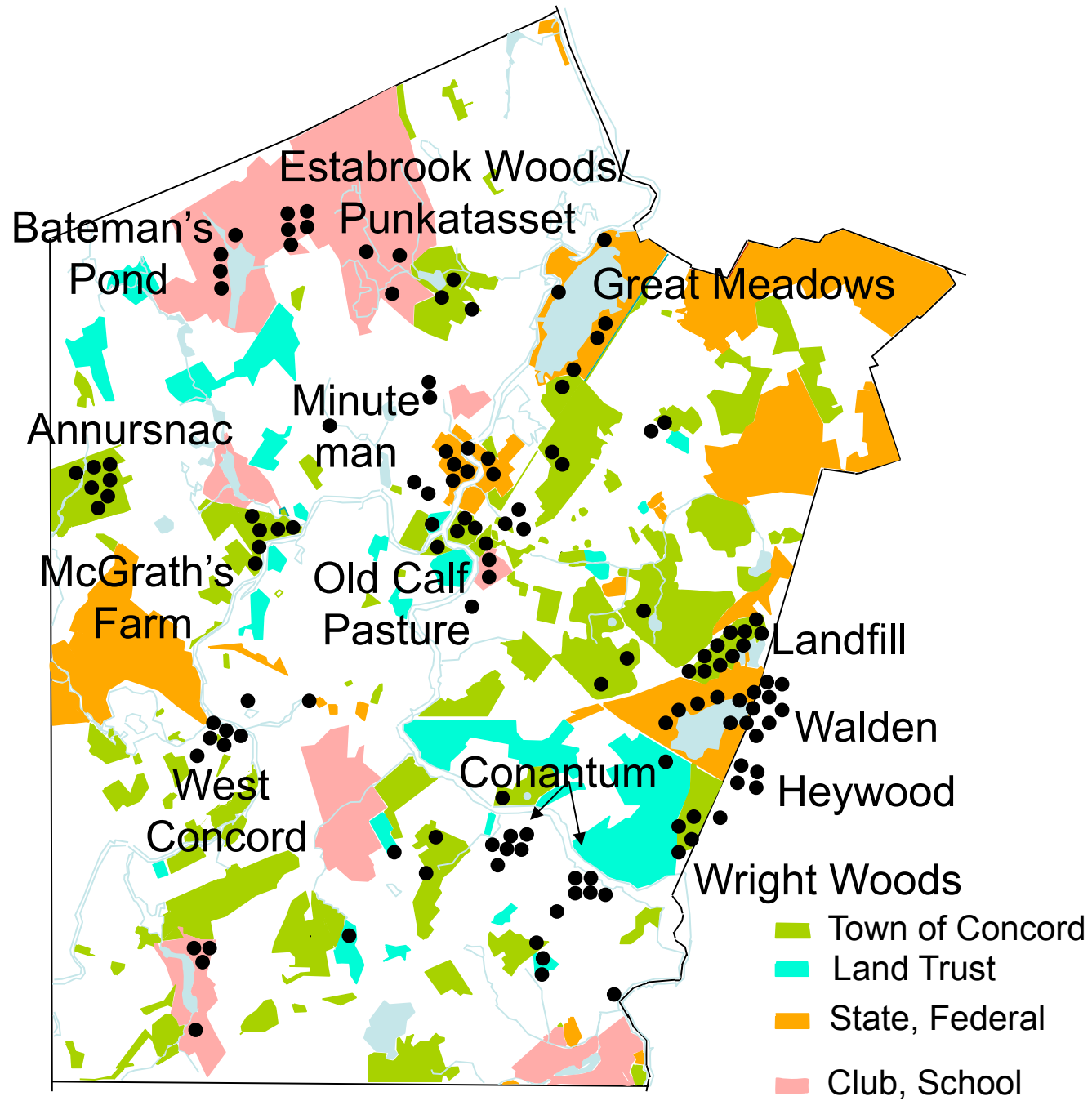


Species lost



Purple fringed orchid
(*Habenaria psychodes*)

- 27% of Thoreau's species now extinct
- 36% now rare (one or two populations)
- Most loss over last 40-50 years - due to many factors



What we have learned: Management is needed



Flowering times predict which species are most successful



Purple loosestrife

Willis et al. 2010 PLoS One

Conclusions

- Spring is arriving earlier; and further changes are coming.
- Interactions are changing.
- Climate is just one cause of changes.
- Management is essential.
- Experiments are needed, including assisted migrations.
- We need to inform and involve the public and students.



Climate change is here
in Massachusetts
already, and we need
to adapt to these
changes!