Rapid range expansion of the pine processionary moth in the southern Alps: the role of the record warm summer of 2003

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Northern / uppermost margin of distribution of *T. pityocampa*

➔ determined primarily by winter larval survival:

1) **Immediate temperature effects**

➔ Lower Lethal Temperature (-16 C)

2) **Cumulative temperature-effects**

➔ temperature controls feeding activity
➔ larvae starve unless:

night air temp > 0 C
AND
previous daytime nest temp > 9 C

In the last three decades…

➔ latitudinal and altitudinal range expansion

- explained by increasing winter temperatures

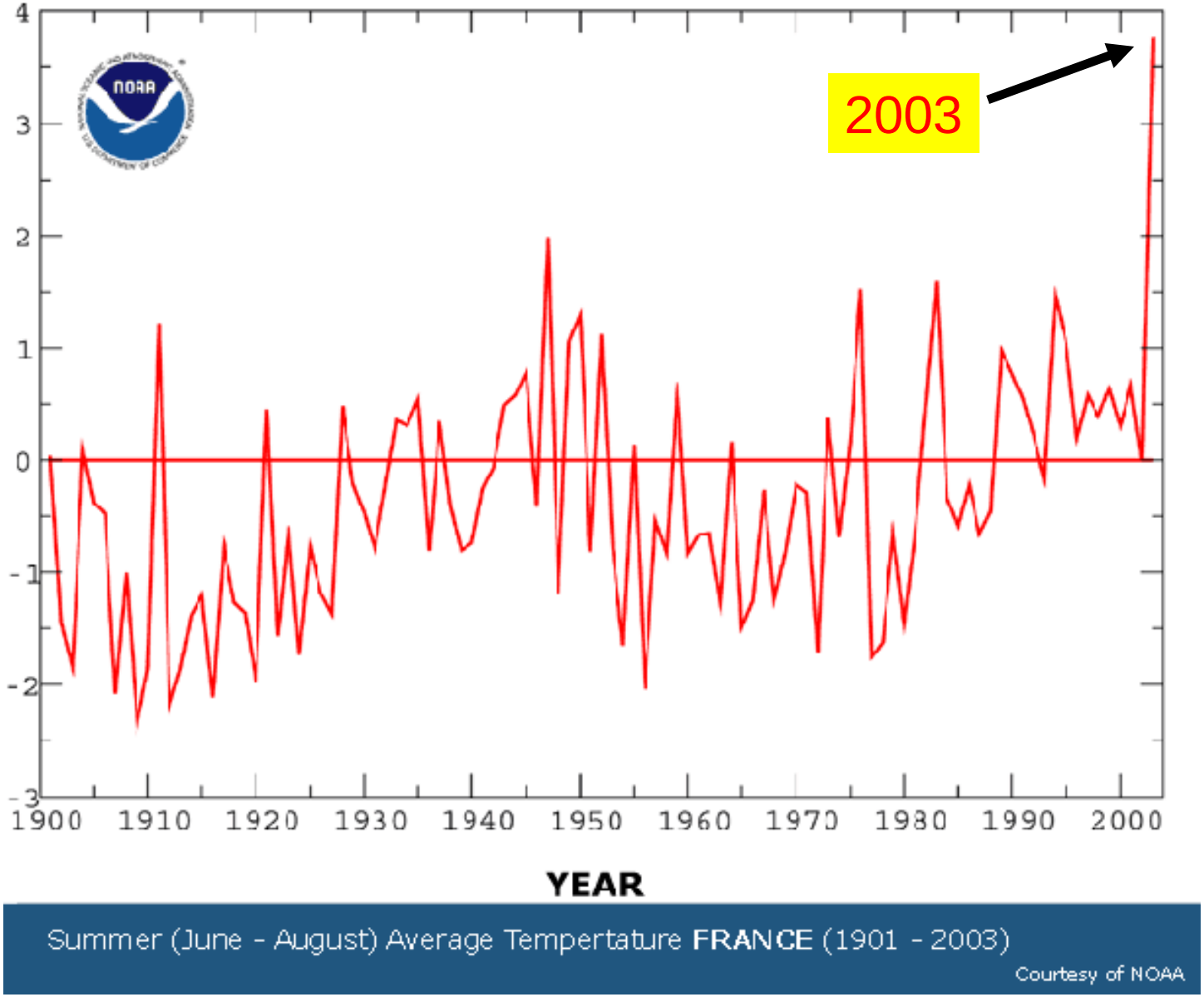
(Battisti et al., Ecological Applications, *in press)*

- assumed to be relatively gradual

➔ females are poor dispersers

➔ dispersal into new sites is largely unaffected by climate (?)

Summer 2003 ➔ 500-year climatic anomaly



In the fall 2003…

…pine processionary moth colonies found in higher elevations in the southern Alps than ever before

➔ **rapid expansion of geographic range**

1) **How does the 2003 expansion compare to previous annual rates of expansion?**

2) **Is there a causal link between the climatic anomaly and rapid expansion? – i.e. did increased temperatures in summer 2003 enhance female dispersal?**

3) **Is the effect only ephemeral, or can it drive future expansion?**

Approach:

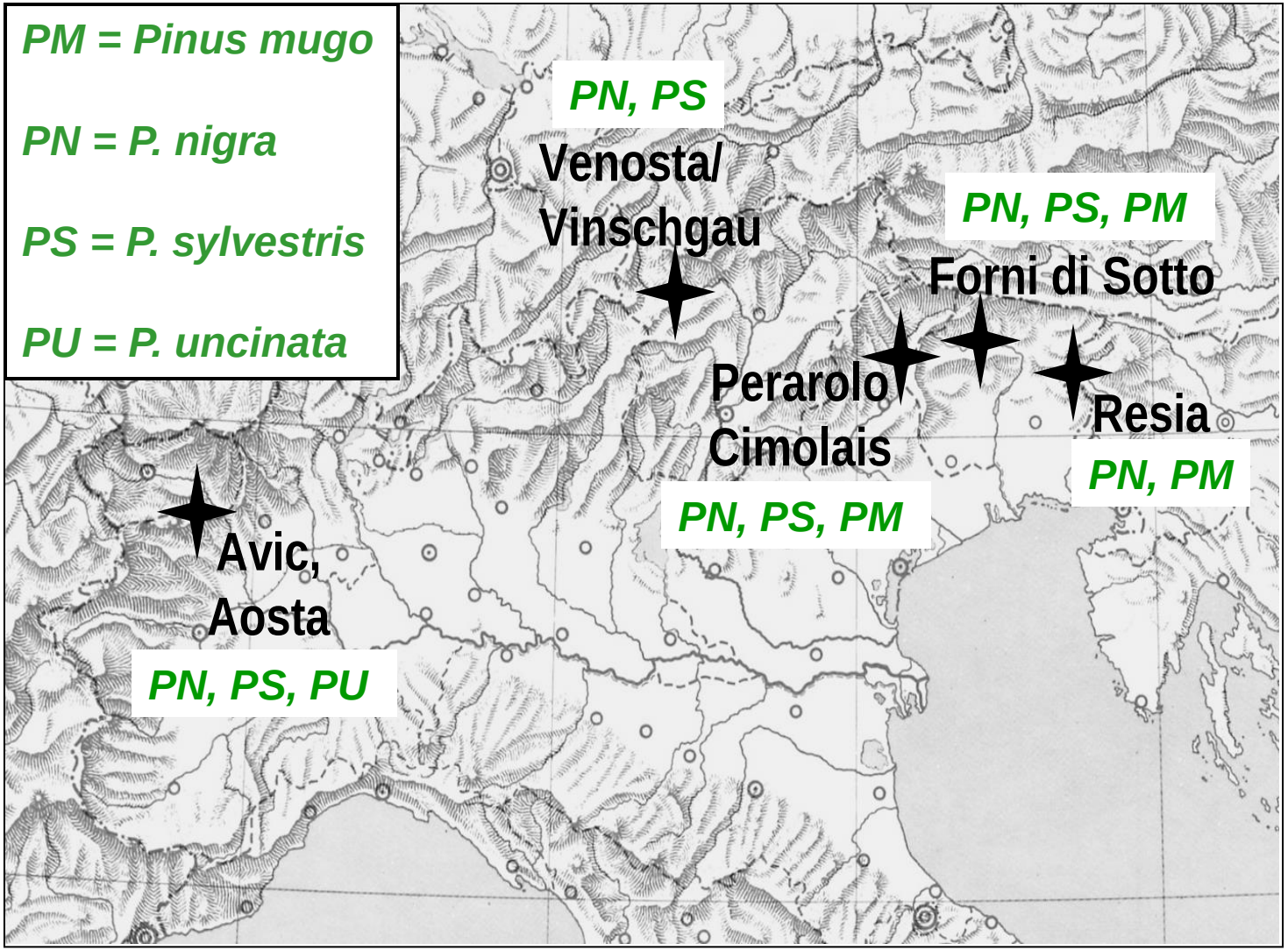
1) Nest surveys to map new altitudinal distribution

2) Cage experiments to test the effect of temperature on female flight

3) Monitoring of nests in newly colonized areas to assess winter survival and potential for population persistence

4) Synthesis of life history traits in the context of expansion

Study sites:


PM = Pinus mugo
PN = P. nigra
PS = P. sylvestris
PU = P. uncinata
PN, PS
Venosta/
Vinschgau
PN, PS, PM
Forni di Sotto
Perarolo
Cimolais
Resia
PN, PM
PN, PS, PM
Avic,
Aosta
PN, PS, PU

2003 expansion

Expansion = lowest straight distance (or elevation) between two extreme nests in respective years

Site	Historical upper limit (m)	2002 upper limit	2003 upper limit	2004 upper limit	Elevation gain 2003 (m)	Distance gain 2003 (m)
Avic, Aosta	1000	1310	1430	1430	113.7 ± 23.0	232.7 ± 22.4
Venosta/Vinschgau	1150	1350	1415	1380	65.0 ± 12.3	120.4 ± 17.2
Perarolo, Cimolais	760	1010	1150	1130	114.3 ± 25.7	642.2 ± 70.7
Forni di Sotto	950	1250	1300	1300	114.5 ± 41.2	243.1 ± 67.4
Resia	860	1090	1210	1200	45.6 ± 11.3	168.8 ± 55.3

2003 expansion

➔ **equals 38% of the overall expansion since 1970s**

avg. rate of 8.6 ± 0.7 m / y *versus* 99 ± 11.3

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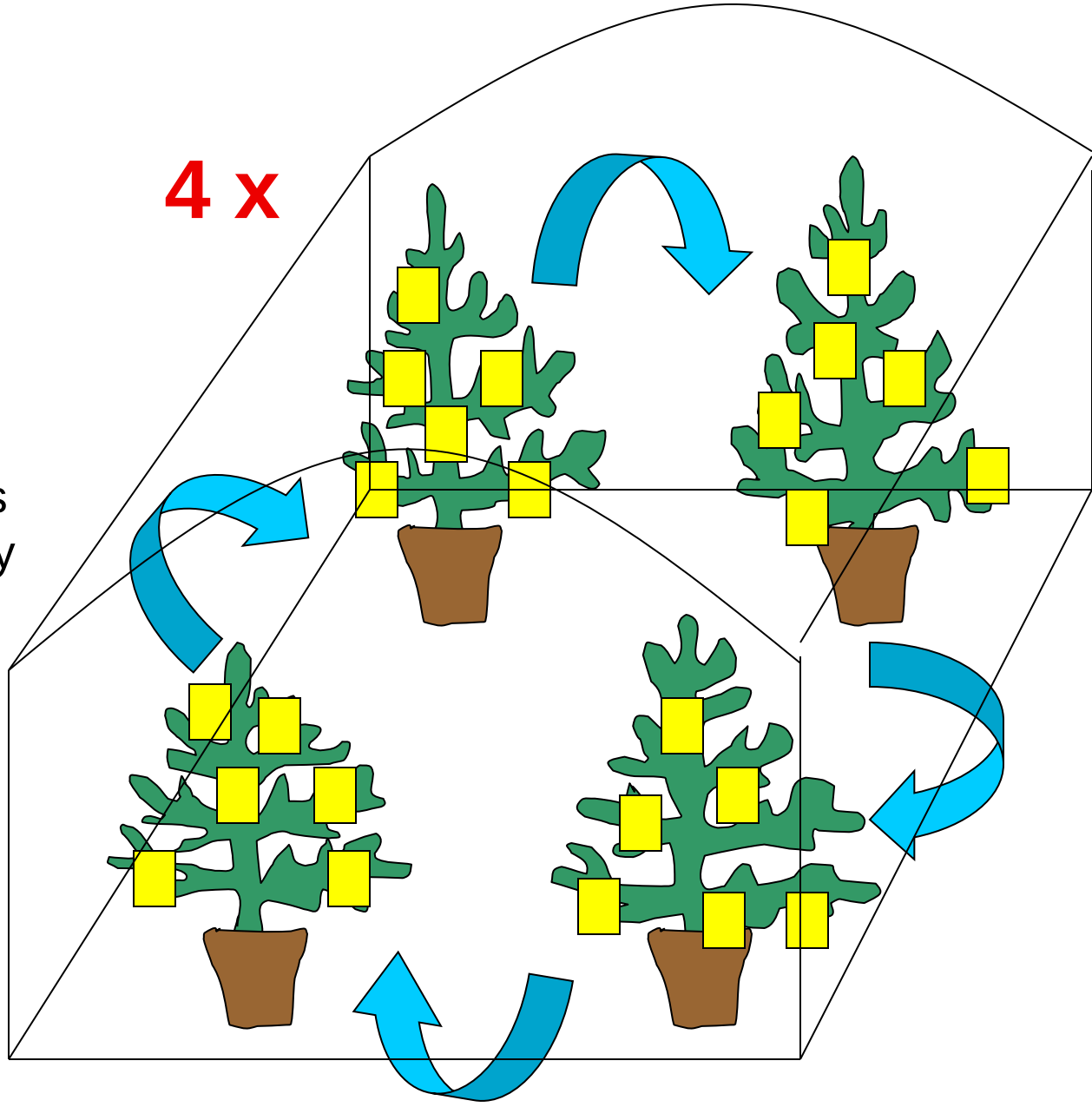
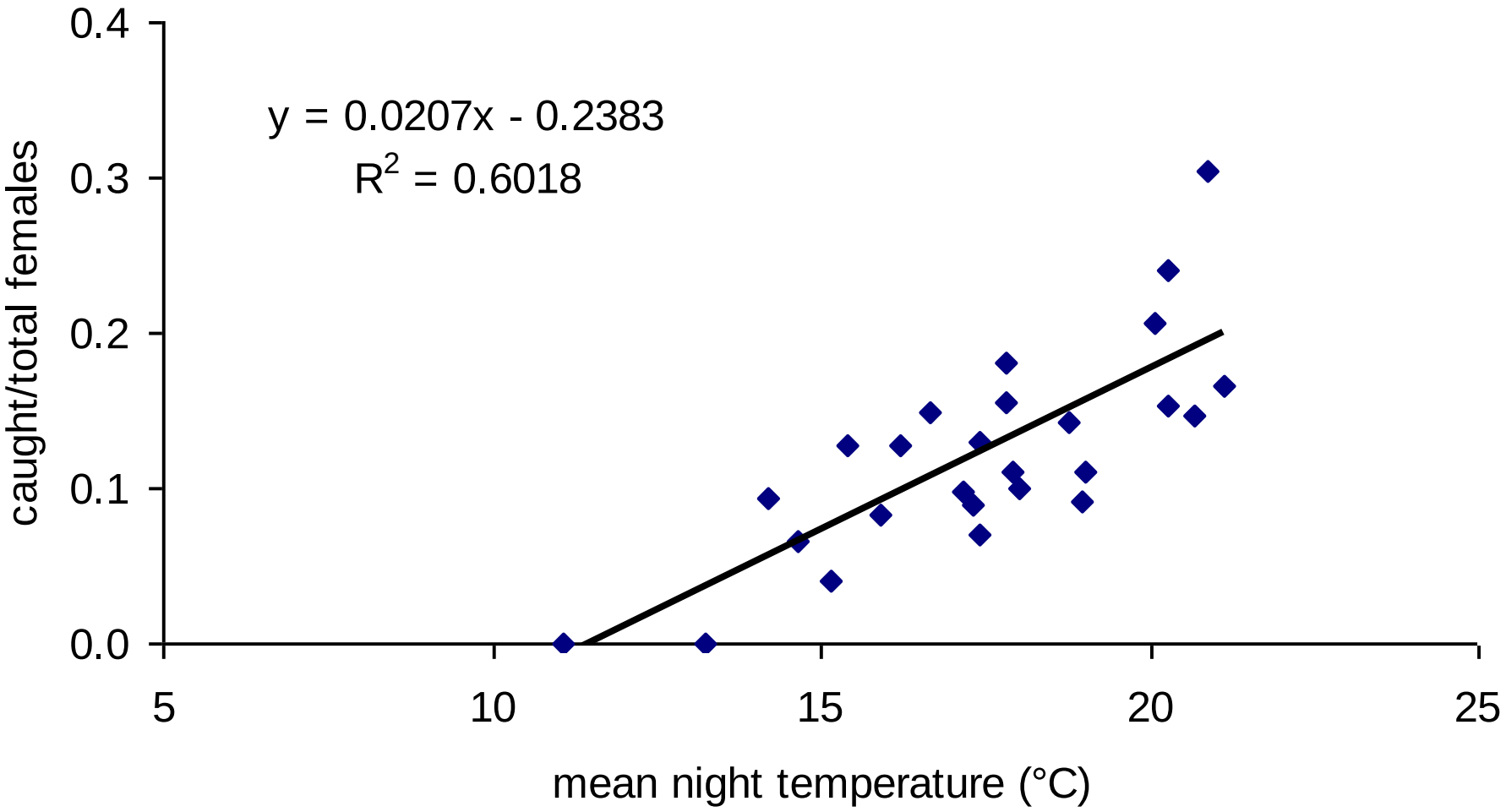
Cage experiments

- outdoor cages at University of Padova, Italy
- flight activity estimated from nightly trap catches of females on sticky traps attached to *P. nigra* trees
- dead females not caught on traps also counted
- temperature recorded hourly



- flight activity increased with night temperature
- take-off only above 14^0C ← ***threshold temperature for flight***



If flight is temperature-dependent, could dispersal in expansion areas be limited by summer night temperatures?

➔ i.e. few females are able to take off for flight?

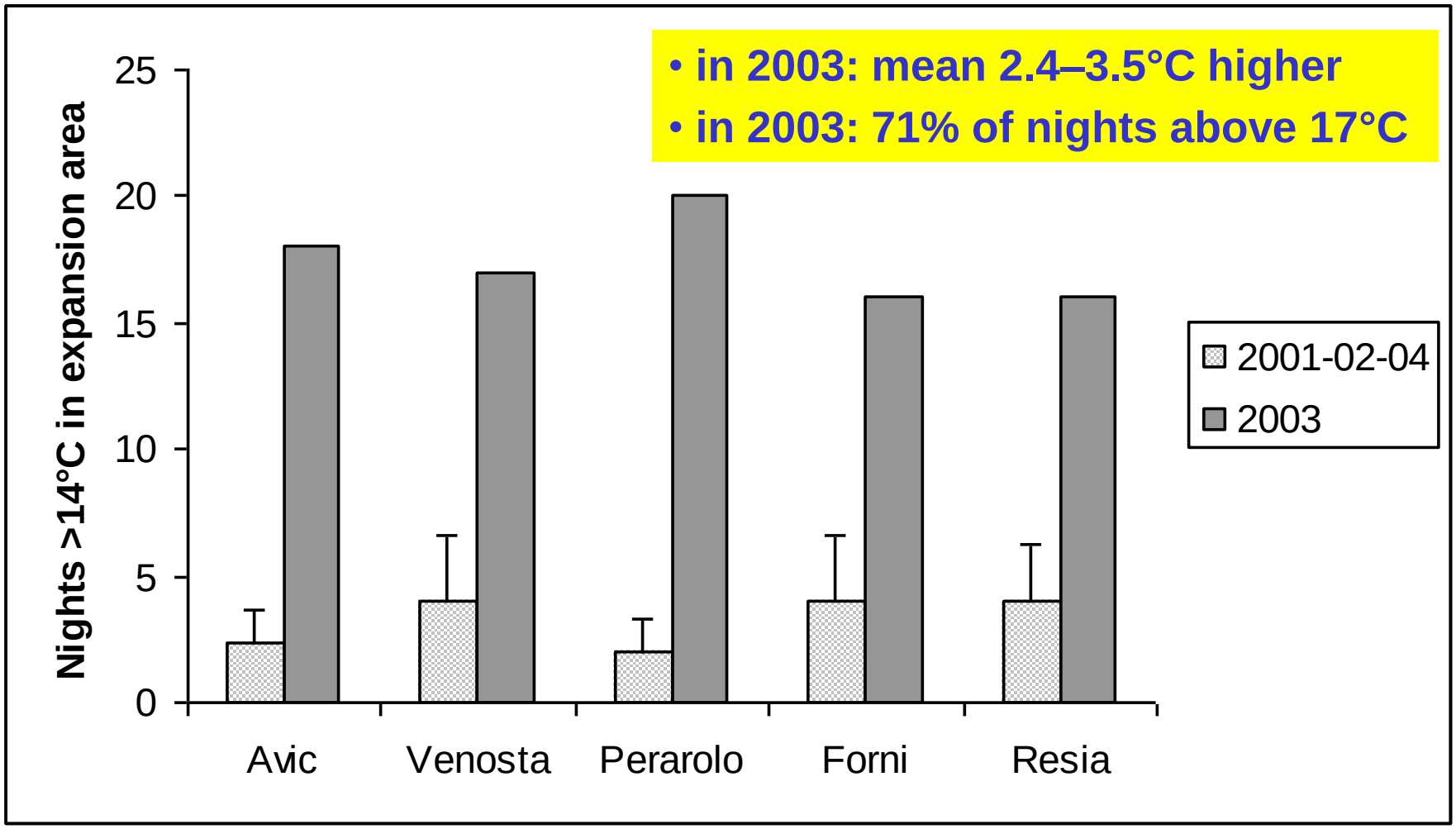
How many nights during the emergence period did females experience temperatures above take-off threshold…

1) during the summer 2003?

versus

2) during an average summer?

Number of nights above the take off threshold of 14°C at the expansion edge in 2003 compared with the mean of 2001, 2002 and 2004.



Warmer nights much more frequent in 2003…

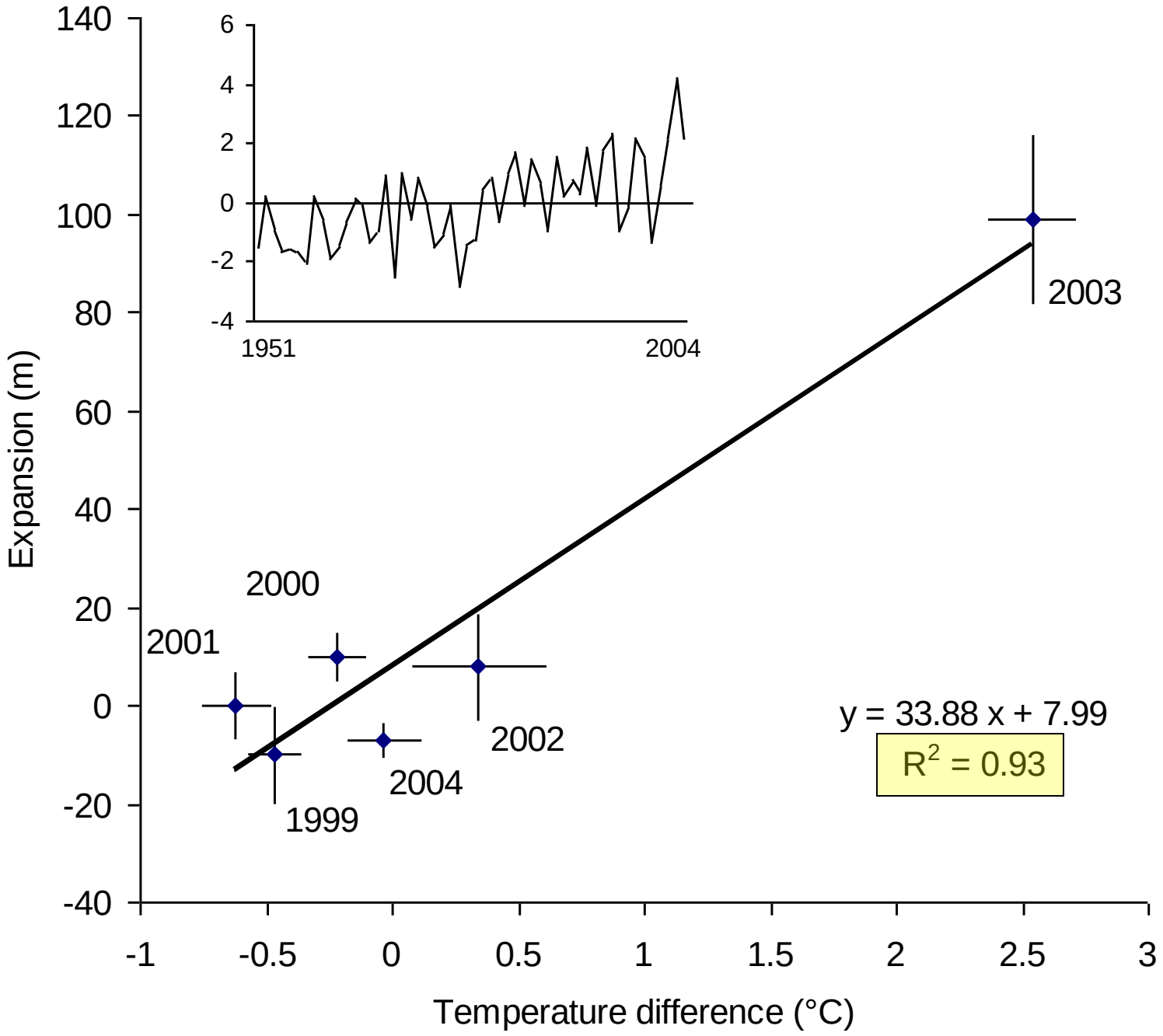
➔ more females take-off

➔ more long-distance dispersal events

➔ increased distance per flight (?)

increased frequency of successful colonization of extreme sites

Evidence of a link between expansion and summer temperature in the past?


Expansion (m)
Temperature difference (°C)
140
120
100
80
60
40
20
0
-20
-40
-1
-0.5
0
0.5
1
1.5
2
2.5
3
6
4
2
0
-2
-4
1951
2004
2003
2000
2001
2002
2004
1999
y = 33.88 x + 7.99
R2 = 0.93

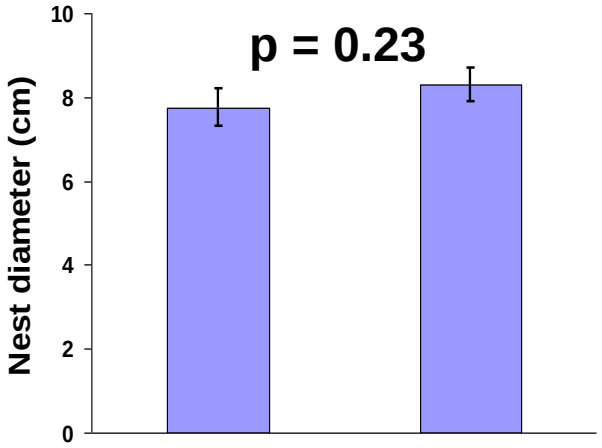
Following unusual expansion due to climatic anomaly, colonies exist beyond the previous range boundary

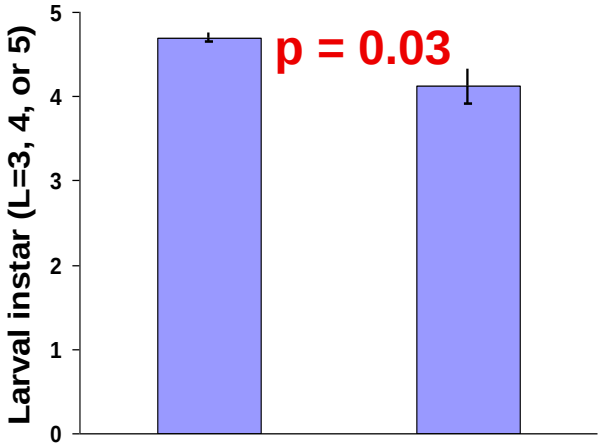
…but can they survive the winter at these elevations??

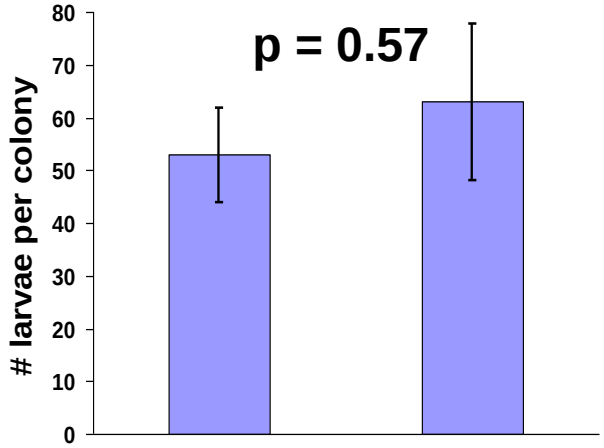
Monitoring of colonies in winter 2003/2004:

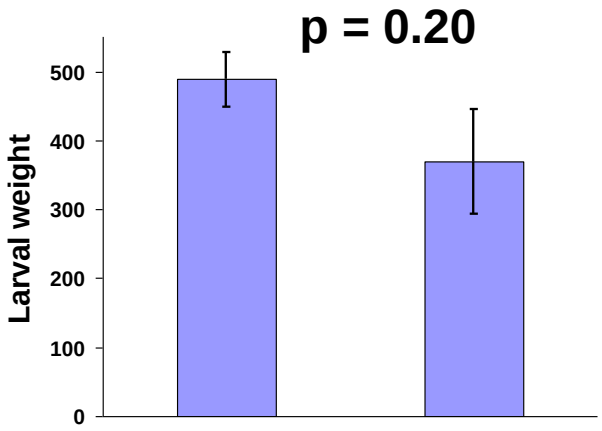
- comparison of 1) extreme sites (2003 expansion)
  2) nearby “core” sites (2002 distribution)

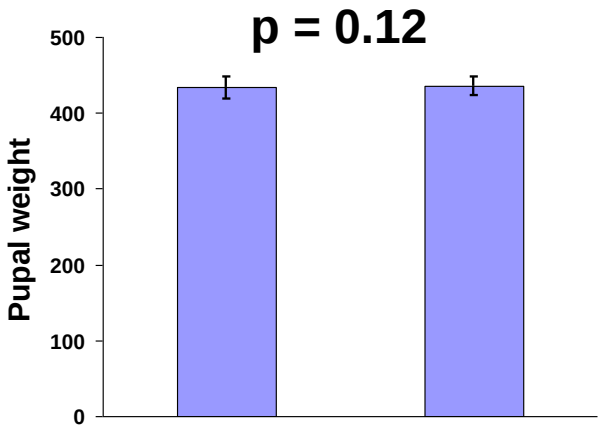
- variables : nest diameter
  : number of larvae per colony
  : larval instar
  : larval weight
  : pupal weight











Extreme sites

➔ **delayed phenology**

➔ **similar colony size, larval size & weight, pupal weight**

In 2004…

➔ **since 2003, upper limit remained constant or contracted slightly:**

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…so what?

Winter of 2003/2004 was just an average winter

➔ sooner or later those populations will go extinct and the range will shrink back to previous extent

Can the anomalous expansion of 2003 have long-term effects on the future range boundary?

1) **Larvae tolerate cold** (physiological and behavioral adaptations)

➔ development possible in environments outside the original range

2) **Pupae can enter prolonged diapause**

➔ bet-hedging strategy balances larval mortality events

population persistence at extreme sites

Synthesis

- **expansion of *T.pityocampa* appears to be dispersal limited**

  ➔ survival in areas outside the historical range is possible (likely due to warming trends)

  ➔ dispersal is enhanced during warmer-than-average summers

  ➔ new range boundary established in 2003 is likely to persist, but further expansion may be delayed

- **extreme climatic events can drive species range dynamics**

Funding:

- *EU QLK5-CT-2002-852 Promoth*
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Climatic & temperature data:

- *Parco Naturale Mont Avic, Aosta*
- *Forest Service Bolzano/Bozen*
- *ARPAV Veneto*
- *OSMER Friuli VG*
- *Axel Schopf and colleagues*

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Comments:

- *Alberta Boato*
- *Marc Johnson*
- *Plant-Insect Interactions Discussion Group at Cornell University*
- *PROMOTH participants*