Bioenergetic influence on the historical development and decline of industrial fisheries, and implications for a warming ocean

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Outline

1 – Observation of a global pattern:

Earlier peak of harvest in high latitude regions.

2 – Comparison with a coupled bio-economic model:

BiOeconomic mArine Trophic Size-spectrum model (BOATS).

3 – Identification of first order mechanisms:

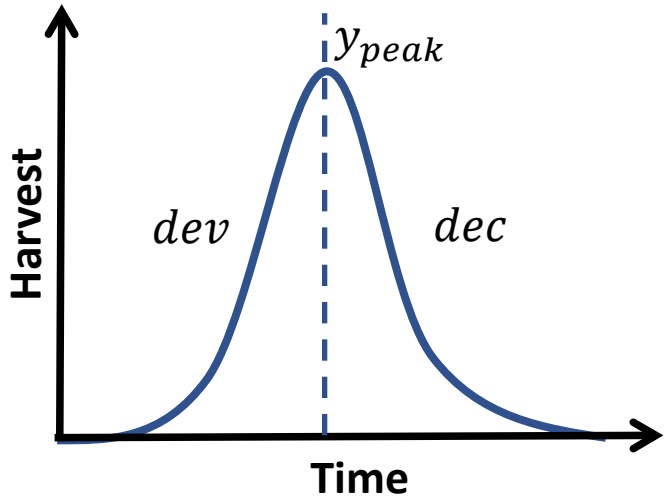
Bioenergetic influence on fisheries development's and implications in a warming ocean.

The development of fisheries (change of harvest with time) can be depicted by a peak:

Development

Maximum

Decline



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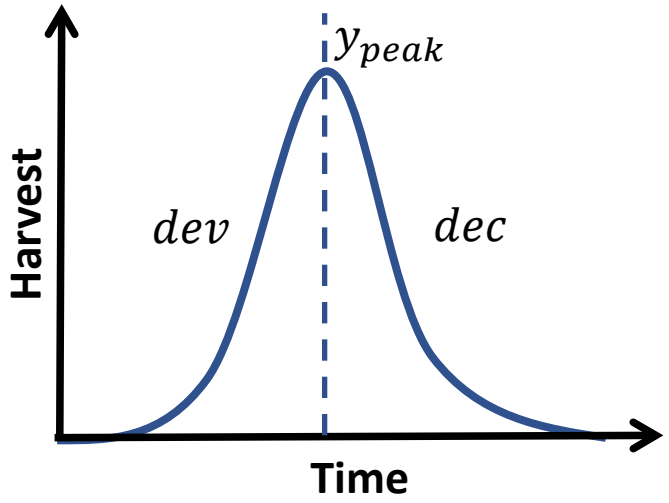
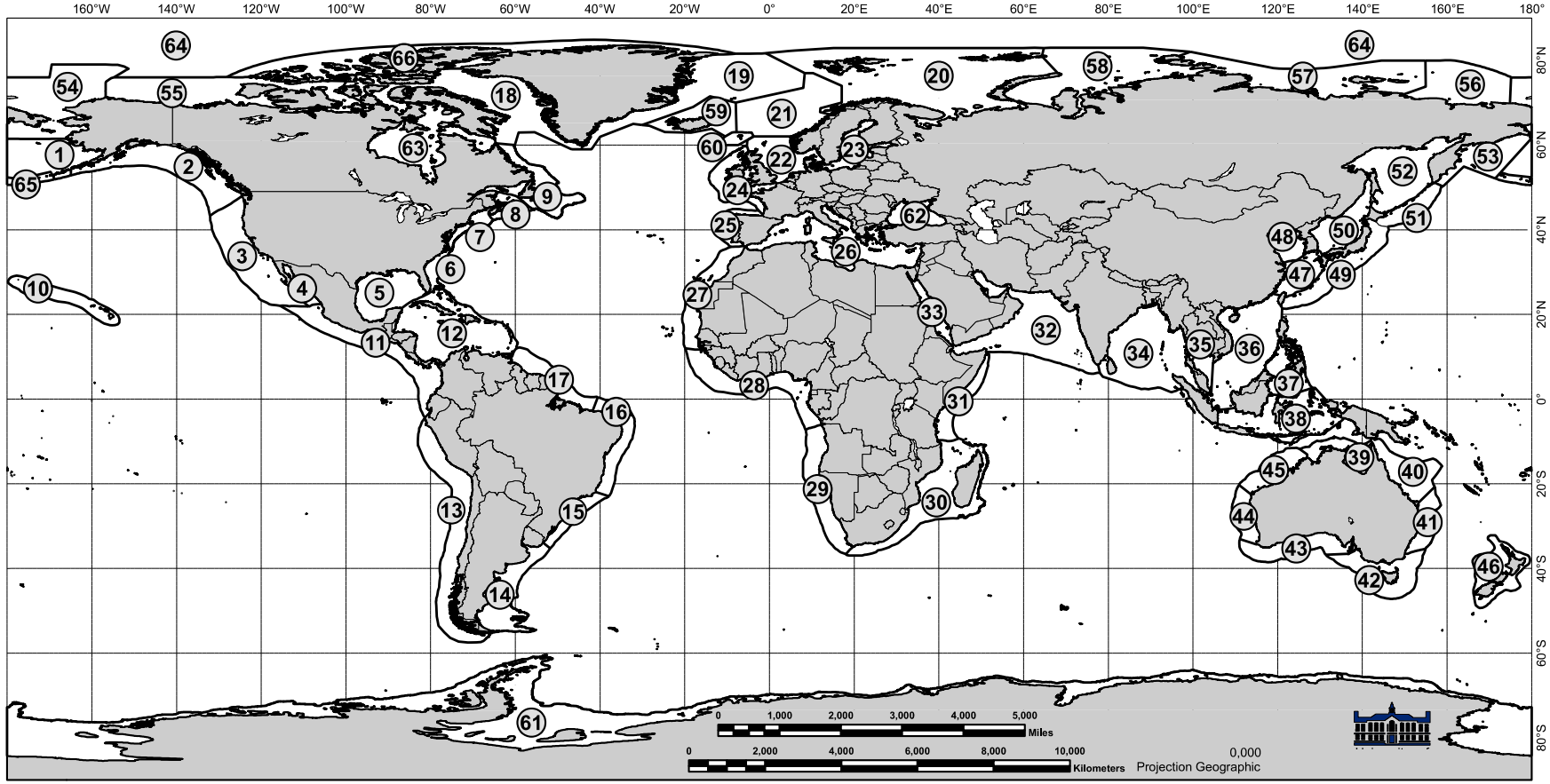


The year of peak harvest (y_{peak}) is an indicator of the development of fisheries.

1 – Observation of a global pattern

Large Marine Ecosystems (LMEs) of the world



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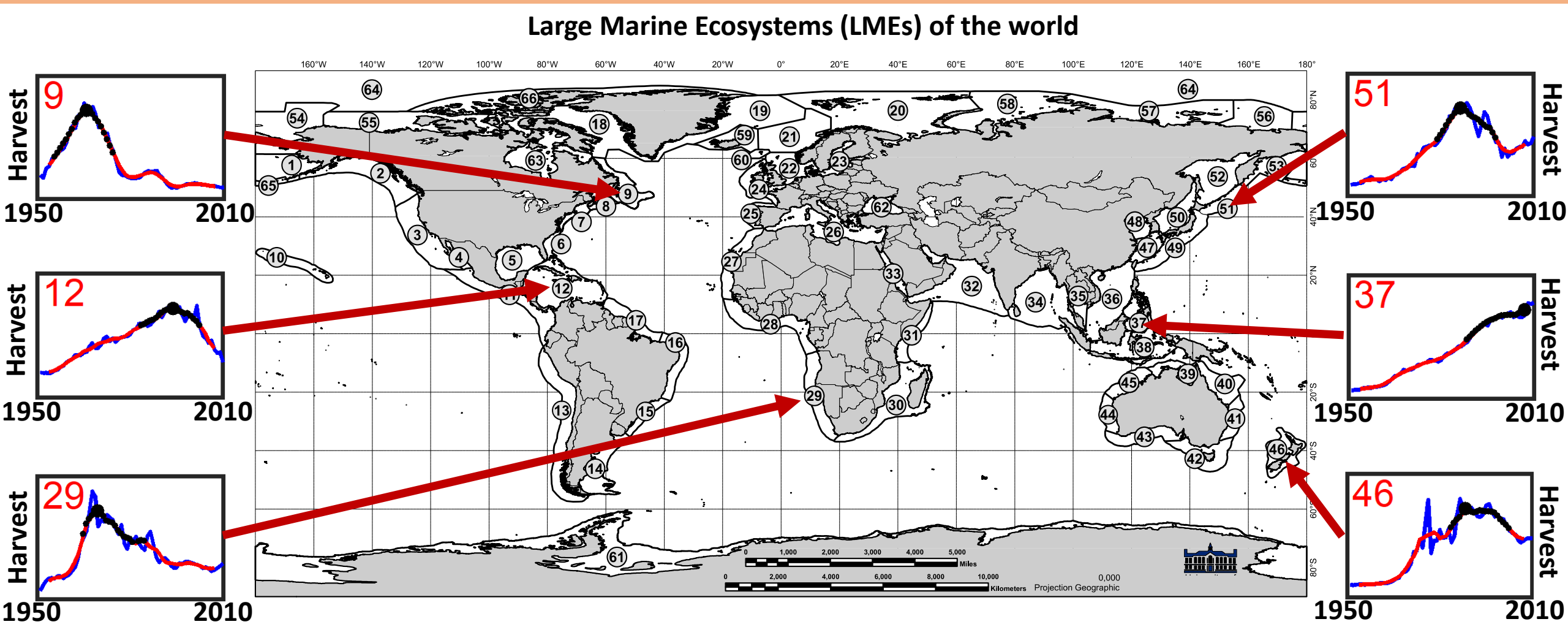

Reconstructed time-series of harvest in LMEs (Sea Around Us Project) indicate a delayed year of peak harvest with decreasing latitude.

1 – Observation of a global pattern

Half of the LMEs' harvest time-series show a harvest peak.

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- Shift of effort because of management.

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The year of peak (y_{peak}) is delayed with decreasing latitude.

Human driver

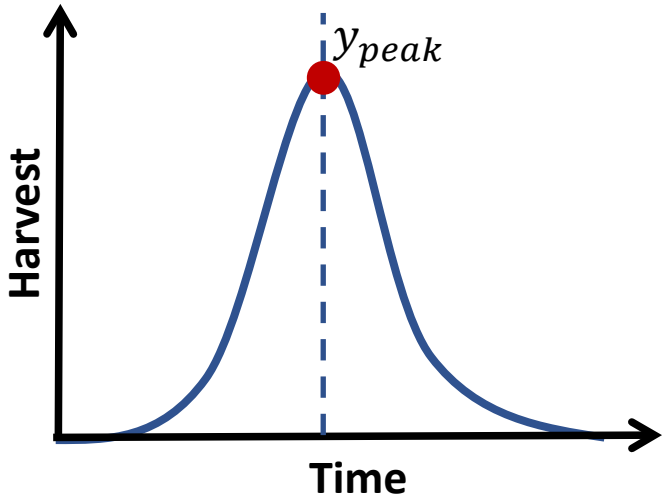
- Earlier technological development at high latitude.
- Shift of effort because of management.

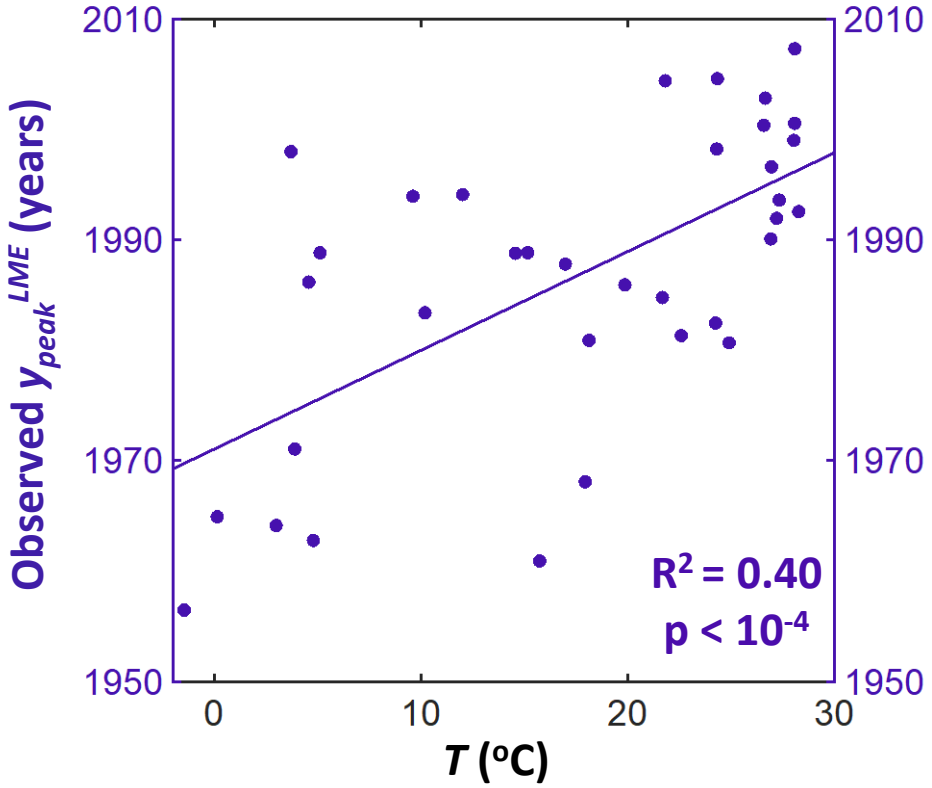
Natural driver

?

Temperature
Prim. prod.

The year of maximum harvest per LME (y_{peak}^{LME}) correlates with the mean LME temperature (T), not prim. prod.





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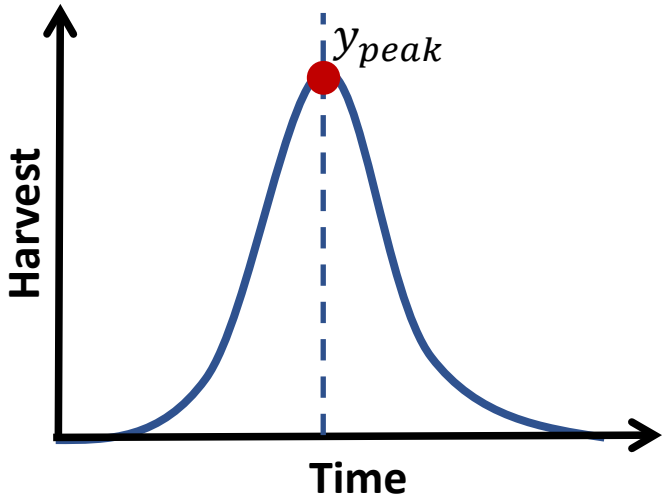
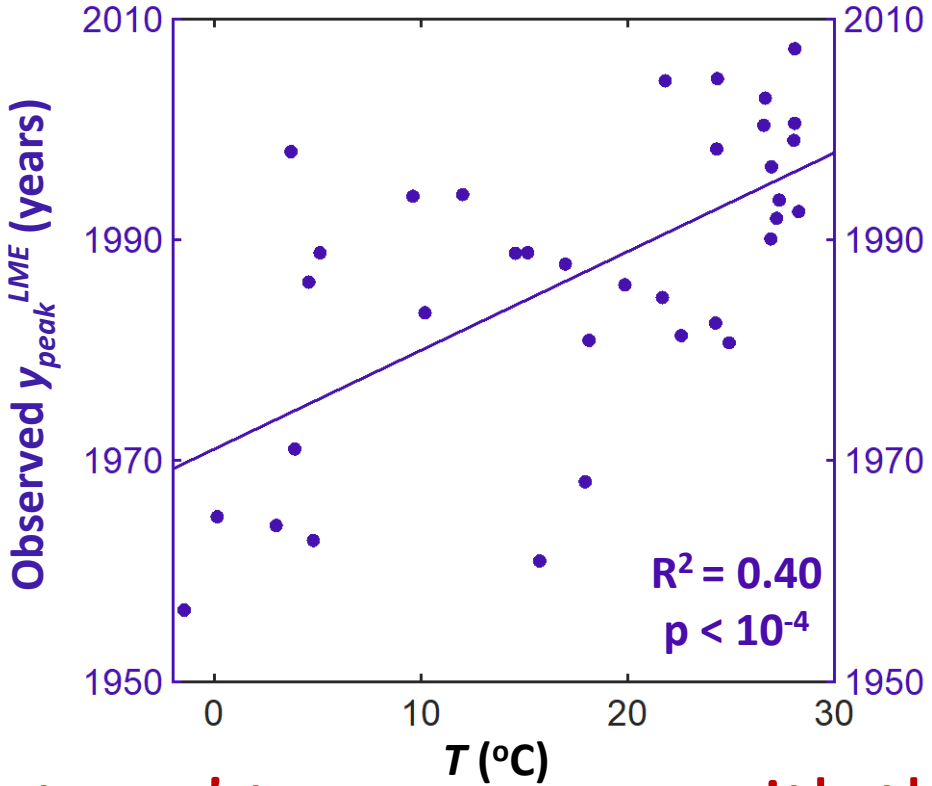
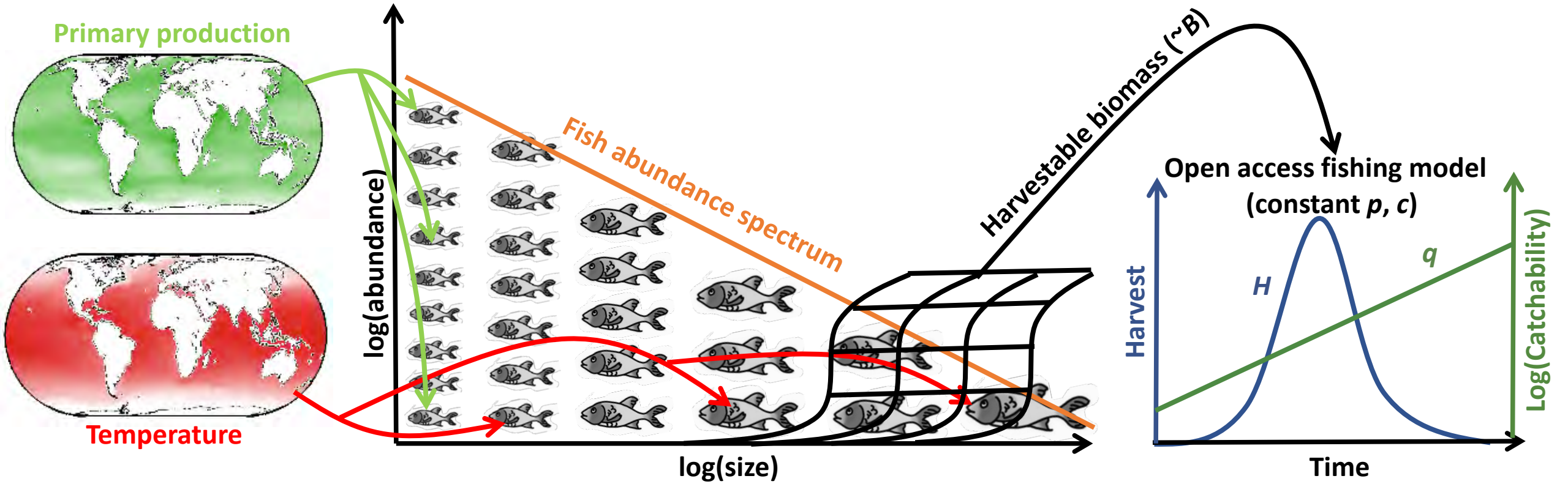




What mechanisms link ecosystems' temperature with the year of maximum harvest (y_{peak}^{LME})?

2 – Comparison with a coupled bio-economic model

BOATS links environmental conditions to fisheries development.



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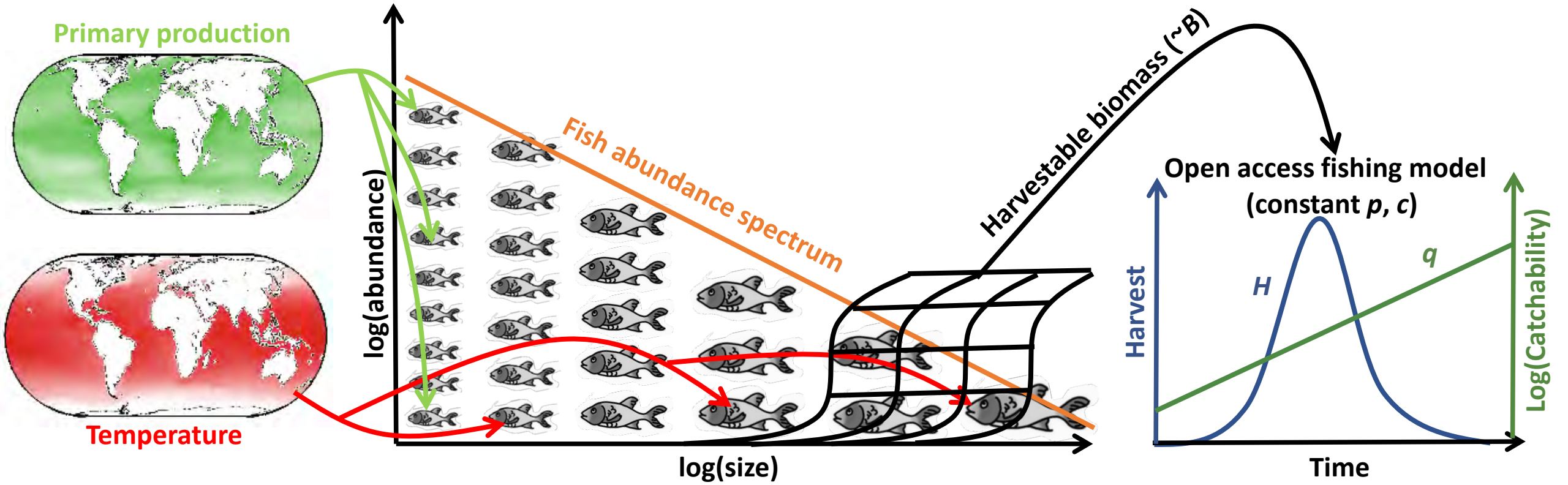
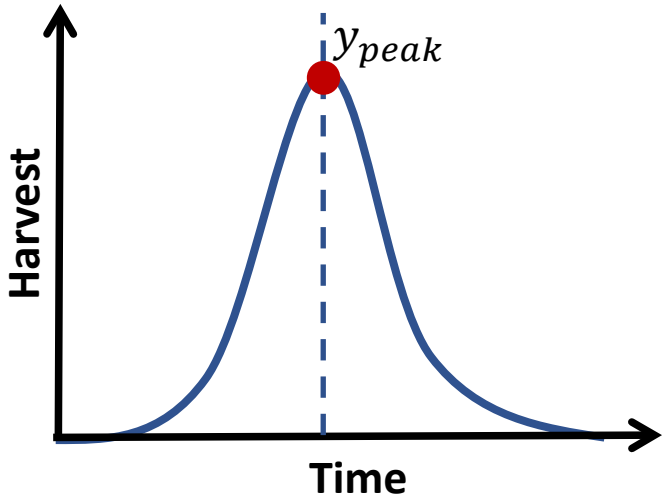
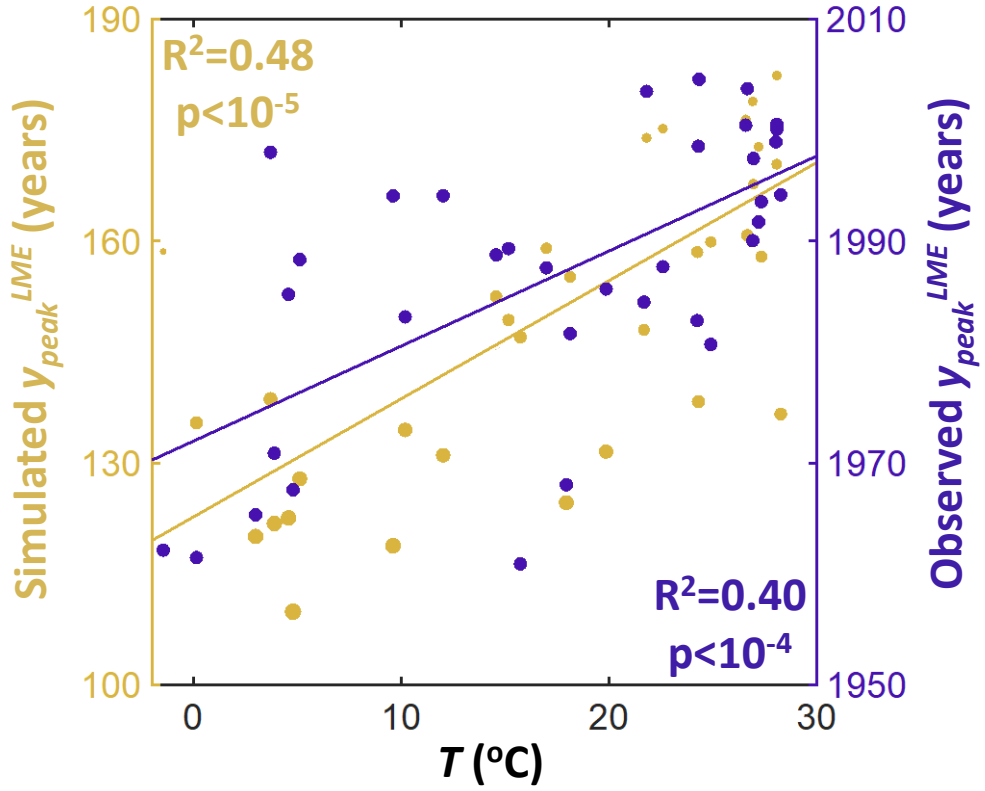


Simulations produce harvest peaks for which spatial differences emerge from different environmental conditions.

2 – Comparison with a coupled bio-economic model

The model reproduces the correlation of the year of maximum harvest ($y_{peak}{}^{LME}$) with the mean LME temperature (T).





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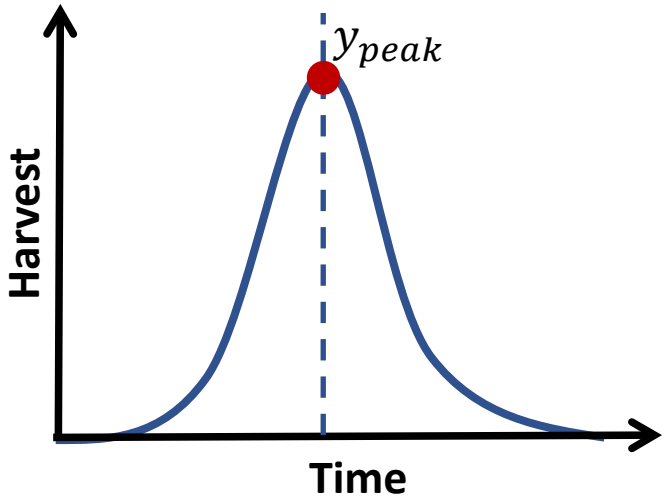
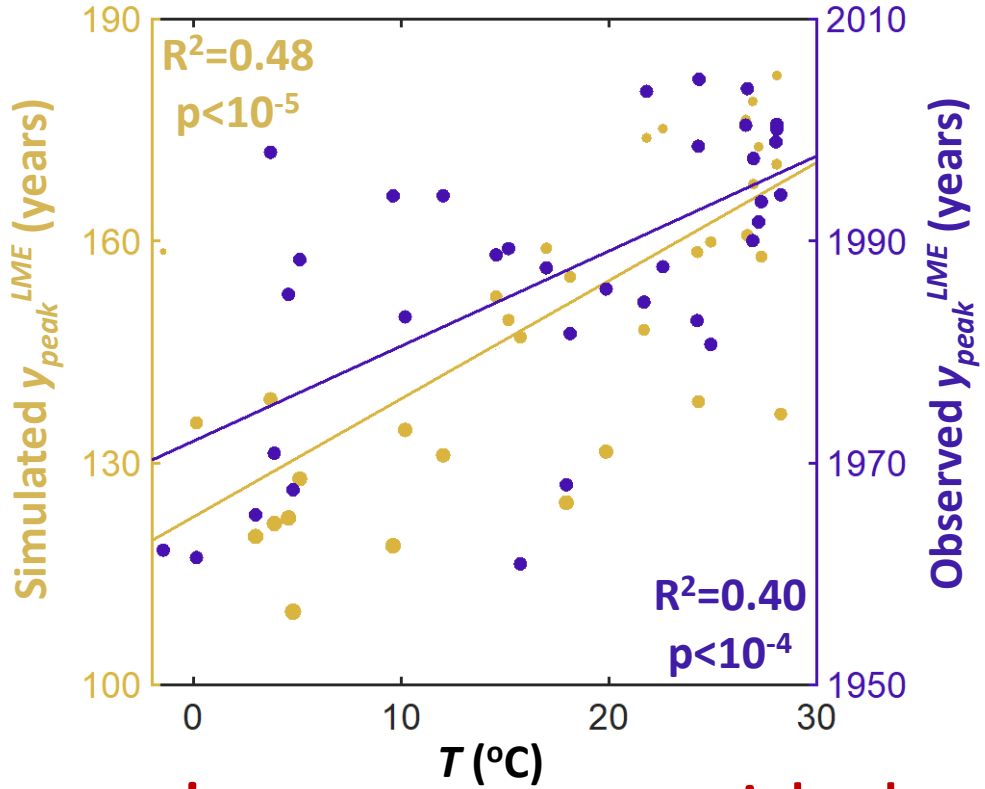
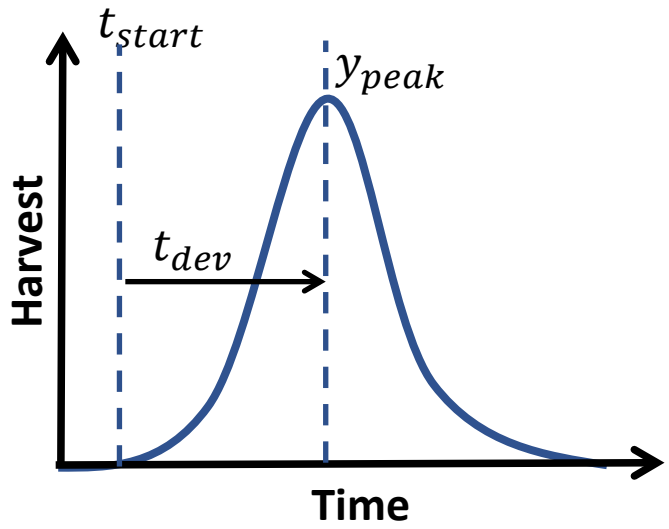




What mechanisms link ecosystems' temperature with the year of maximum harvest (y_{peak}^{LME})?

The year of maximum harvest (y_{peak}) depends on the year when fishing starts (t_{start}) and on the development time (t_{dev}).



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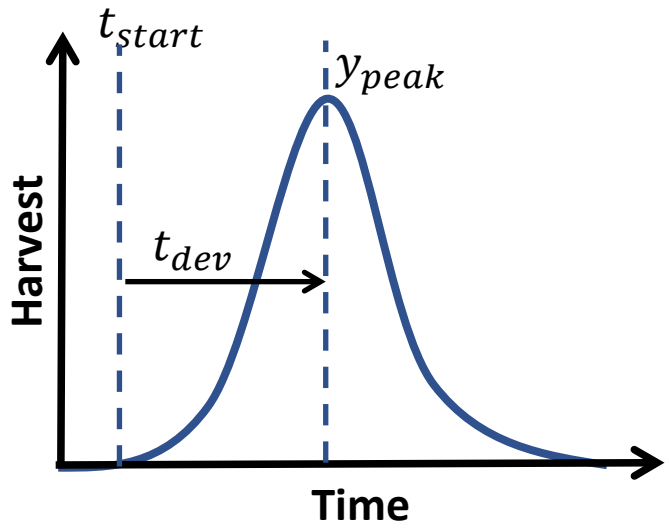


The model allows the exploration of the processes influencing the times (t_{start}) and (t_{dev}).

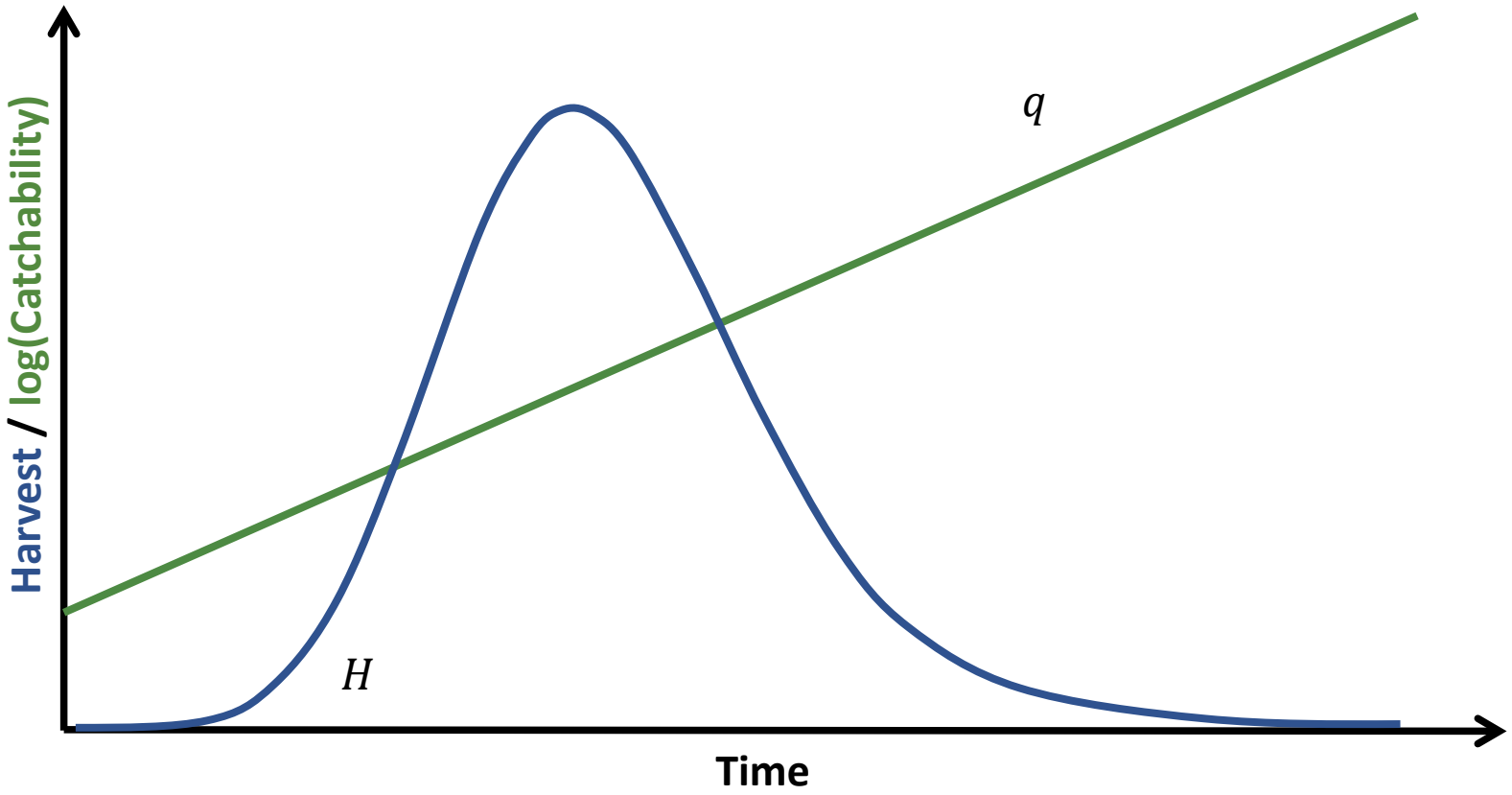
The onset of fishing (t_{start}).

Harvest start when revenues exceed costs:

$$revenue = p\ H \propto p\ q\ B\ E$$

$$cost = c\ E$$

p	Price of harvested biomass *H*
c	Cost of fishing
q	Catchability of biomass *B*
E	Fishing effort



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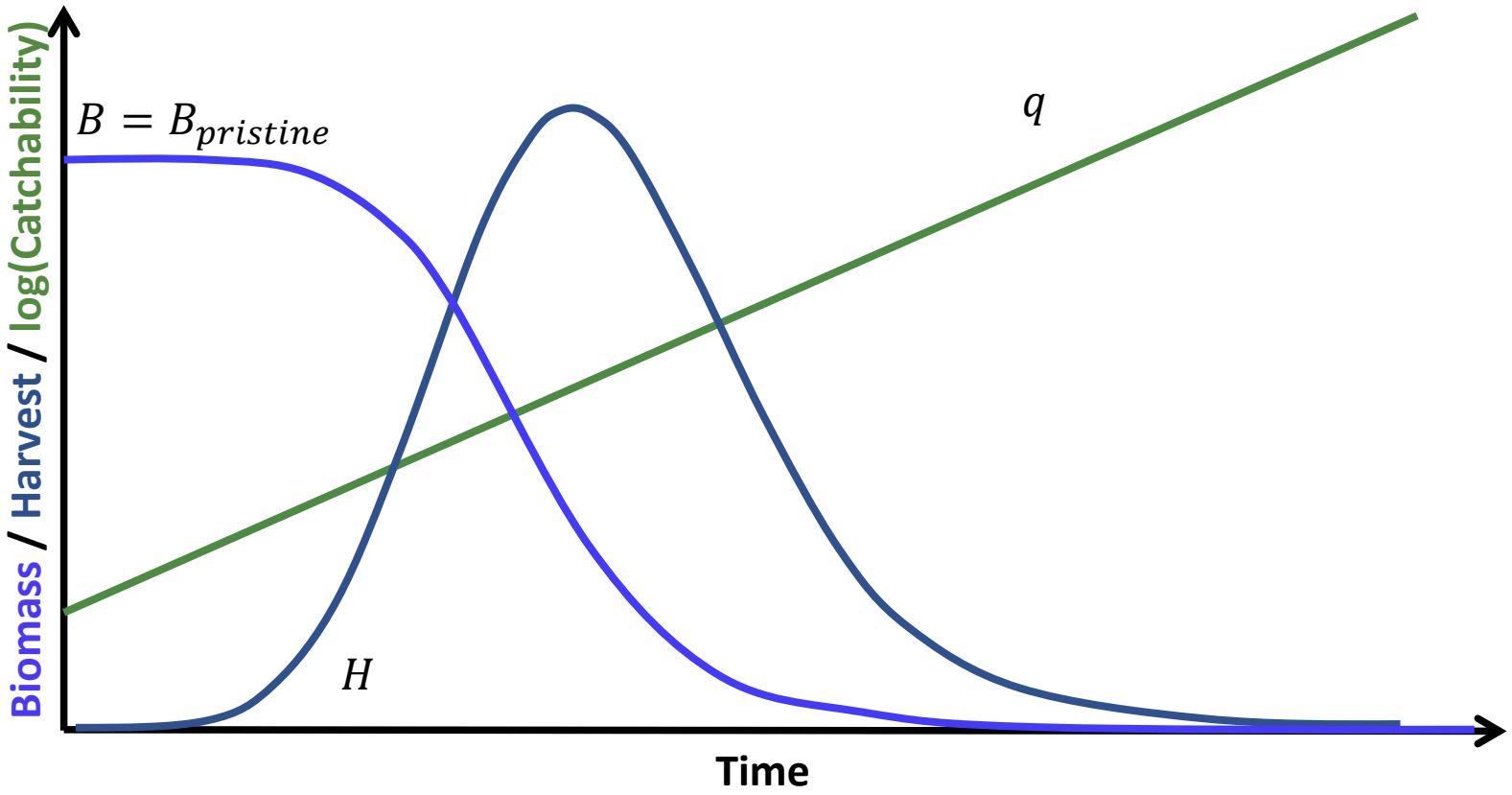
$$p\,q\,B > c$$

when

$$q > \frac{c}{pB}$$



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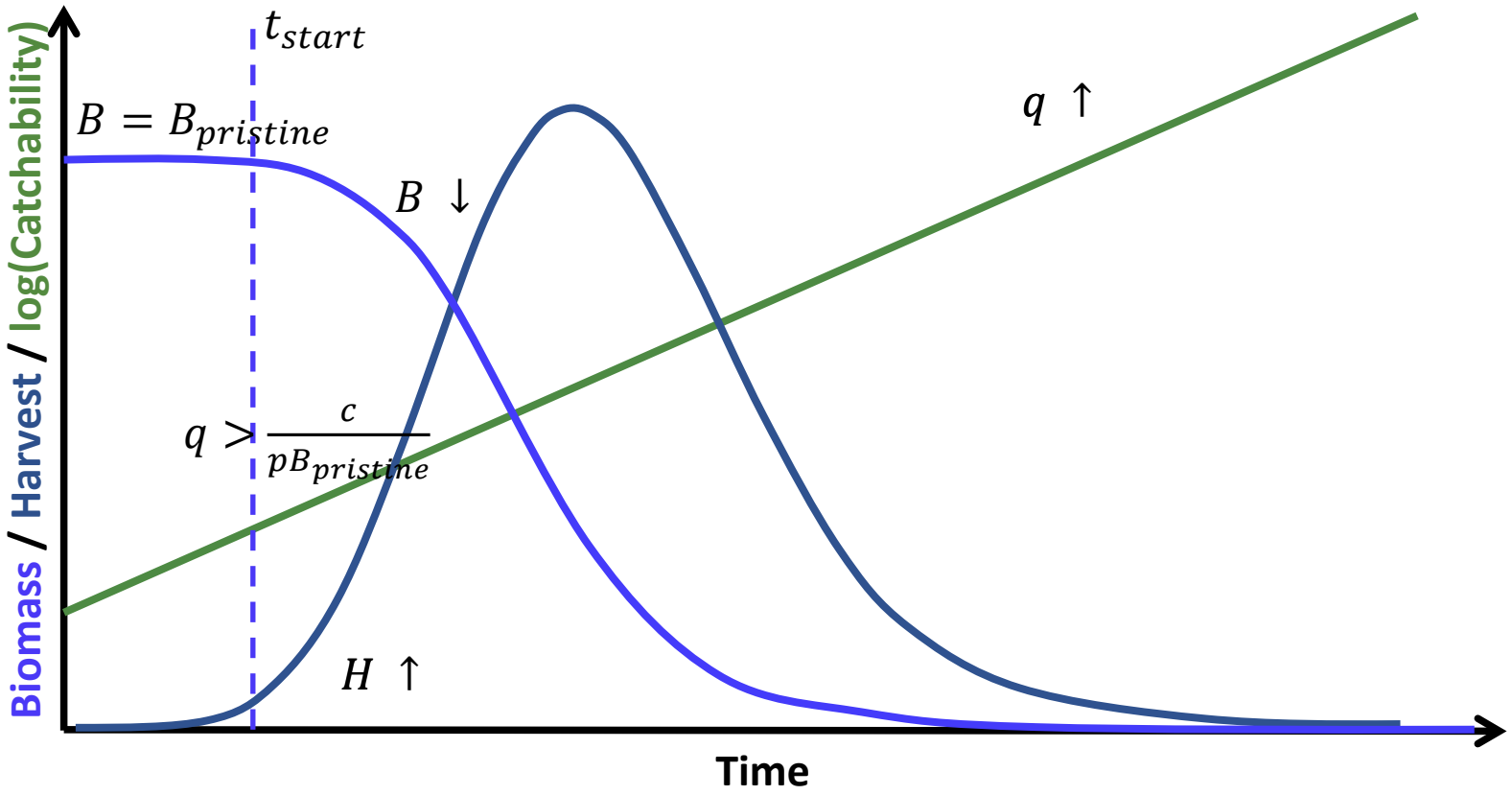

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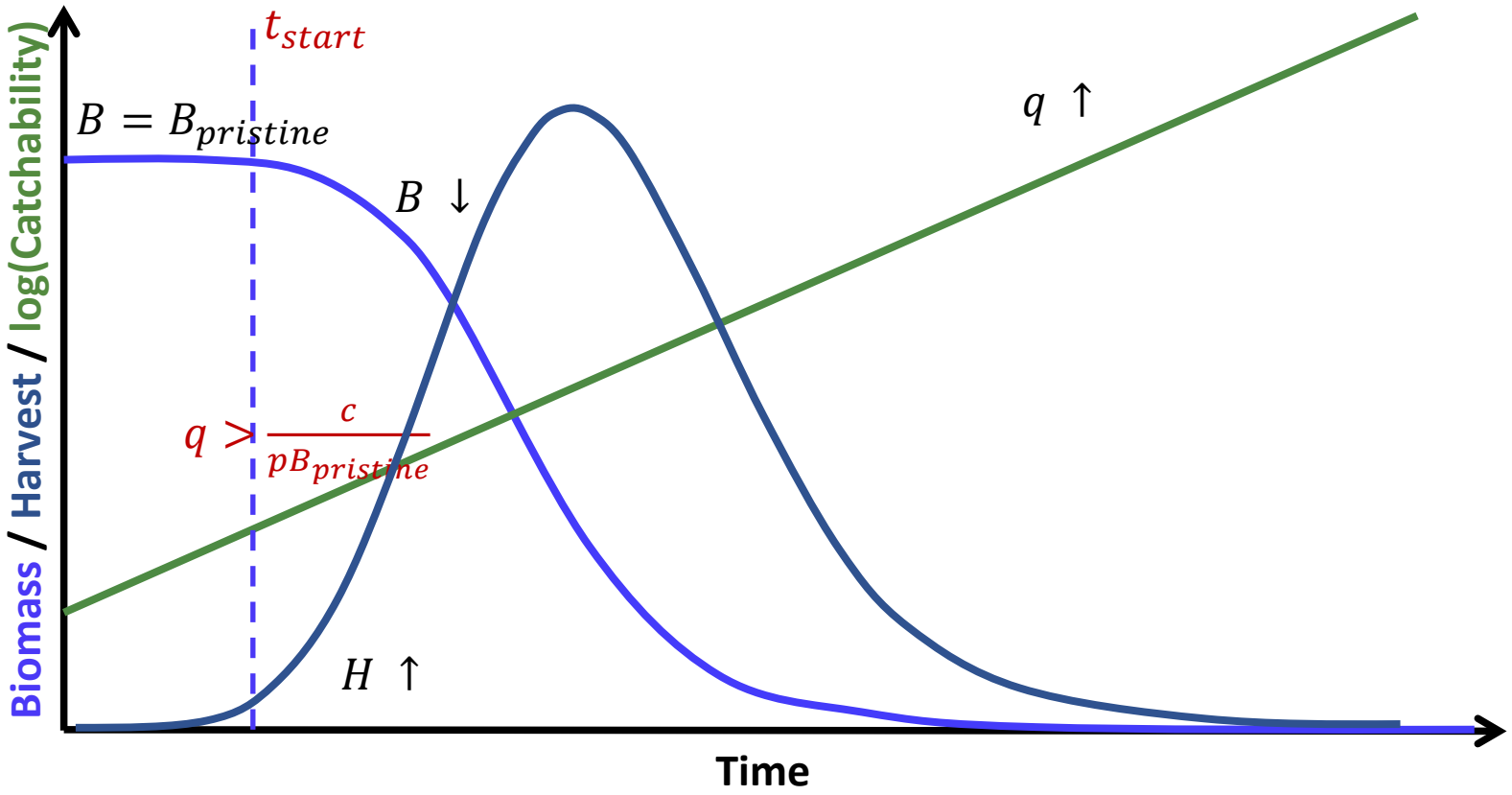
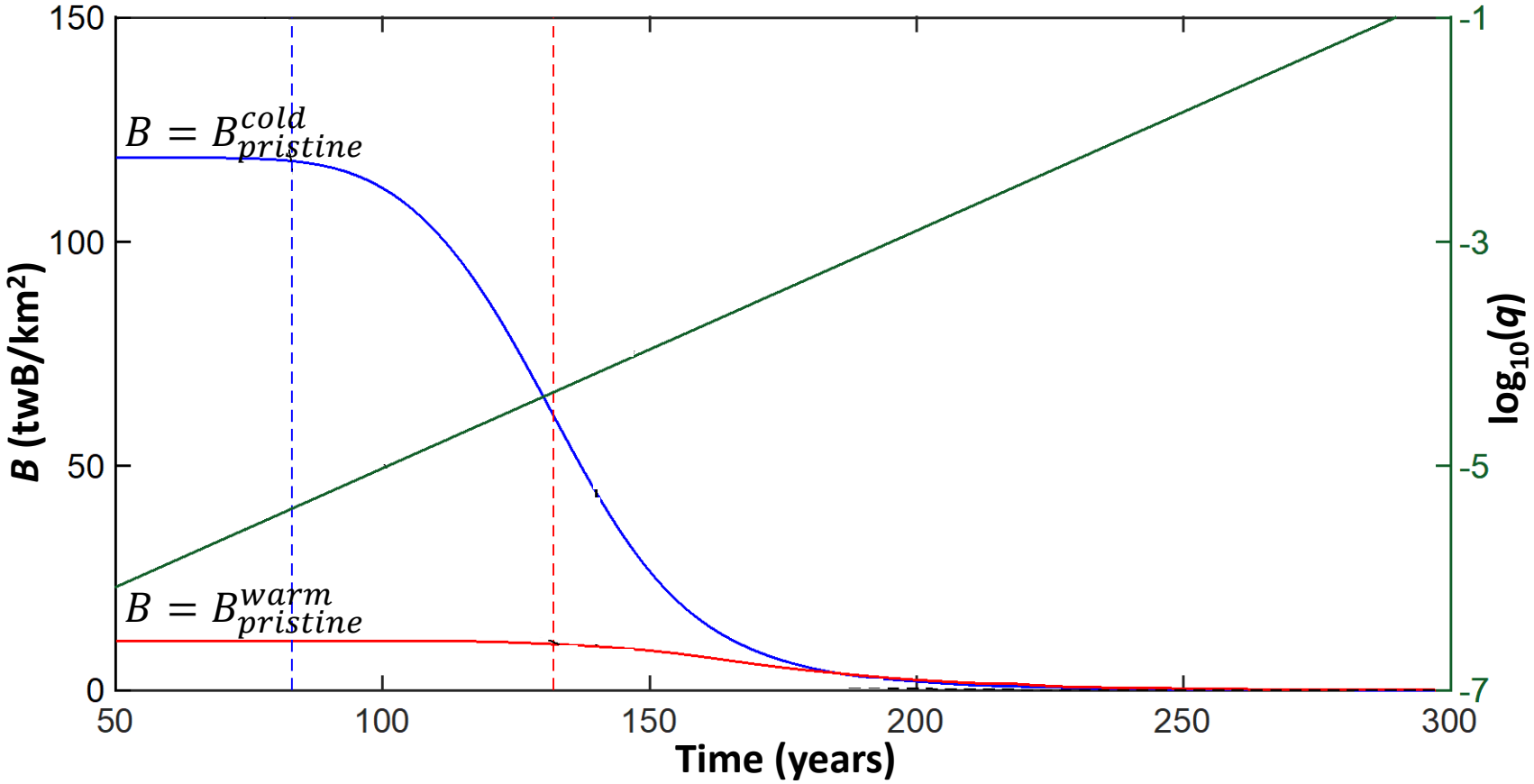


t_{start} depends on the standing biomass ($B_{pristine}$) ?

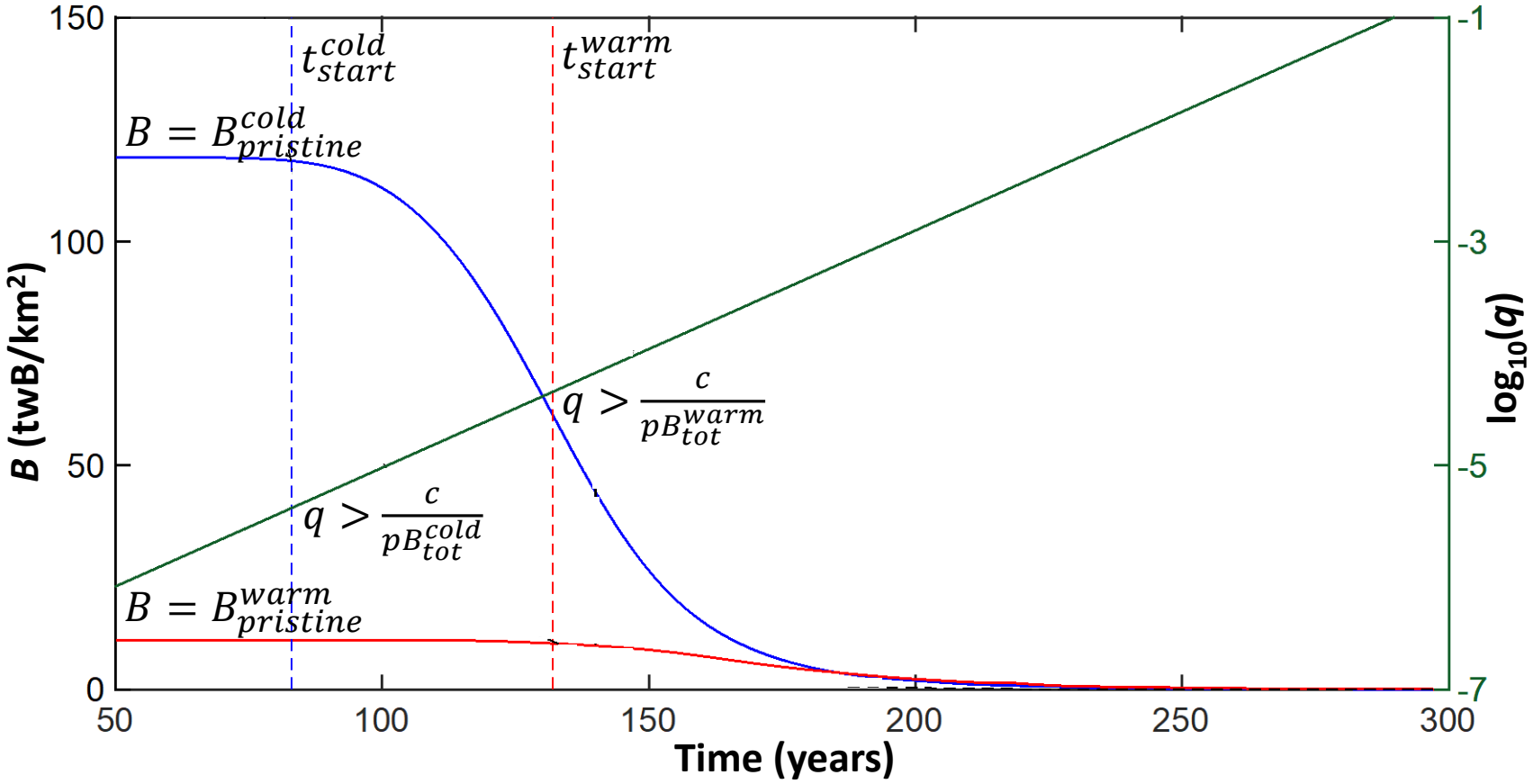
Colder ecosystems have a higher standing biomass ($B_{pristine}$).



Colder ecosystems have a higher standing biomass ($B_{pristine}$).

A higher standing biomass induces an earlier exploitation:

$$t_{start}^{cold} < t_{start}^{warm}$$



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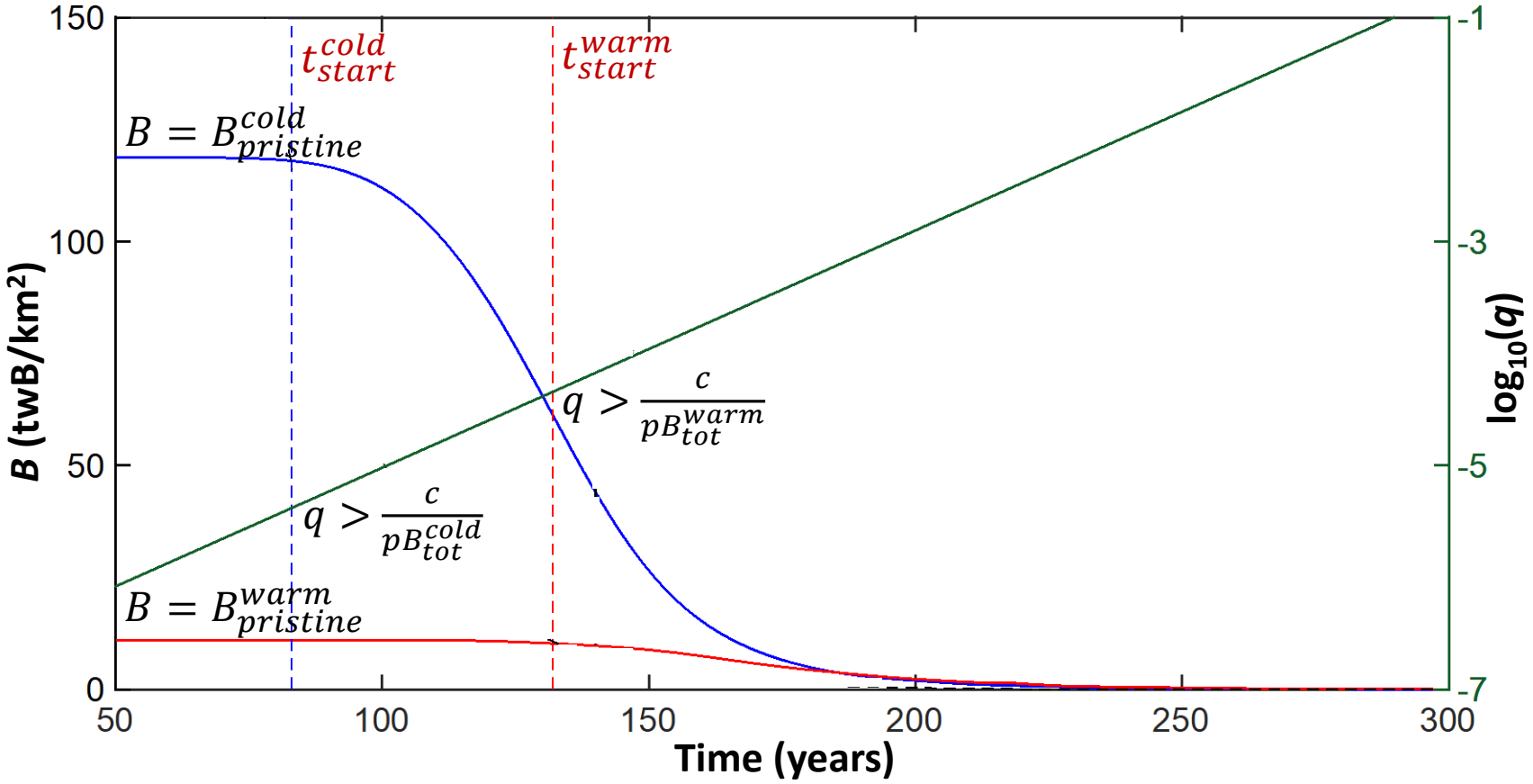


The onset of fishing (t_{start}) is earlier in colder LMEs.

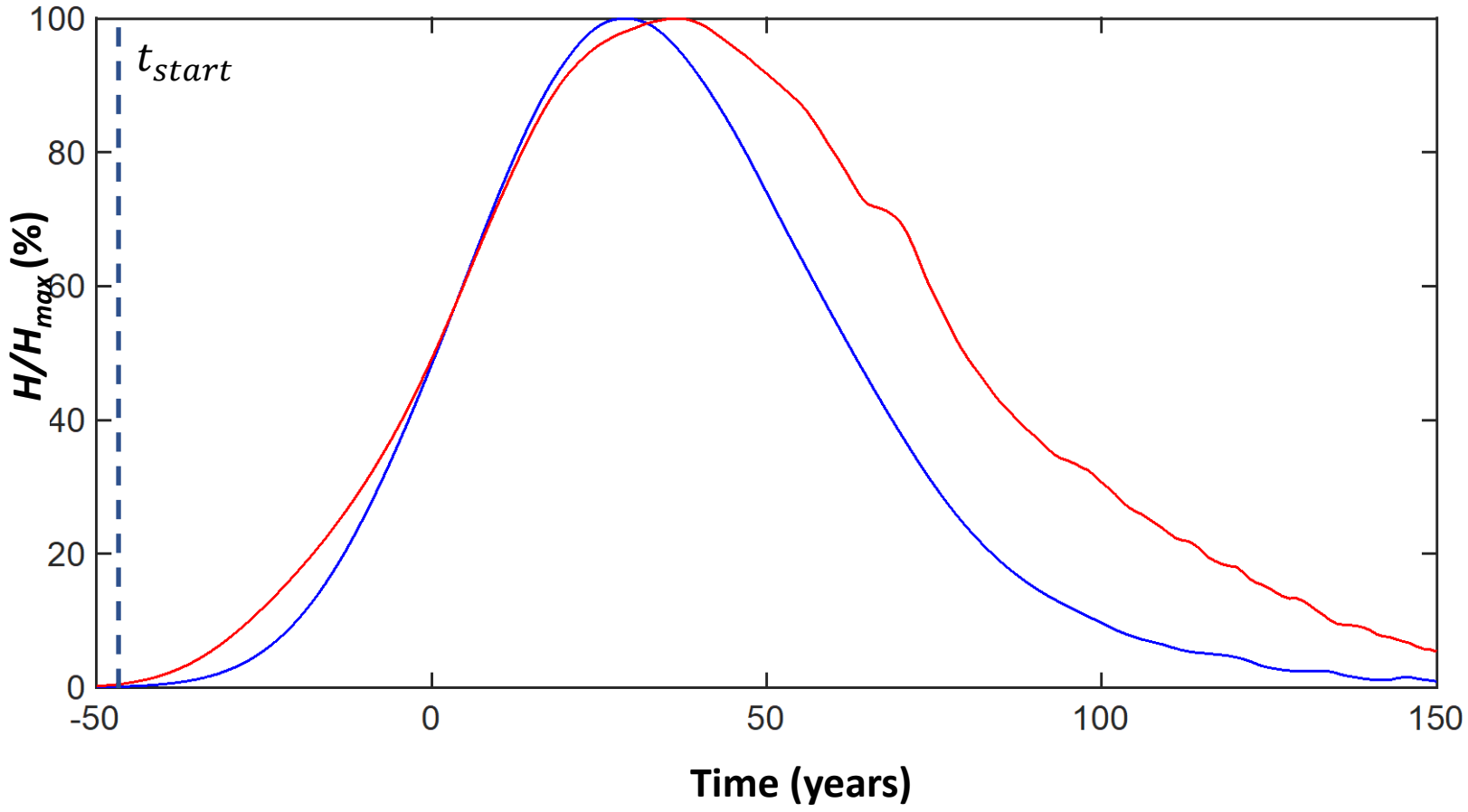
The peak development time (t_{dev}).

Harvest :

$$H \propto q\ B\ E$$

q Catchability of biomass B

E Fishing effort



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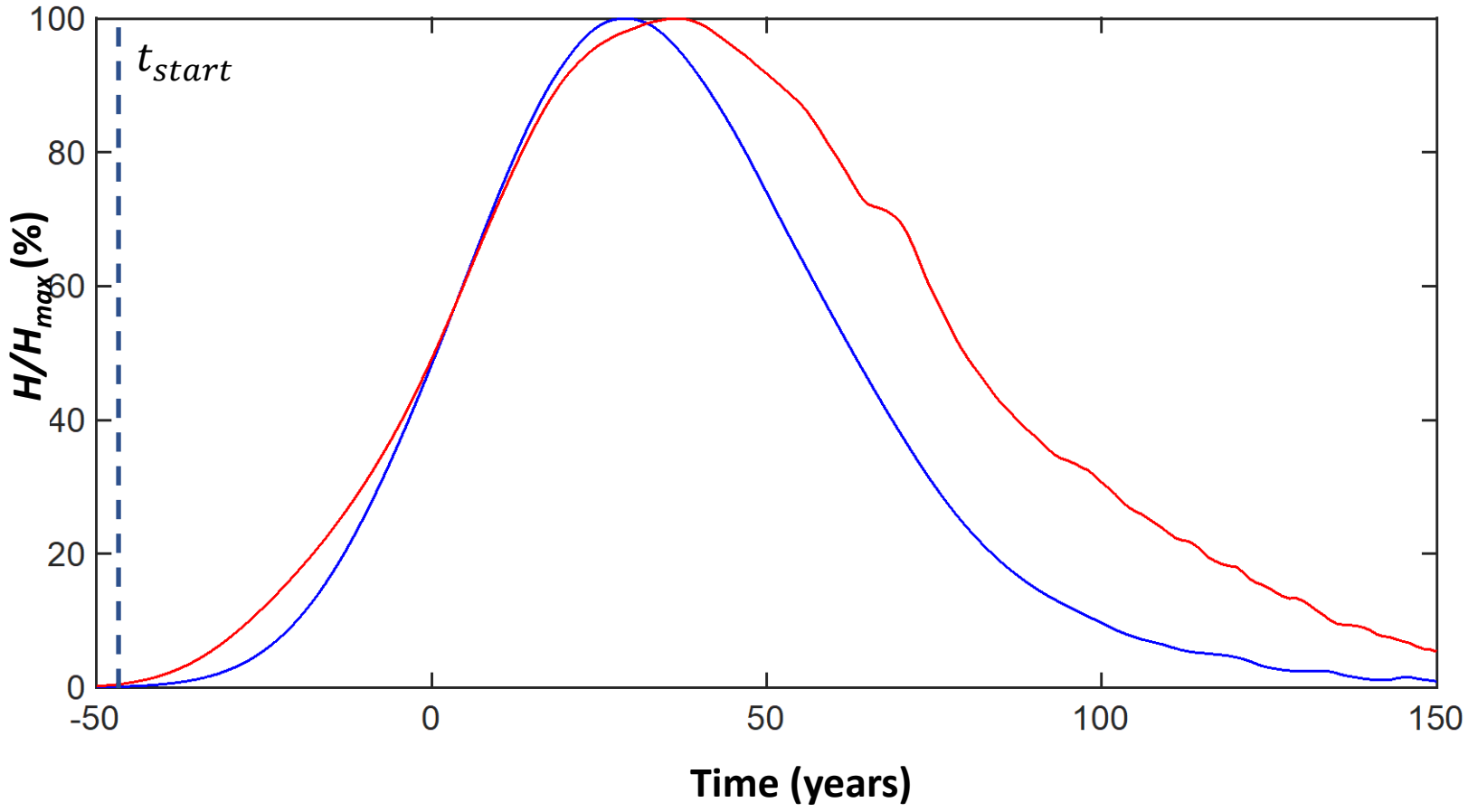

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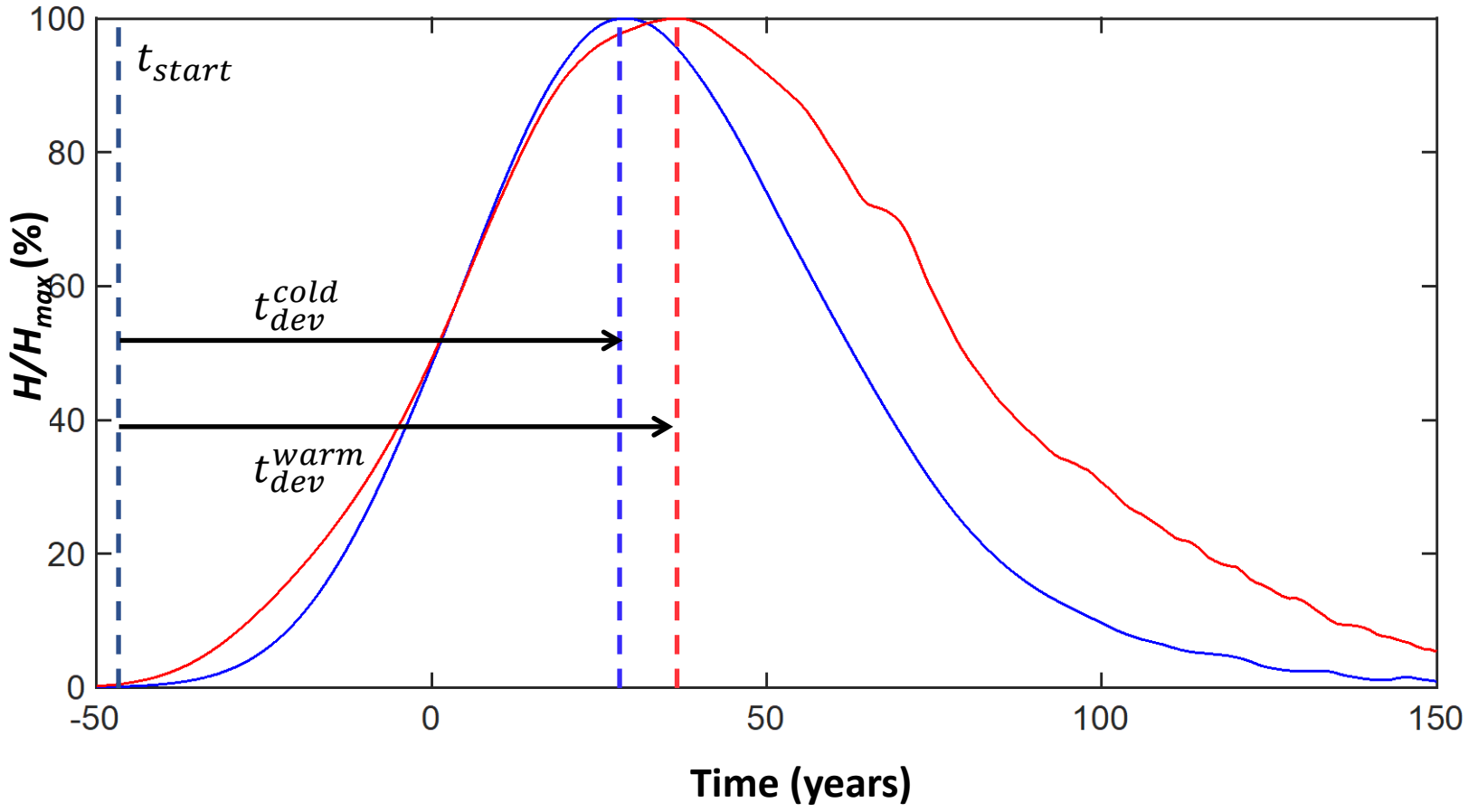
$$t_{dev}^{cold} \cong t_{dev}^{warm}$$



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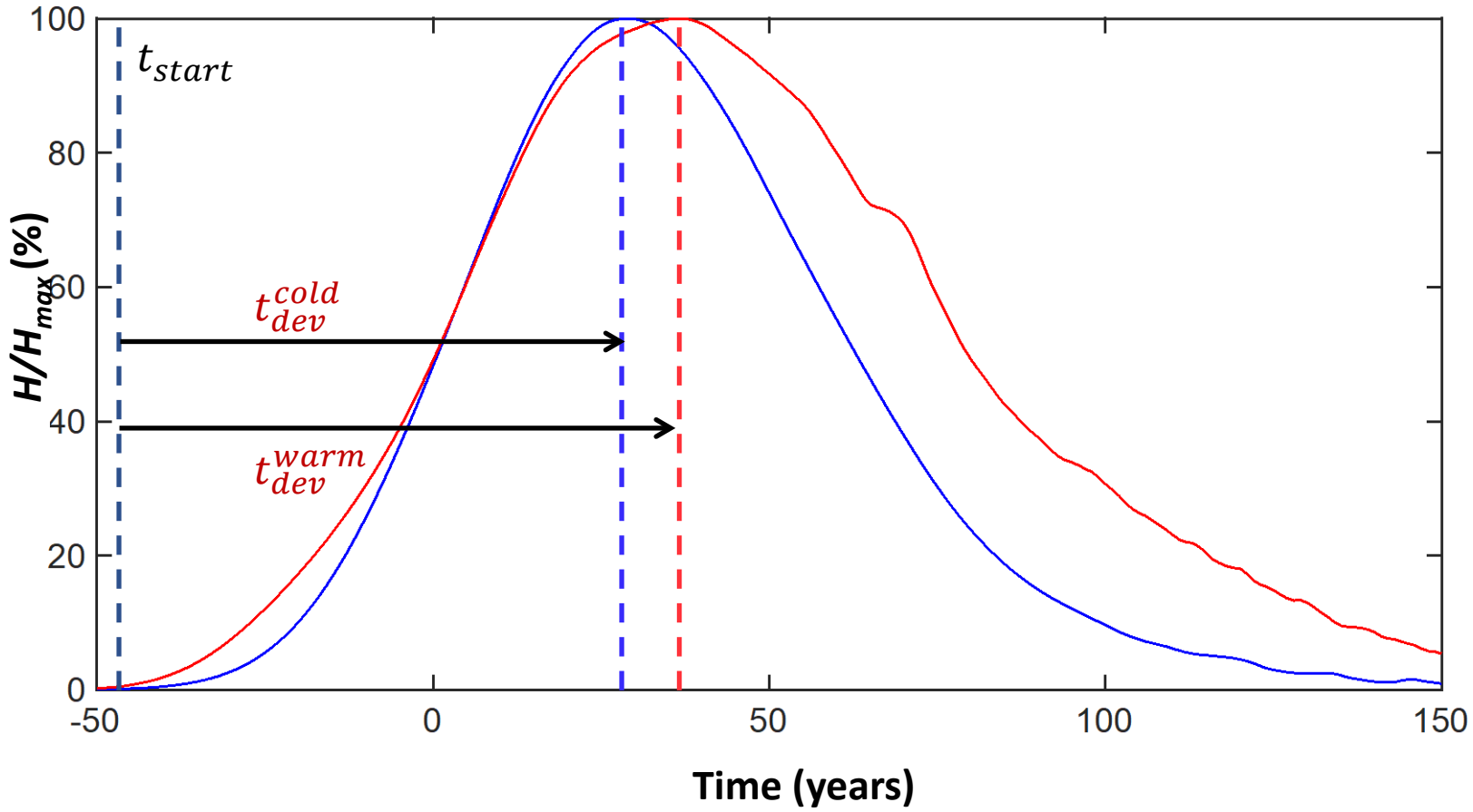
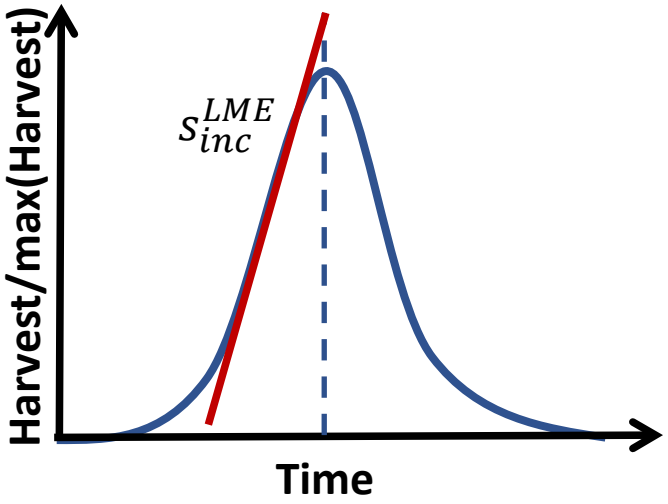
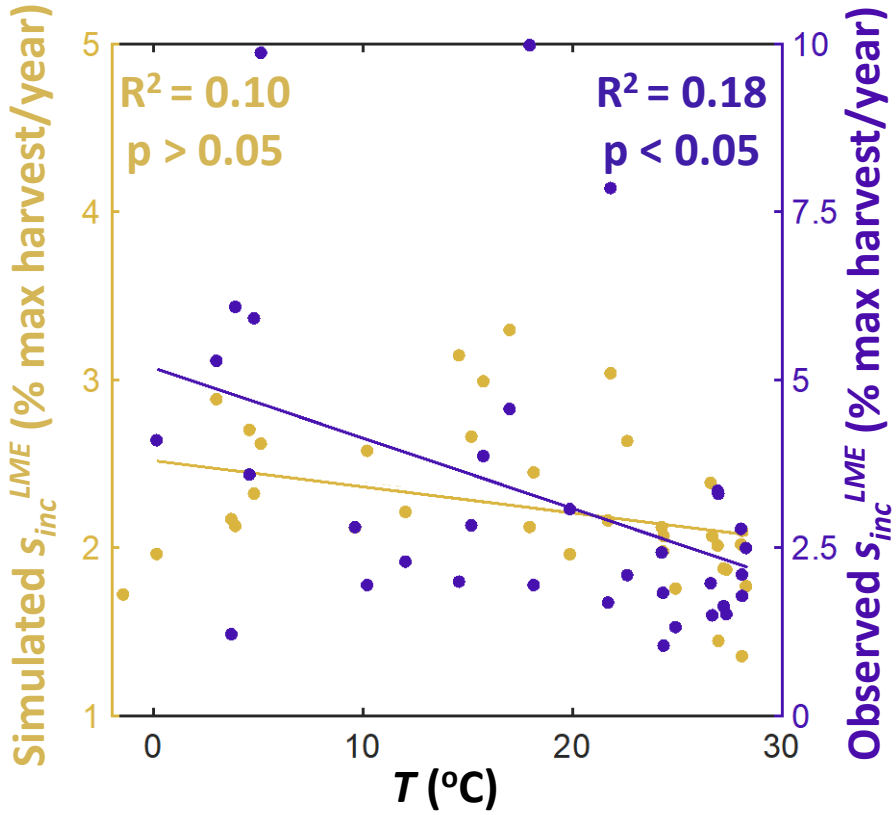


The peak development time (t_{dev}) is independent of temperature.

The slope of the increase of harvest per LME (s_{inc}^{LME}) poorly correlates with the mean LME temperature (T).

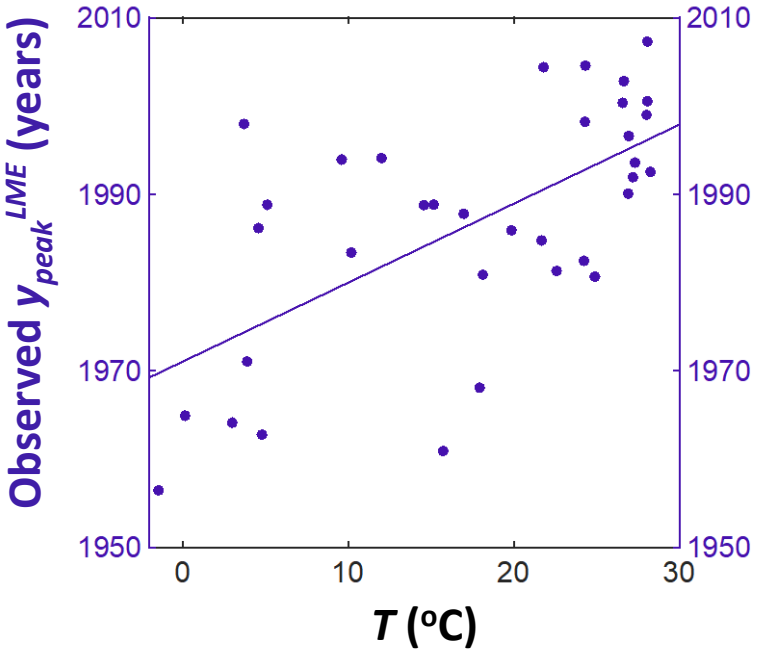




Observation support the model prediction.

Summary

Earlier peak of harvest (y_{peak}) in higher latitude, colder LMEs.



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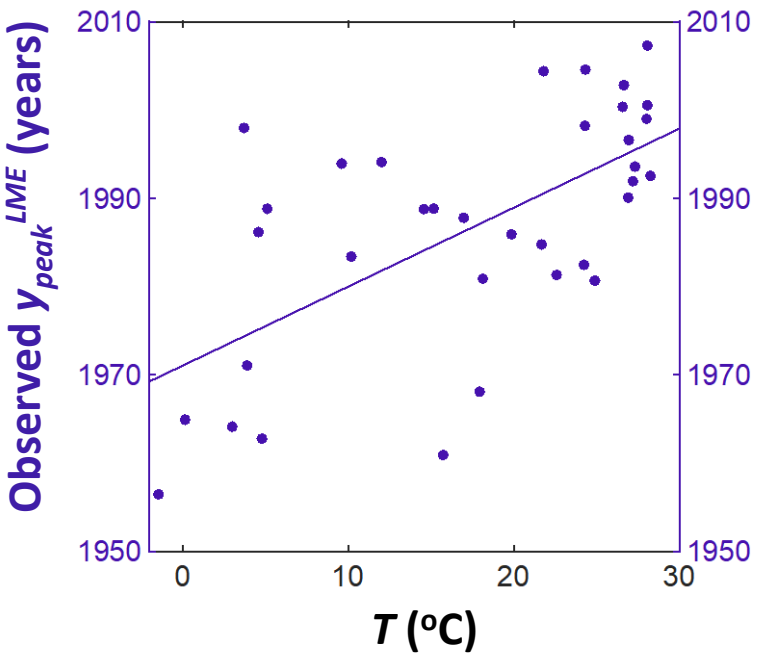
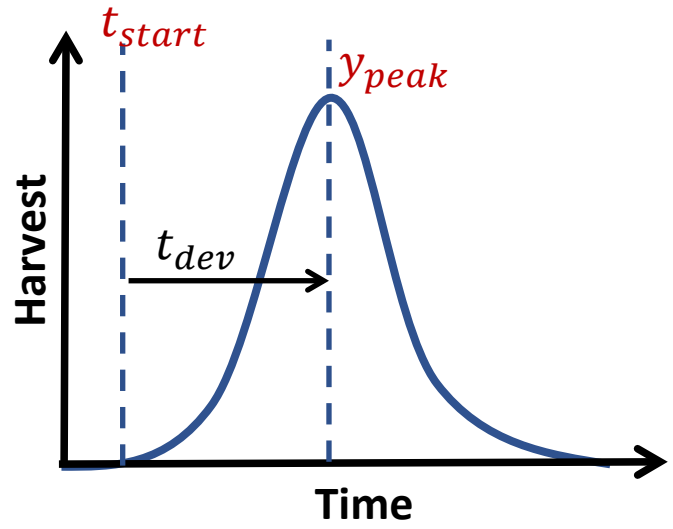
Because temperature (T) influences standing biomass, t_{start}, but not t_{dev}.





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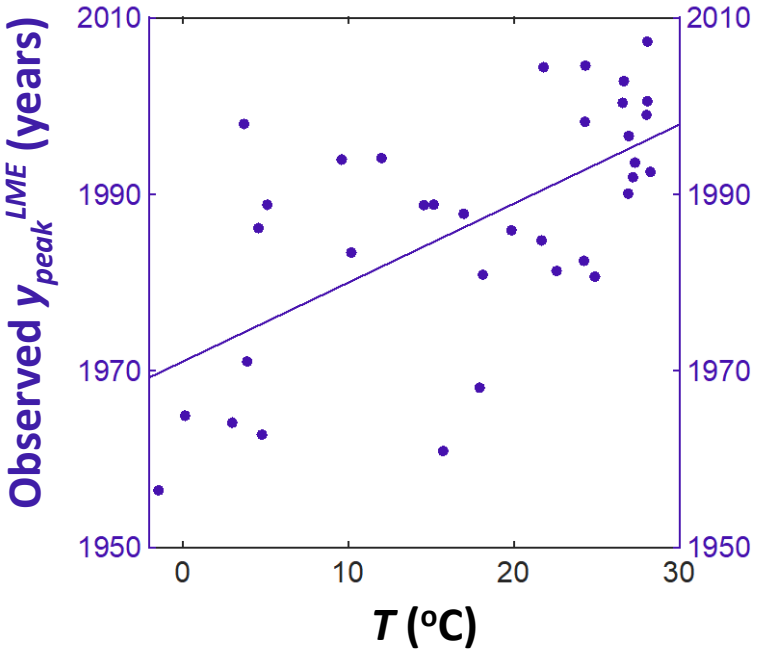
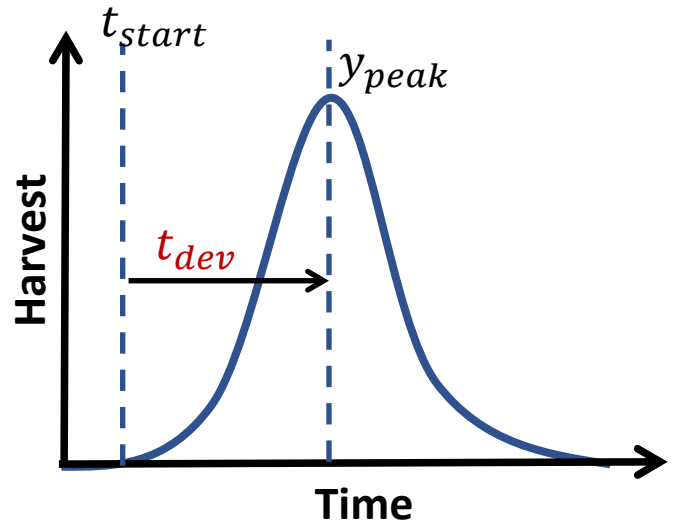
Because temperature (T) influences standing biomass, t_{start}, but not t_{dev}.

The impact of a warming ocean on the development of fisheries could be unnoticed since t_{dev} is independent of temperature.





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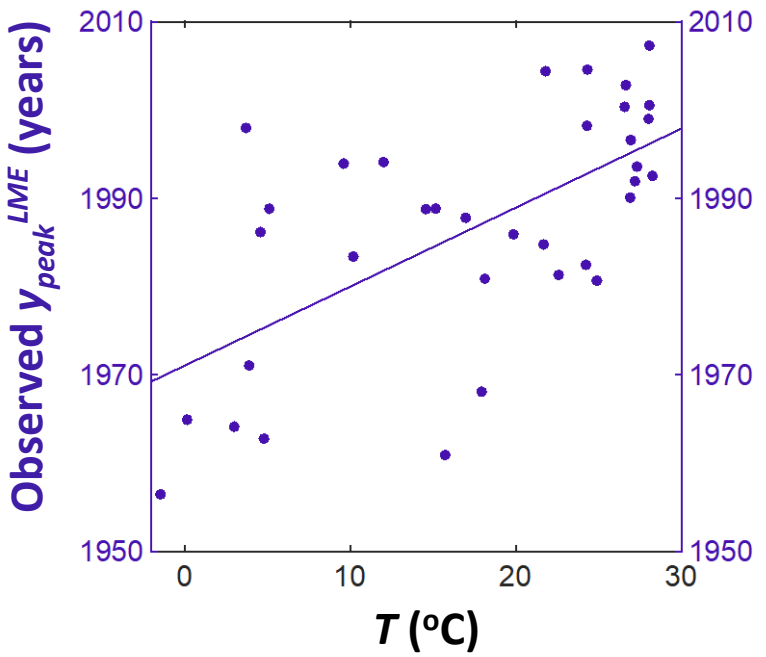
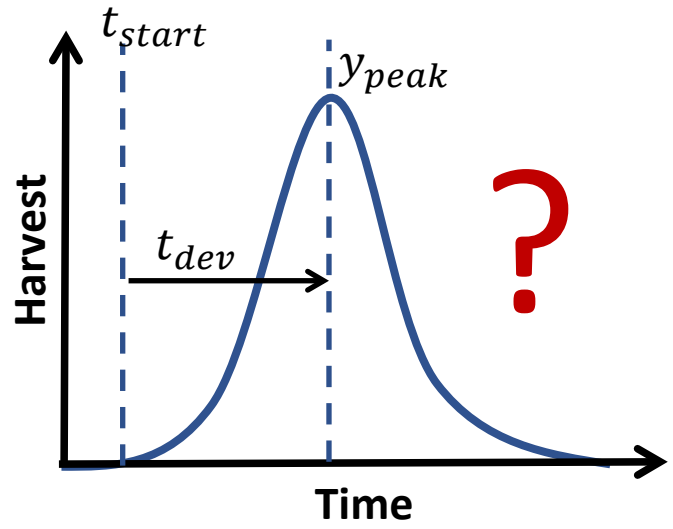




The decline of harvest after the peak.

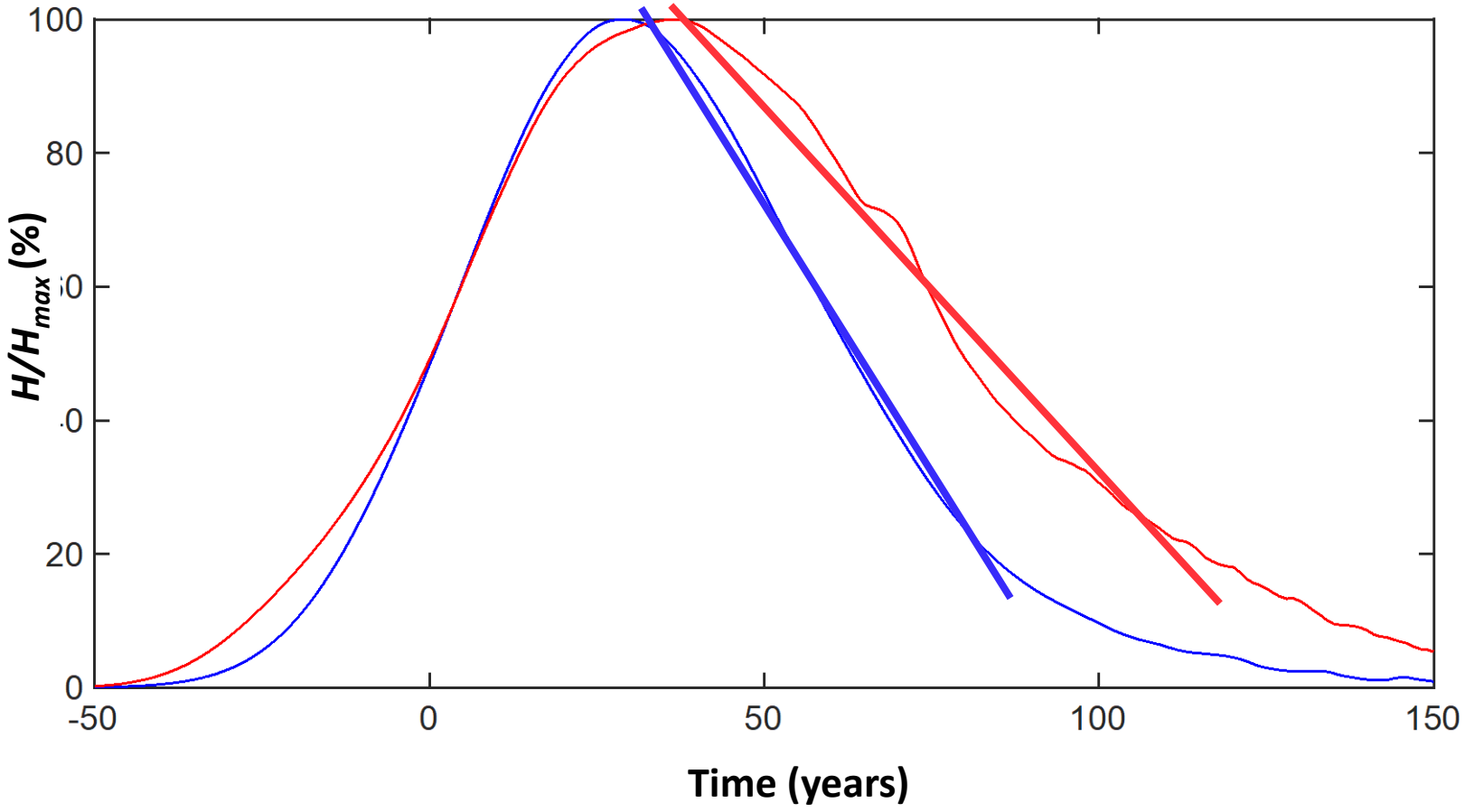
Harvest :

$$H \propto q\ B\ E$$

H controlled by rates :

$$r_q \longrightarrow q \uparrow$$
$$r_b \longrightarrow B \downarrow \quad (f(T))$$

The biomass (*B*) dominates ?



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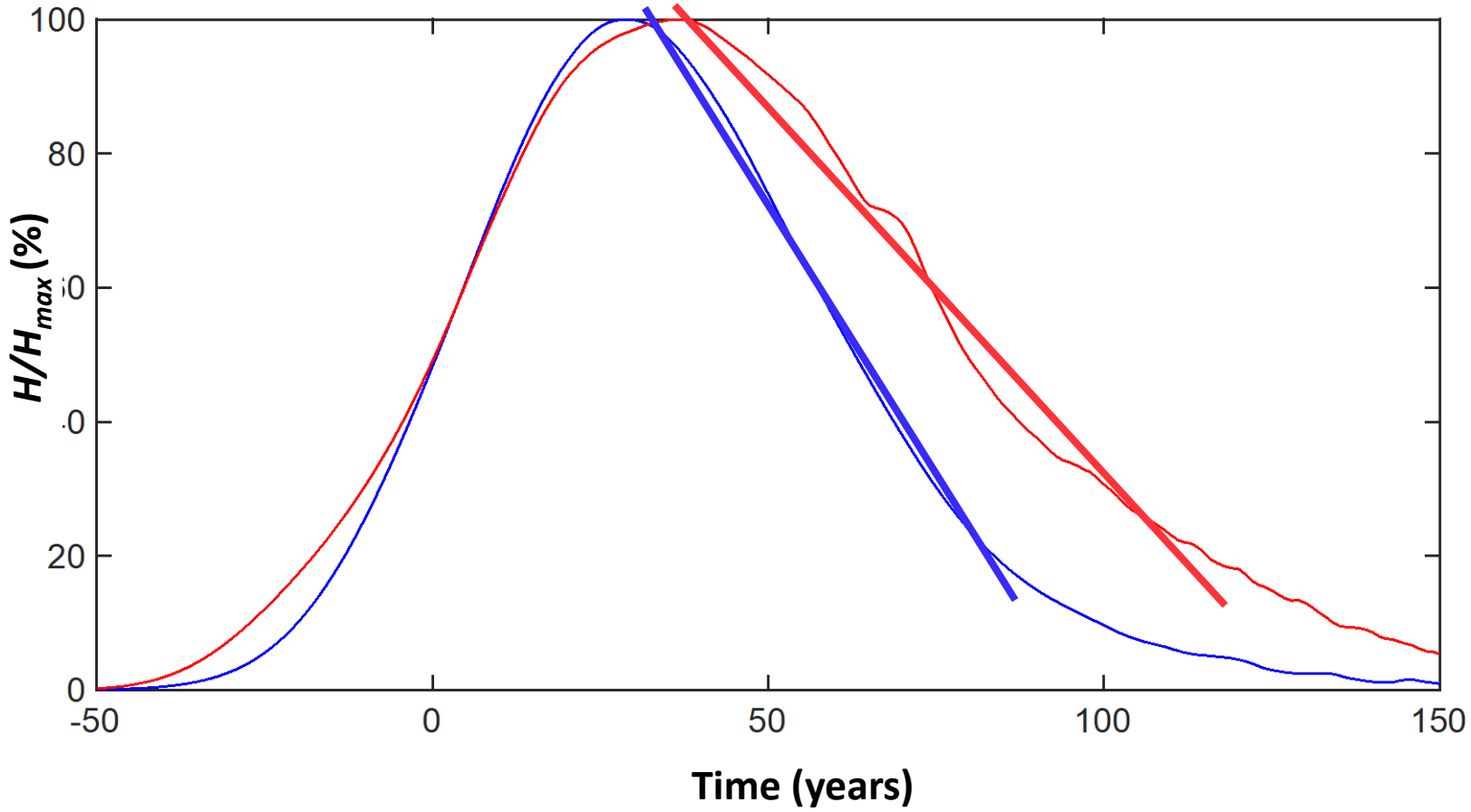
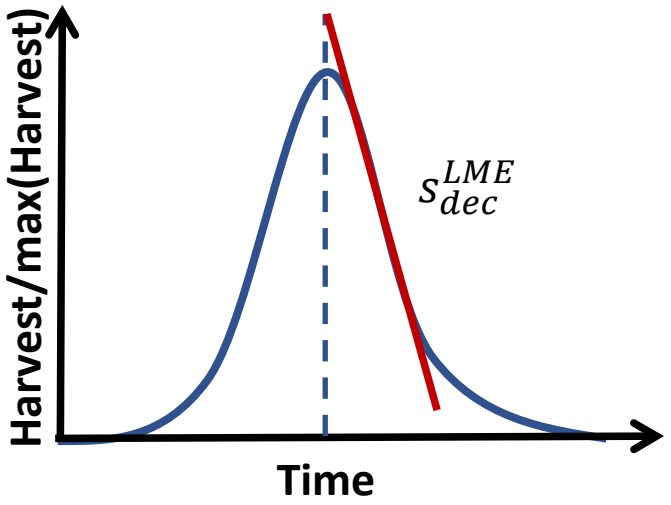
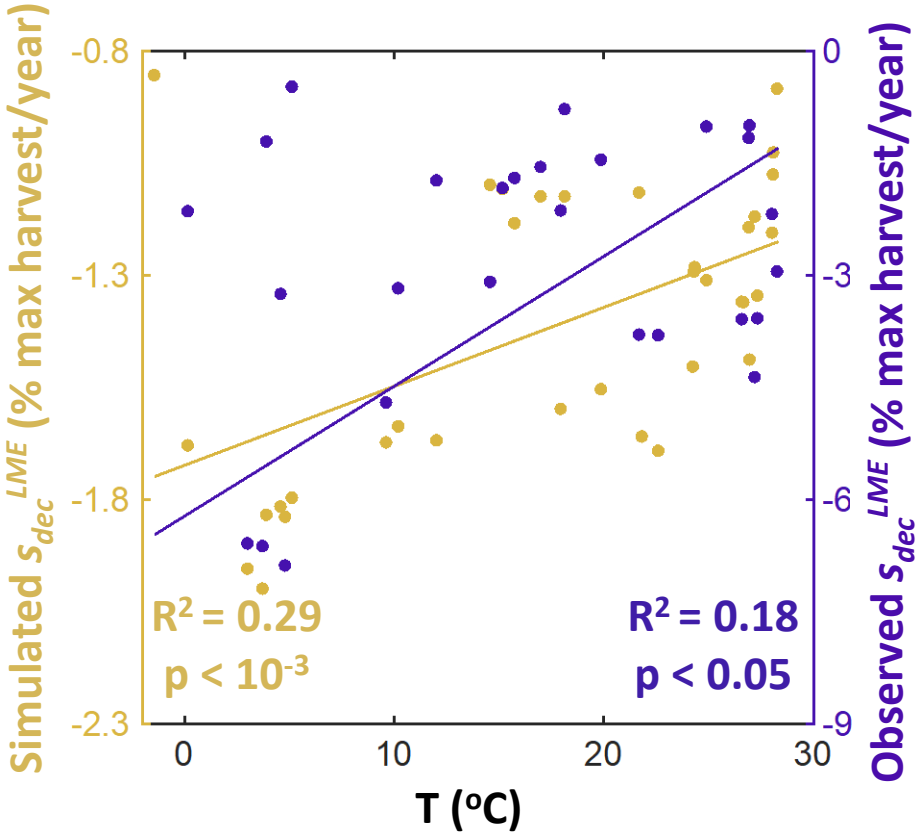


Harvest declines faster in colder LMEs.

The slope of the decrease of harvest per LME (s_{dec}^{LME}) correlates with the mean LME temperature (T).





The decline of harvest (or recovery) depends on temperature.

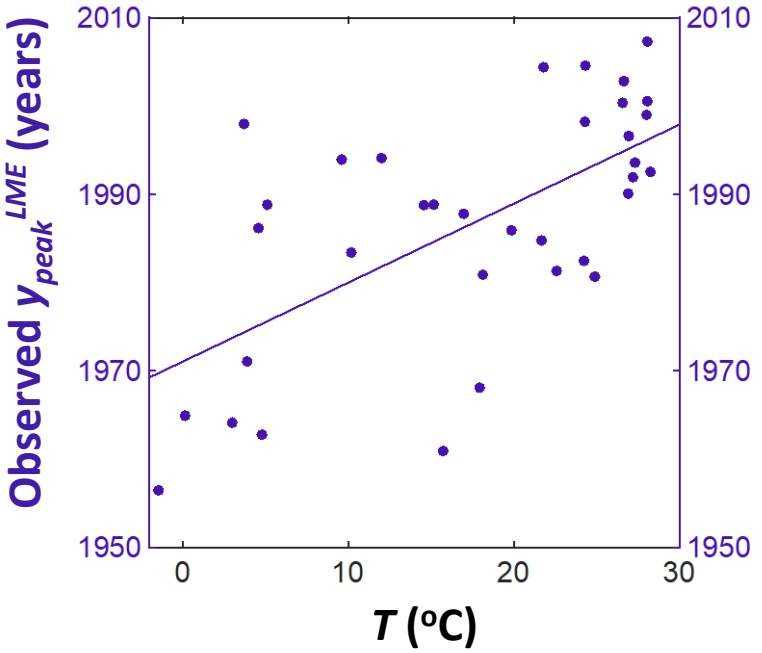
Summary

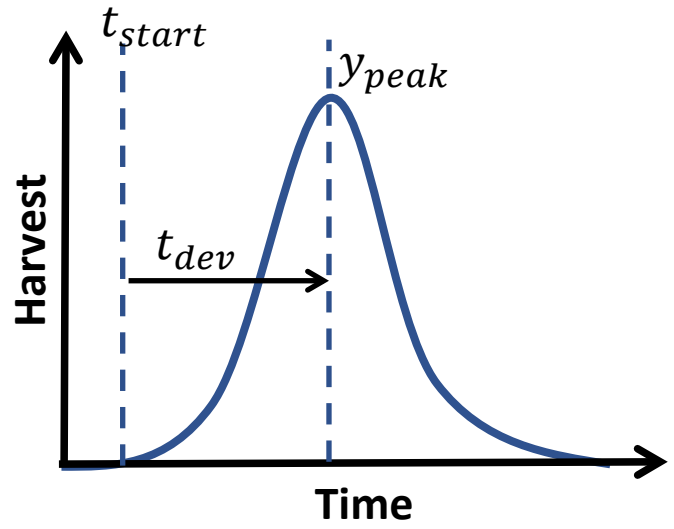
Earlier peak of harvest (y_{peak}) in higher latitude, colder LMEs.

Because temperature (T) influences standing biomass, t_{start}, but not t_{dev}.

The impact of a warming ocean on the development of fisheries could be unnoticed since t_{dev} is independent of temperature.

A warming ocean could influence the decrease and recovery of ecosystems.





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