Density dependent range expansion of Northeast Atlantic mackerel is delineated by temperature

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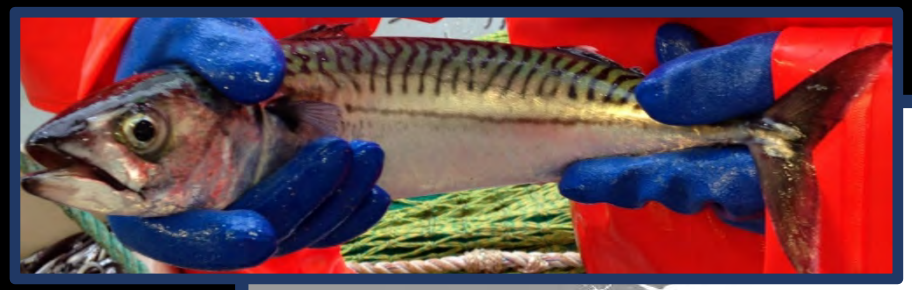
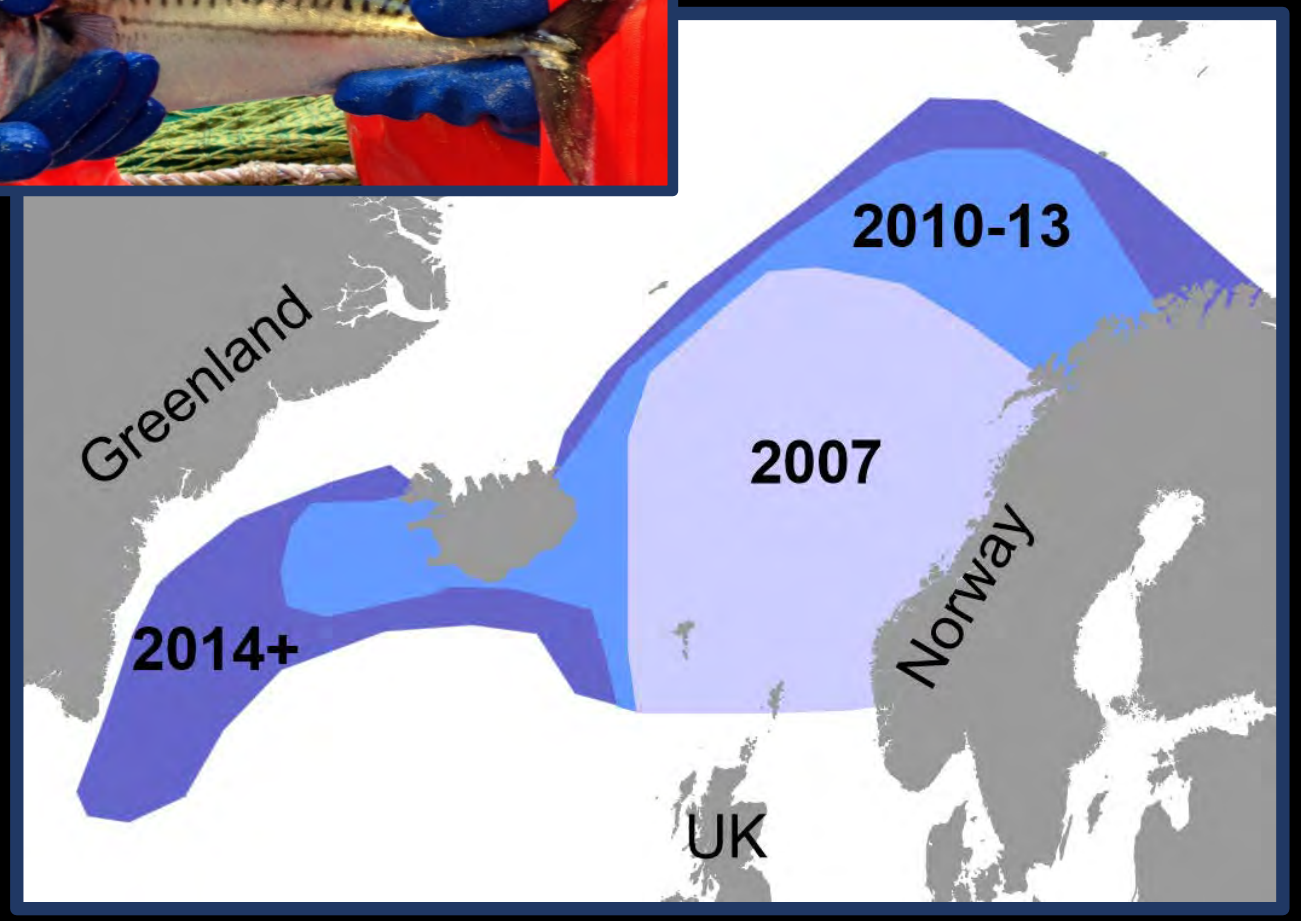




Mackerel:

latitude 35 – 75 °N

seasonal migrations

-northward feeding in summer

-southward winter and spawning

Summer feeding in the north

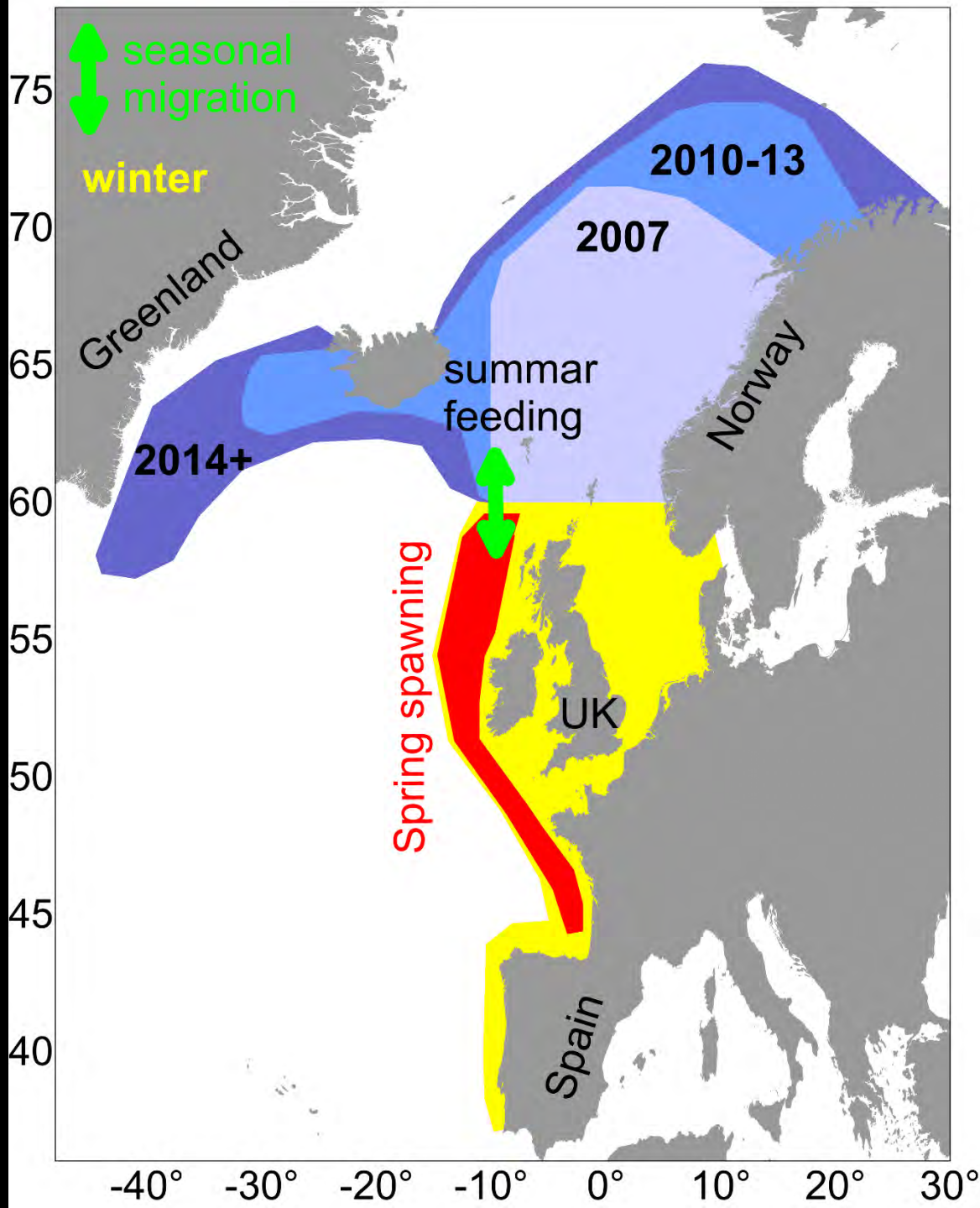
24-hour sunlight

visual feeders in surface ~30m

doubling of range from 2007-2016

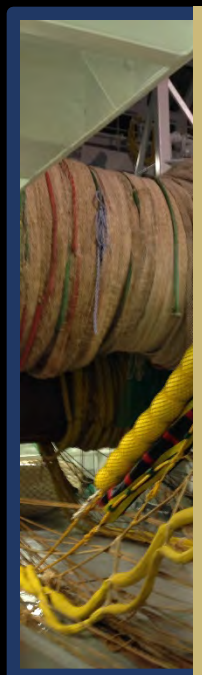
Annual catch >1 million tonnes

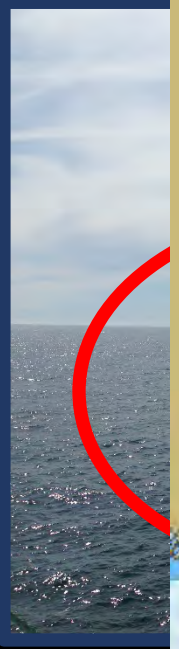
human consumption $$$$$$$$

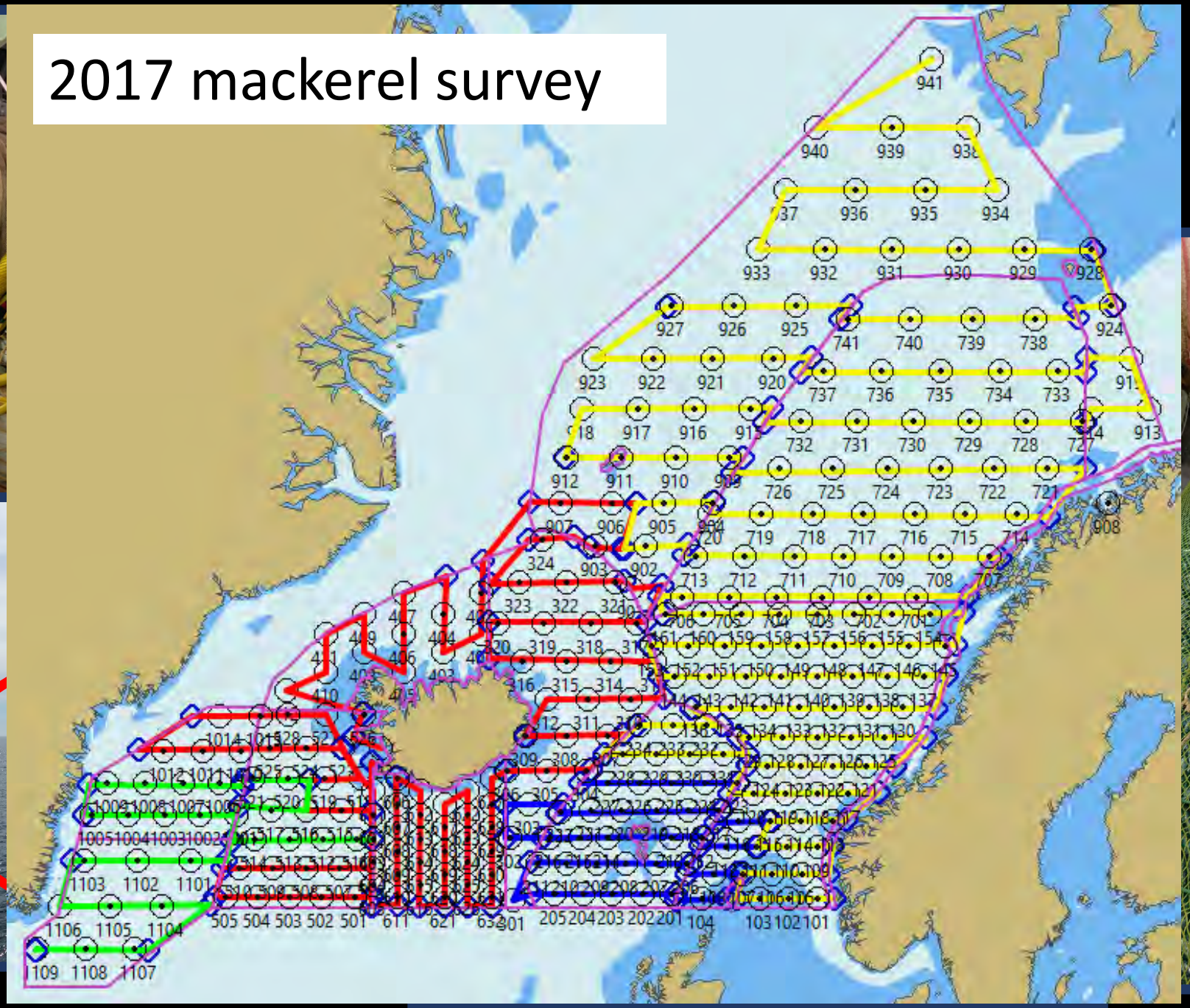


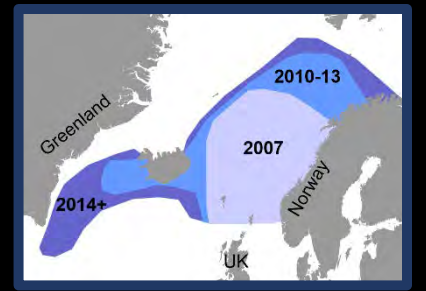
The mackerel survey: International Summer Survey in Nordic Seas (IESSNS)

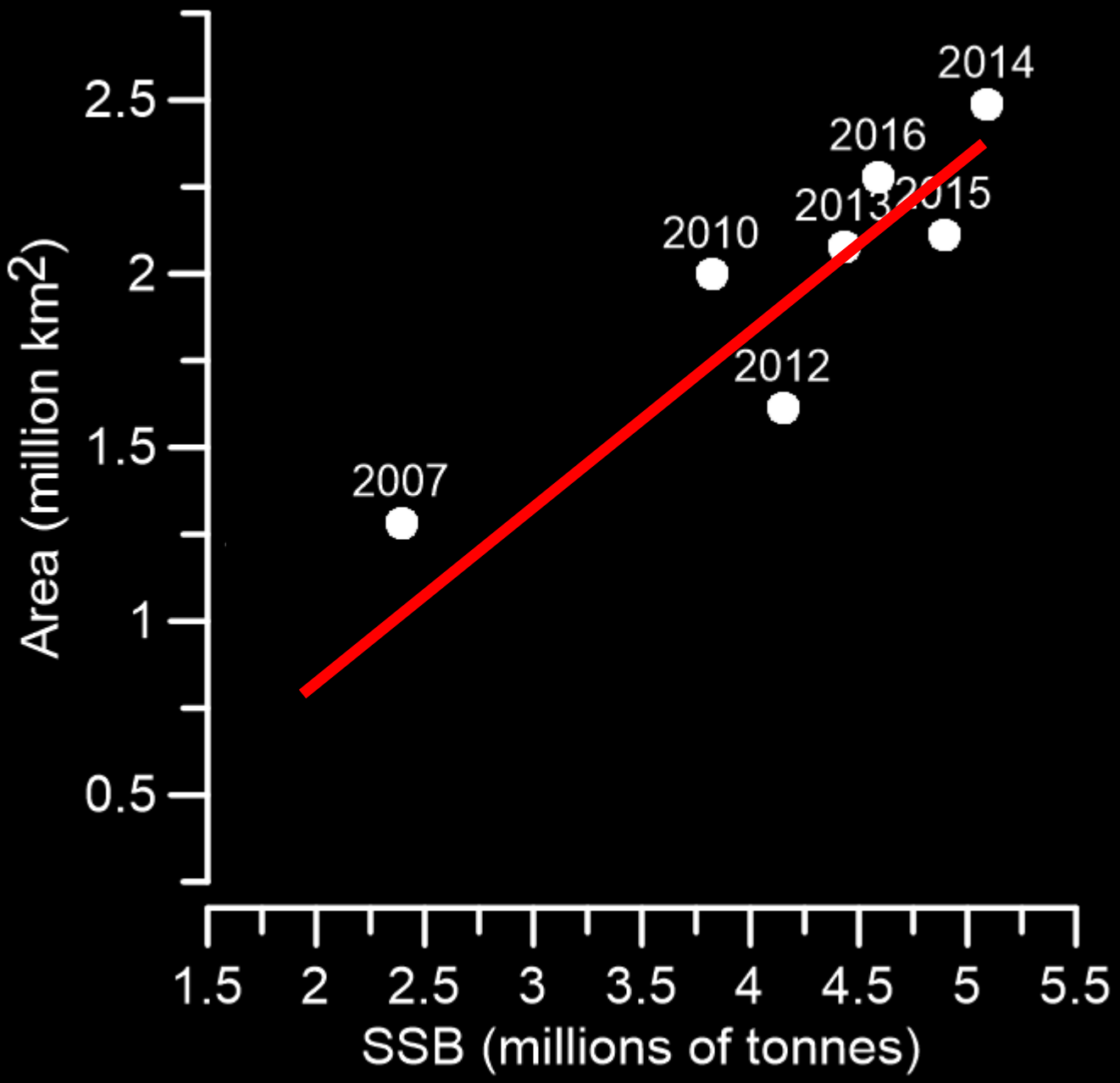
2017 mackerel survey











the mackerel survey:
2007-2016

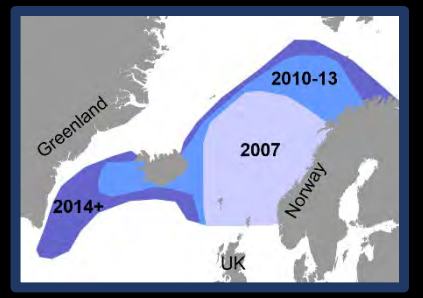
Norwegian Sea surveys:
1997-98, 2002-3, 2006

r = .95

positive correlation SSB - distribution range (r=.95)

$\neq$

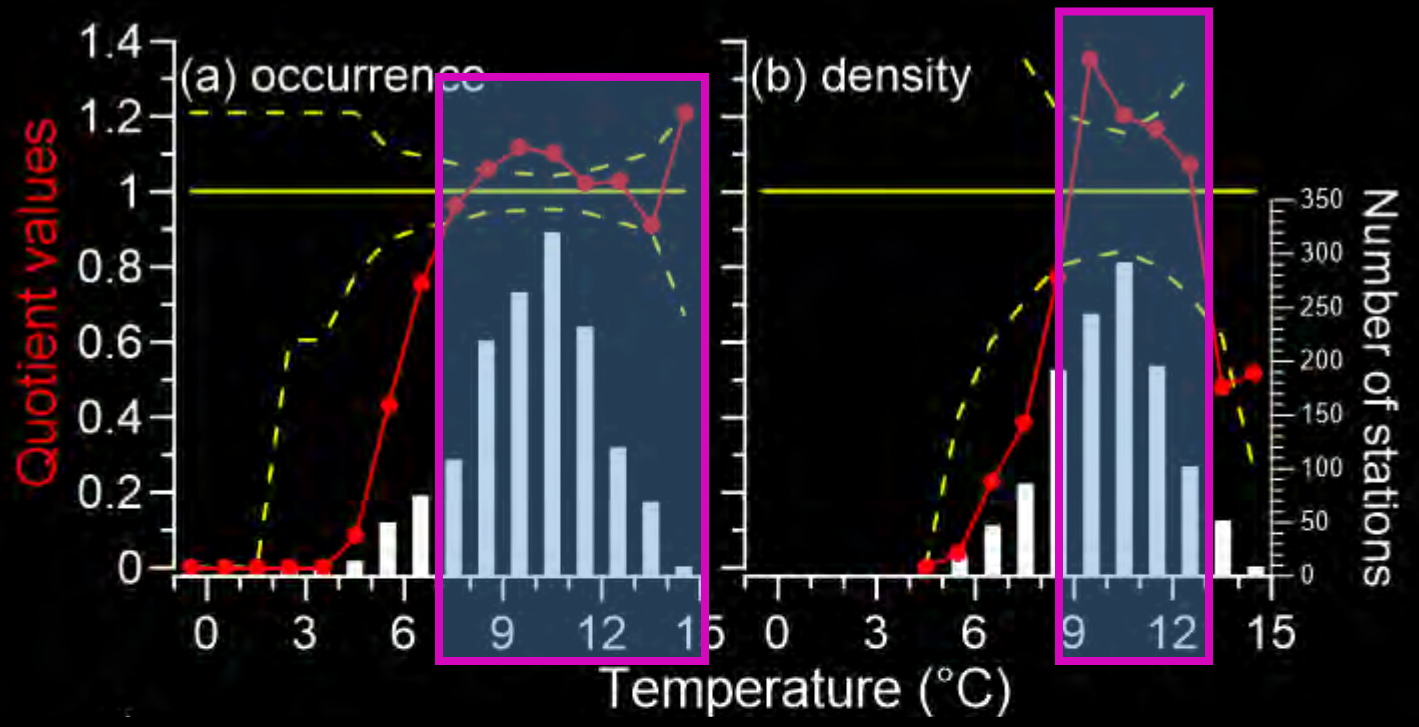
density-dependent habitat selection
(ideal free distribution)



Density-dependence: "behaviorally mediated changes in habitat exploitation, and thus distribution, due to density-dependent effects"

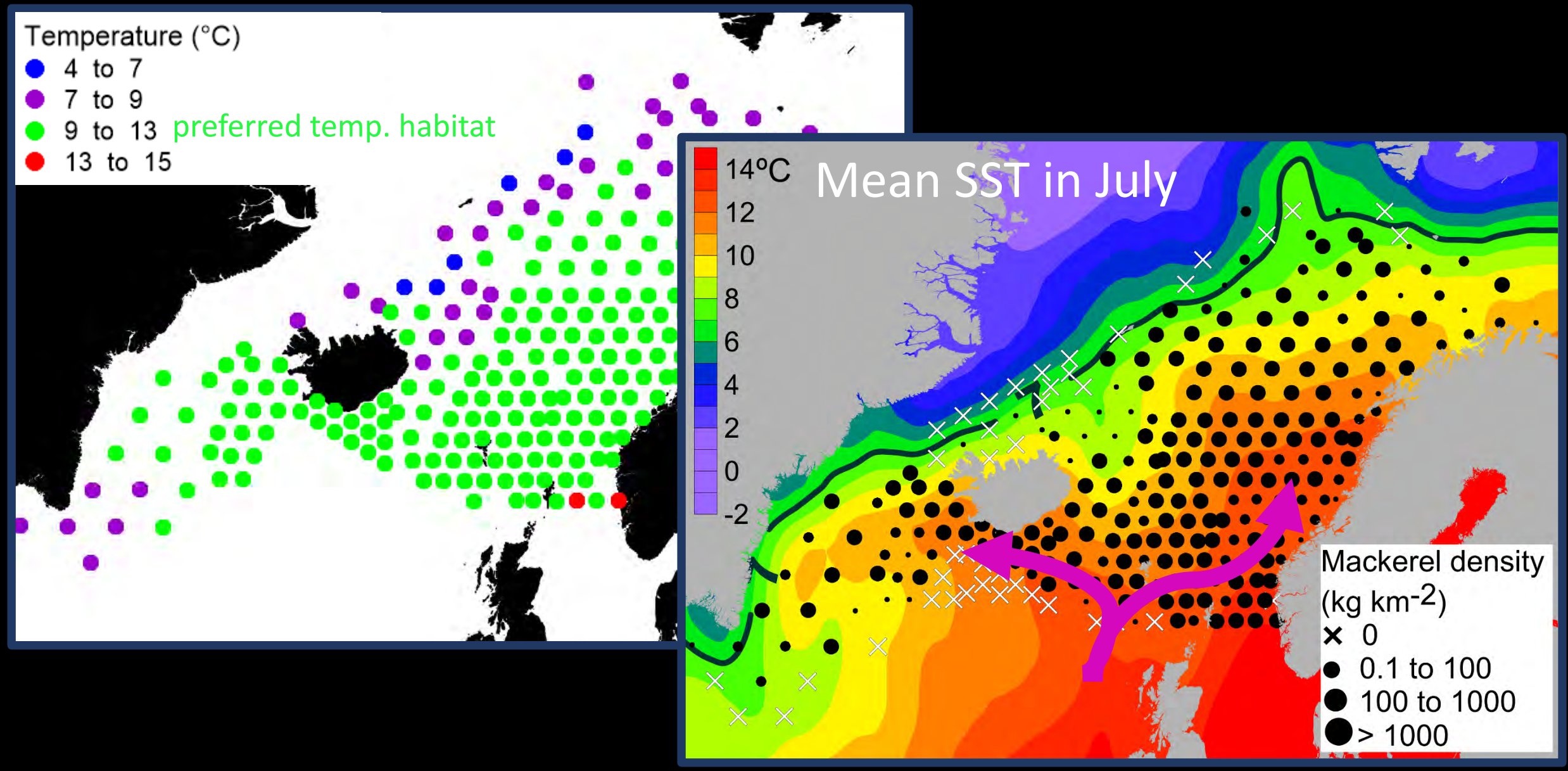
Density-independent influences: environmental changes (temperature)

Mackerel habitat selection during summer:
(a-b) temperature
(c-d) zooplankton

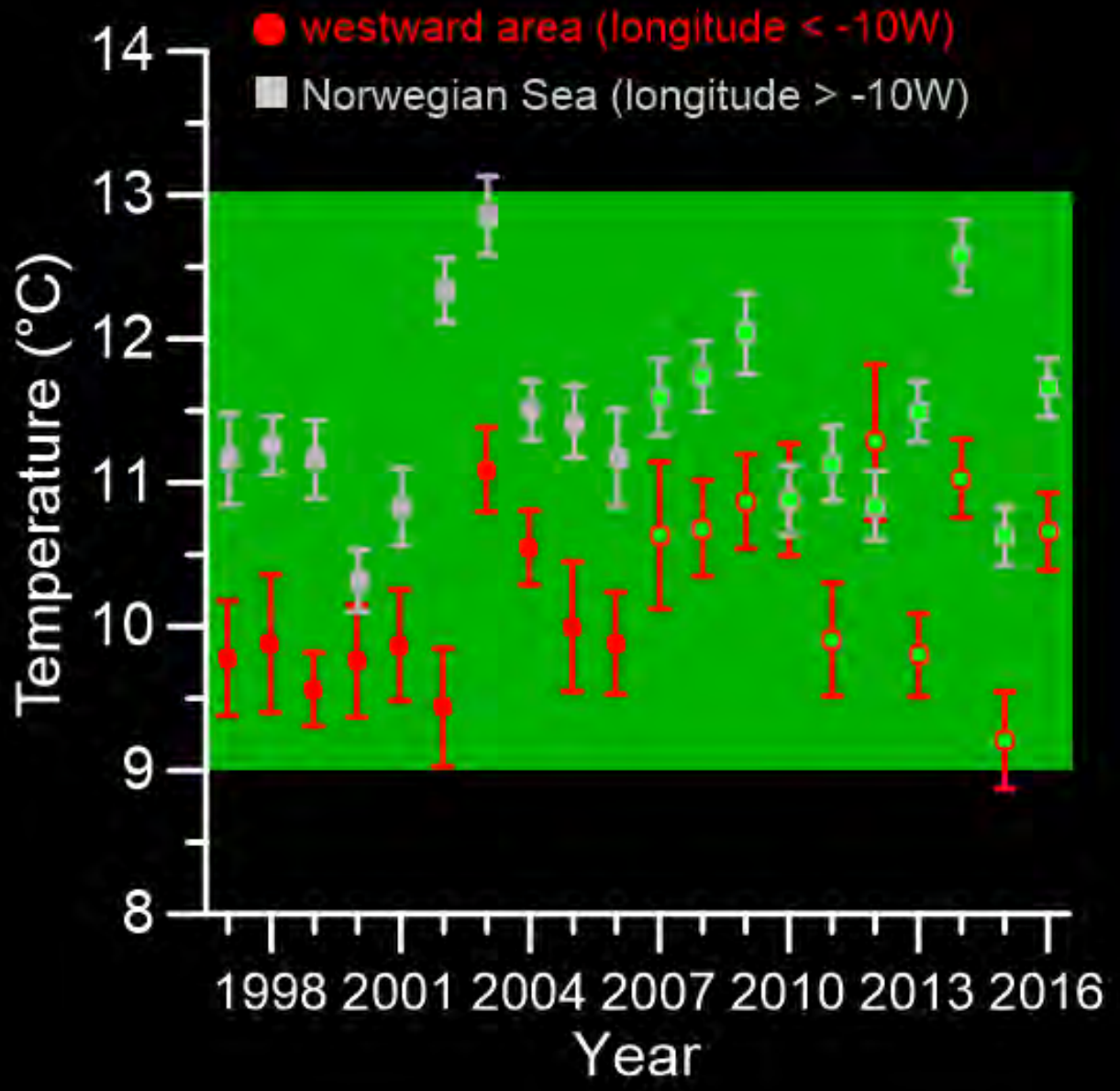


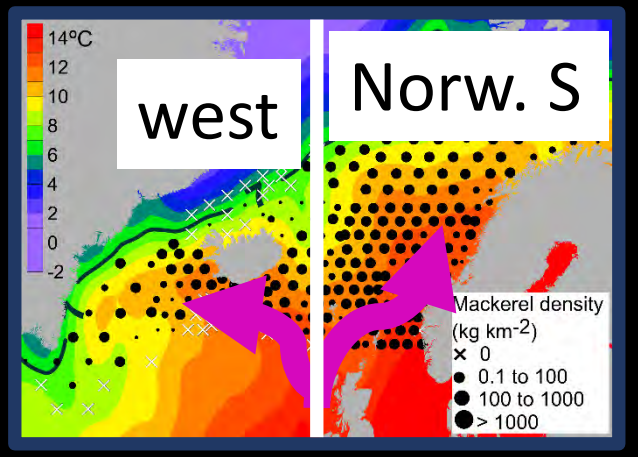
$$Q = \frac{\left(\frac{P_i}{P}\right)}{\left(\frac{N_i}{N}\right)}$$

The mackerel survey 2016



Mean SST in July from 1997 to 2016 in two areas





-Favorable temperature habitat was always available in the westward area.
-Direct effects of temperature cannot explain why mackerel began expanding westward in 2007.

positive correlation SSB - distribution range (r=.

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density-dependent habitat selection
(ideal free distribution)

Density-dependence: "behaviorally mediated changes in habitat exploitation, and thus distribution, due to density-dependent effects"

Density independent influences: environmental changes (temperature)

NO DIRECT temperature effects

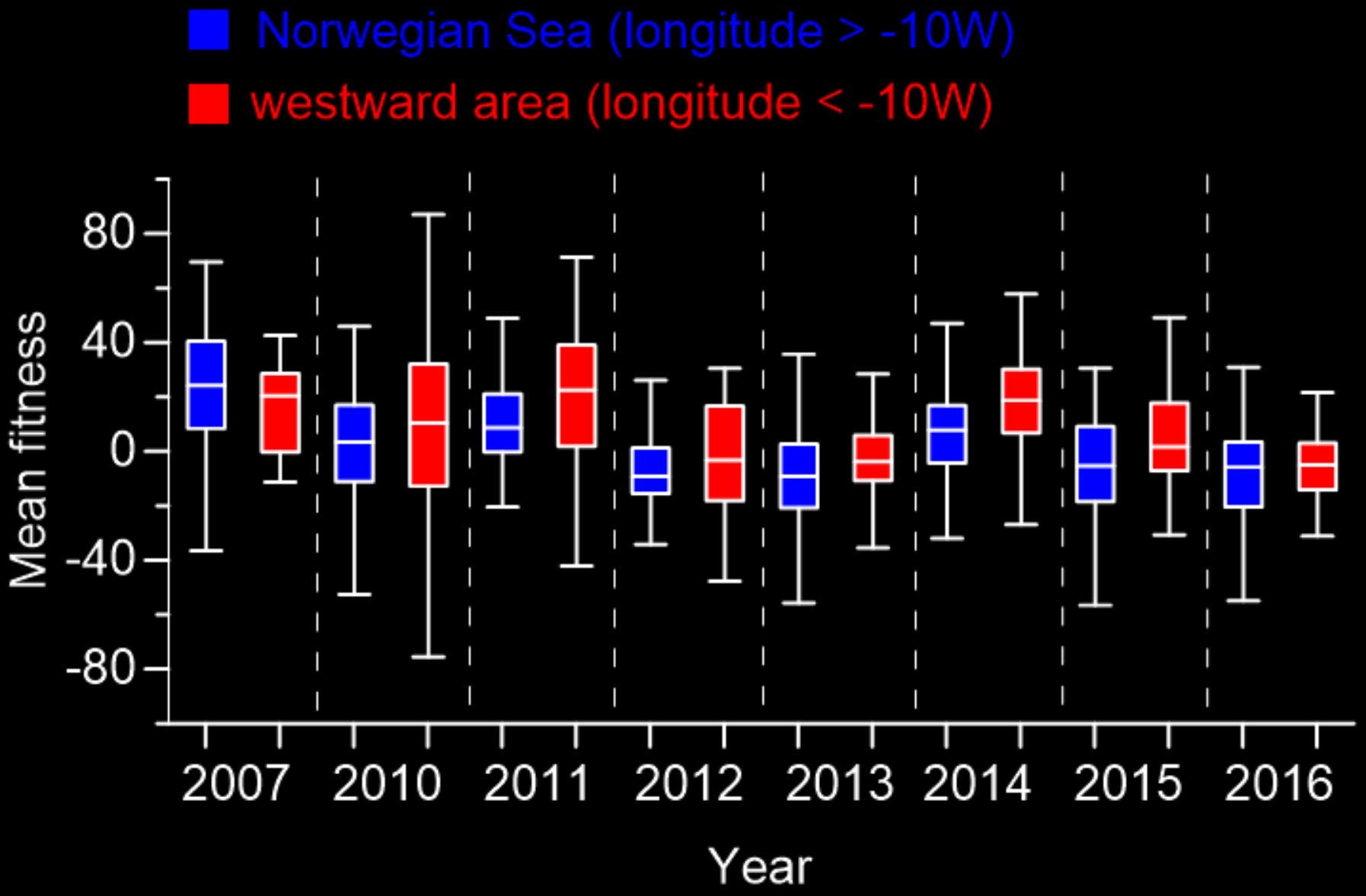
density-dependent habitat selection
(ideal free distribution):
"behaviorally mediated changes in habitat exploitation, and thus distribution, due to density-dependent effects"

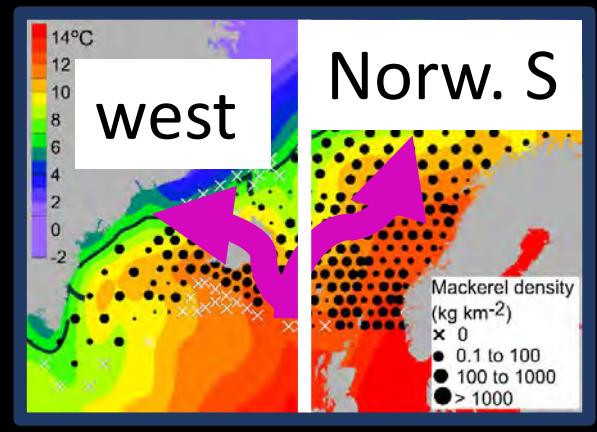
To test if range expansion is density-dependent, we need ***a priori*** information of how habitat quality changes as mackerel density changes: there are no such continuous habitat measurements.

Mackerel fitness can be used as proxy for habitat quality experienced during the feeding season.

Density-dependent habitat selection (ideal free distribution), using mackerel fitness as proxy for habitat quality during the feeding season, predicts:

No difference in mackerel relative mean fitness between the Norwegian Sea and the westward area. (GAM model results).





Density dependent range expansion of Northeast Atlantic mackerel is delineated by temperature

1) From 2007 to 2016: 100% increase in range.

2) Strong positive correlation between SSB and distribution range (r = .95).

3) Density-dependent range expansion (ideal free distribution) as no difference in mackerel fitness between the two areas.

4) No direct effect of temperature as the temperature habitat was available but not occupied prior to 2007.

-thank you