Potential reference points for mean trophic level of macrofauna in the Sea of Okhotsk

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Trophic level (TL) was determined accordingly to the same method as in:

Gorbatenko K.M., Kiyashko S.I., Lazshentsev A.E., Nadtochy V.A., Savin A.B.

Trophic relationships and bento-pelagic relations on the western Kamchatka shelf by the data of stomach contents and stable isotopes ^{13}C and ^{15}N //

Izv. TINRO. — 2013. — Vol. 175. — P. 3–25.

$$TL = \lambda + (\delta^{15}N_c - \delta^{15}N_b)/\Delta,$$

$\delta^{15}N_c$ - Is stable isotope ratio of nitrogen ($^{15}N_c/^{14}N_c$) for consumer

$\delta^{15}N_b$ - Is stable isotope ratio of nitrogen ($^{15}N_b/^{14}N_b$) for the base, which was represented by *Eucalanus bungii* (6.9 ‰) and *Yoldia bartschi* (6.7 ‰) with the overall mean = 6.8 ‰

Δ - Is stable isotope ratio change between each TL, which is assumed to be 3.4 ‰ after Minagawa M. and E. Wada (1984)

λ - Is TL for the base, which is 2.

Thus

$TL = (^{15}N_c/^{14}N_c)/3.4$

<u>This method is based on the same assumptions as in:</u>

Post D.M.

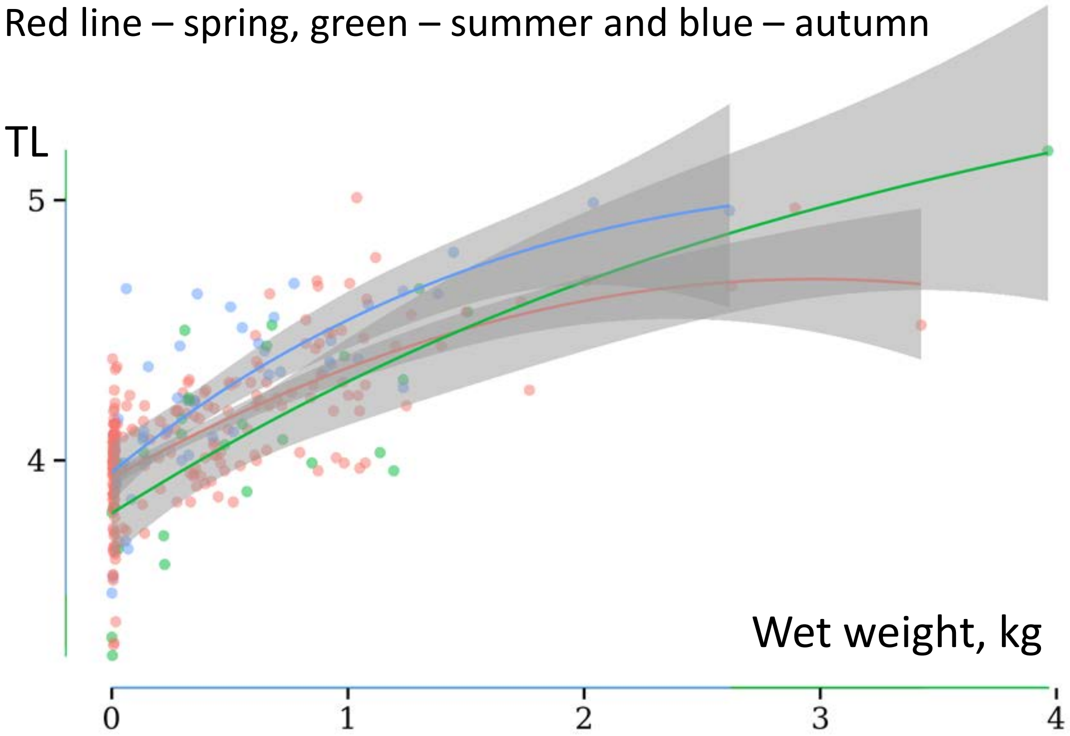
Using stable isotopes to estimate trophic position: models, methods, and assumption //

Ecology. — 2002. — Vol. 83. — P. 703–718.

Obviously TL determined by stable isotope ratio of nitrogen depends on season
(due to fresh import of nitrogen after spring bloom)
and on the age (size of mouth opening) of the consumer.

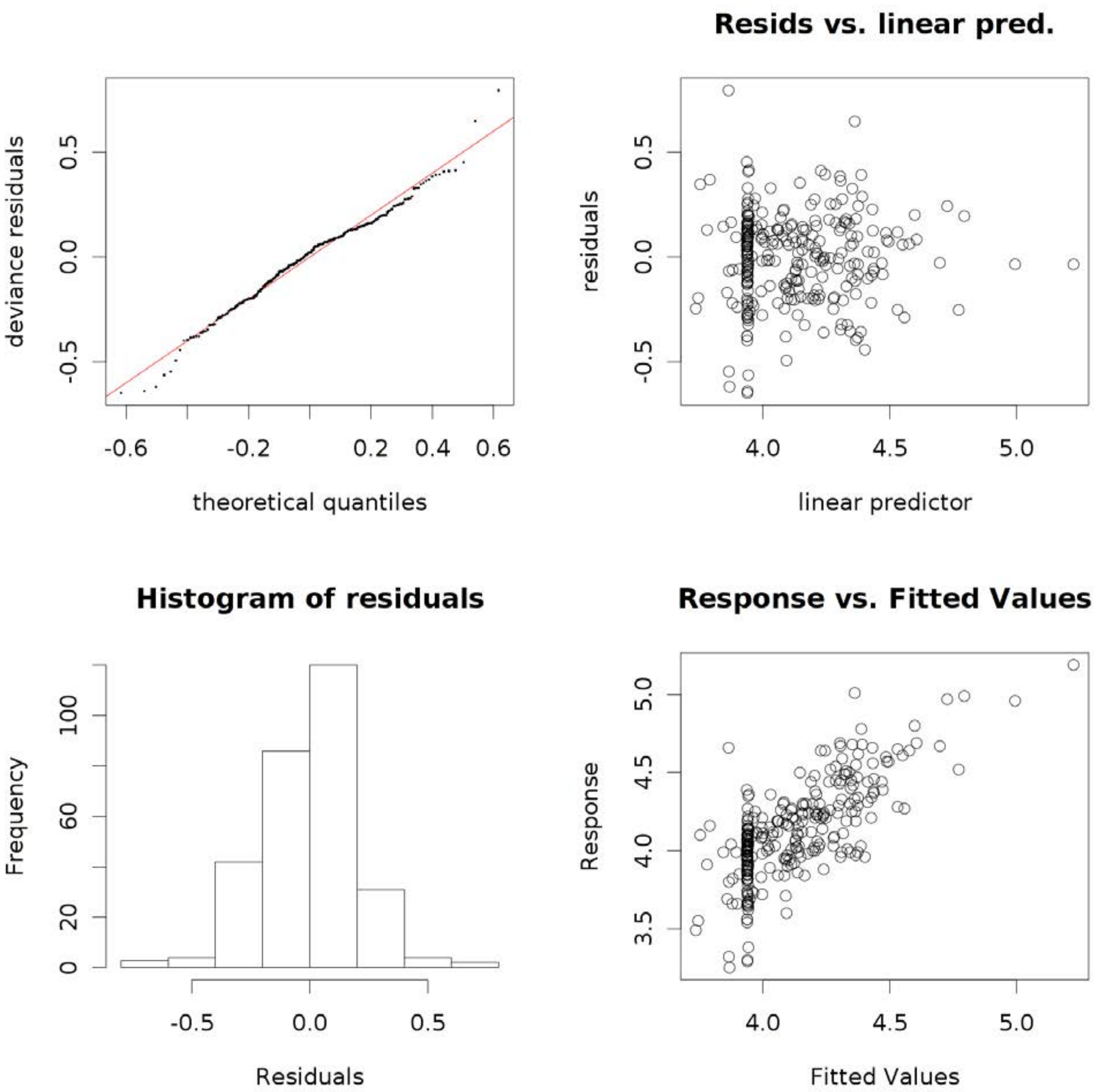
We have mean weight (in kg) for every species in every observed catch,
that is why we used it to get mean weighted average (muTL) of every catch.

Red line – spring, green – summer and blue – autumn



LOESS with span = 2 by seasons for walleye pollock in the Sea of Okhotsk

Mean TL of walleye polock was estimated according to season
and its weight using cubic regression splines in **mgcv** package of **R** language.



We also have sufficient data to distinguish seasonal variations of the TL in spring, summer and fall for *Clupea pallasii* and *Leuroglossus schmidti*

But we had to assume that in winter the TL was likely to be in the middle (arithmetic average) between fall and spring.

In other cases we could not clearly see the significant difference of the TL by seasons.

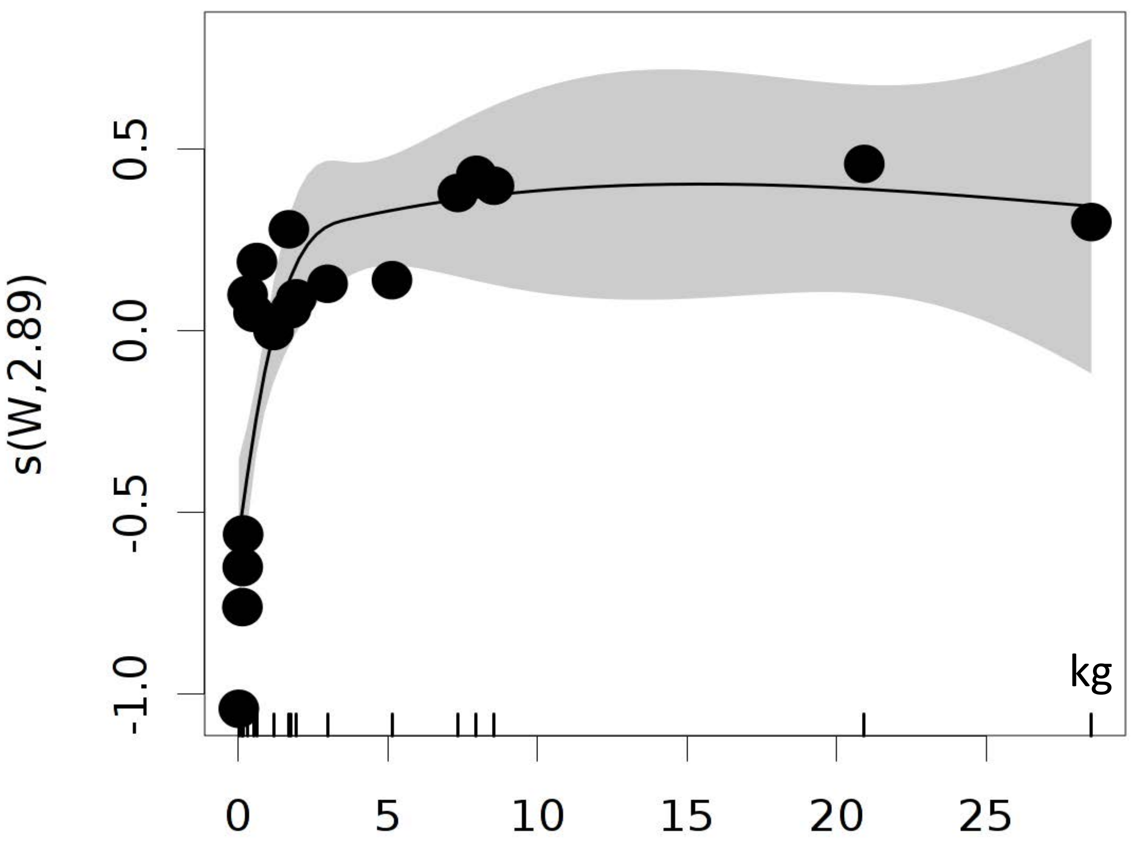
But we could regress the TL on weight for the other 9 fish:

1. *Bathyraja parmifera*
2. *Eleginus gracilis*
3. *Gadus macrocephalus*
4. *Hemilepidotus jordani*
5. *Hippoglossus stenolepis*
6. *Myoxocephalus polyacanthocephalus*
7. *Platichthys stellatus*
8. *Reinchardtius hippoglossoides*
9. *Sebastolobus macrochir*

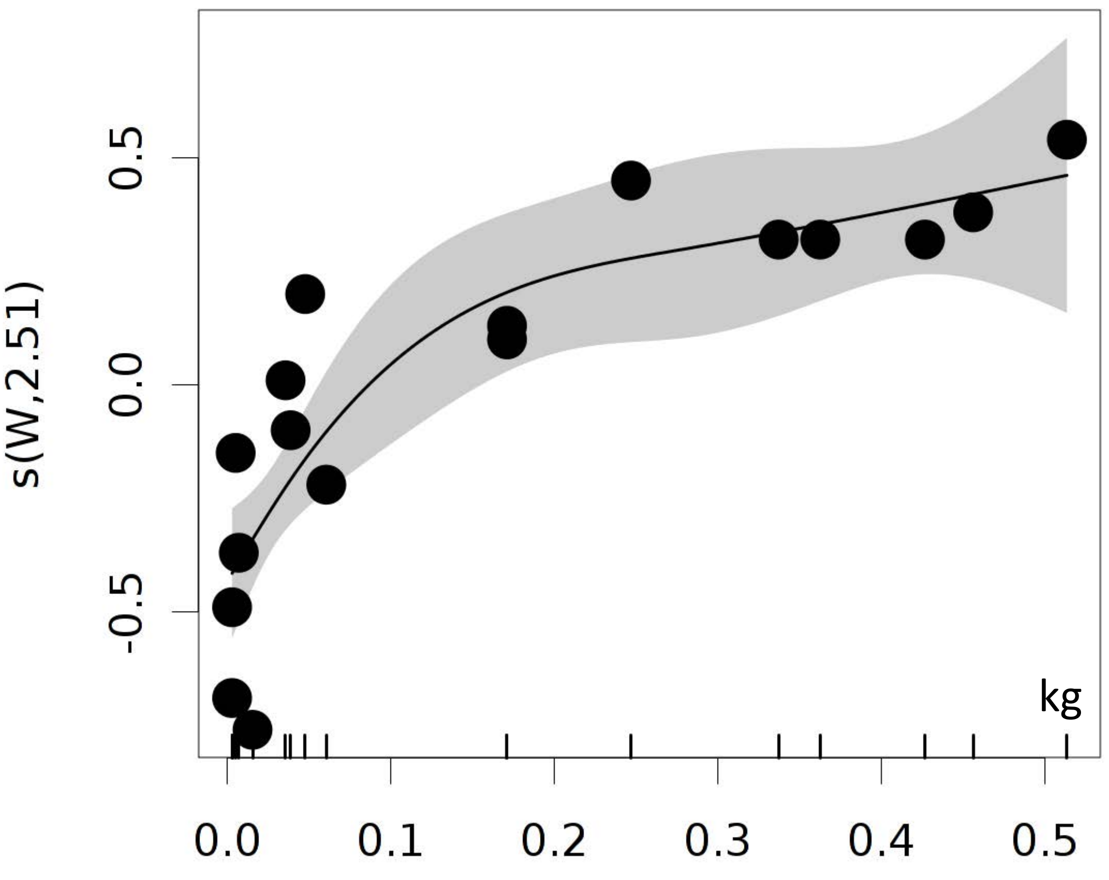
and 2 squid species:

1. *Berryteuthis magister*
2. *Gonatus madokai*

Reinchardtius hippoglossoides
TL ~ 4.52 + f(W)

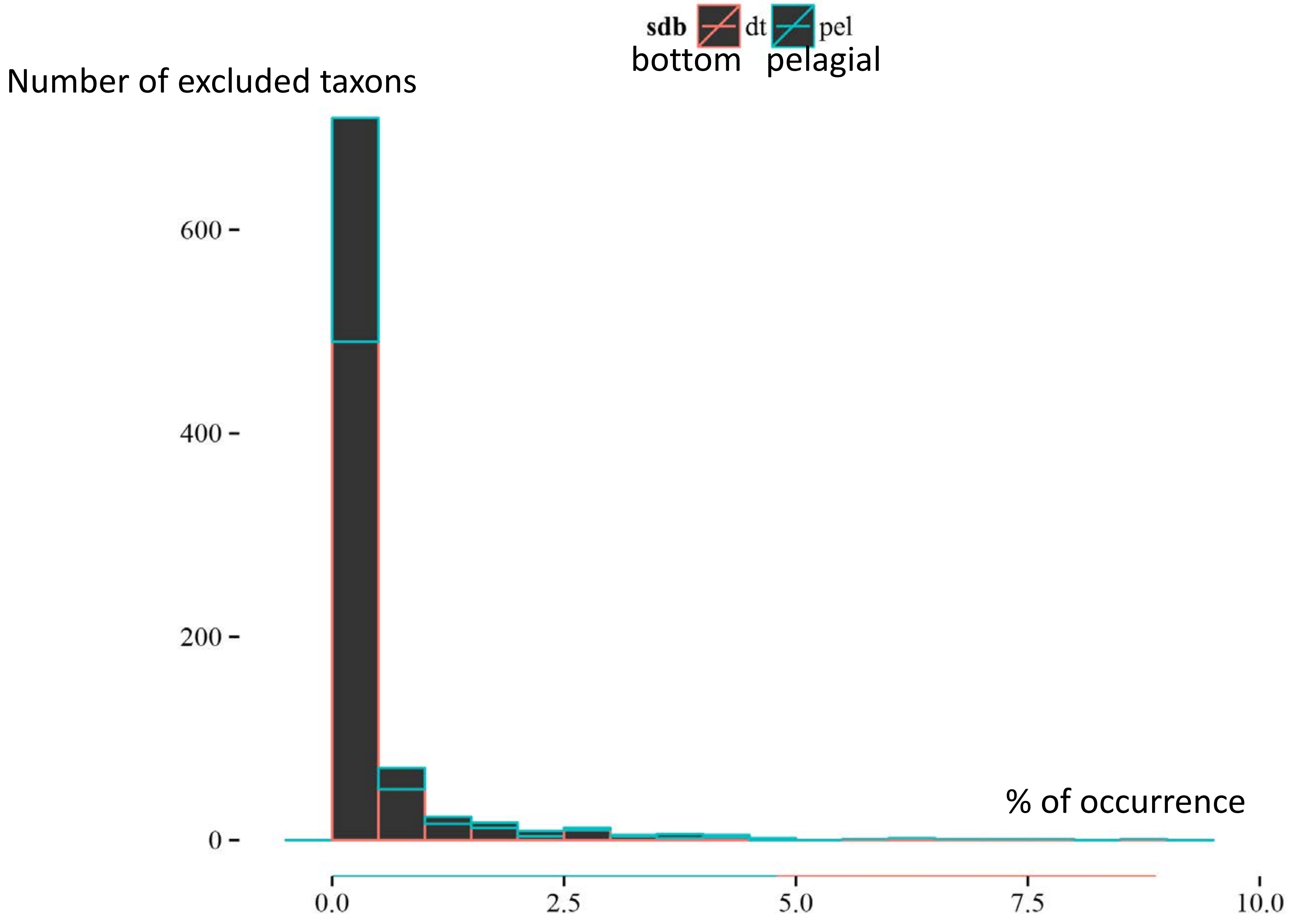


Berryteuthis magister
TL ~ 3.82 + f(W)



Examples of used regressions

The TL of 67 fish, 6 squid and 5 Decapod species was taken as the average without regression on weight and we also included 147 species using estimates of TL from www.fishbase.org
All the other species of macrofauna were occasional and thus we excluded them.

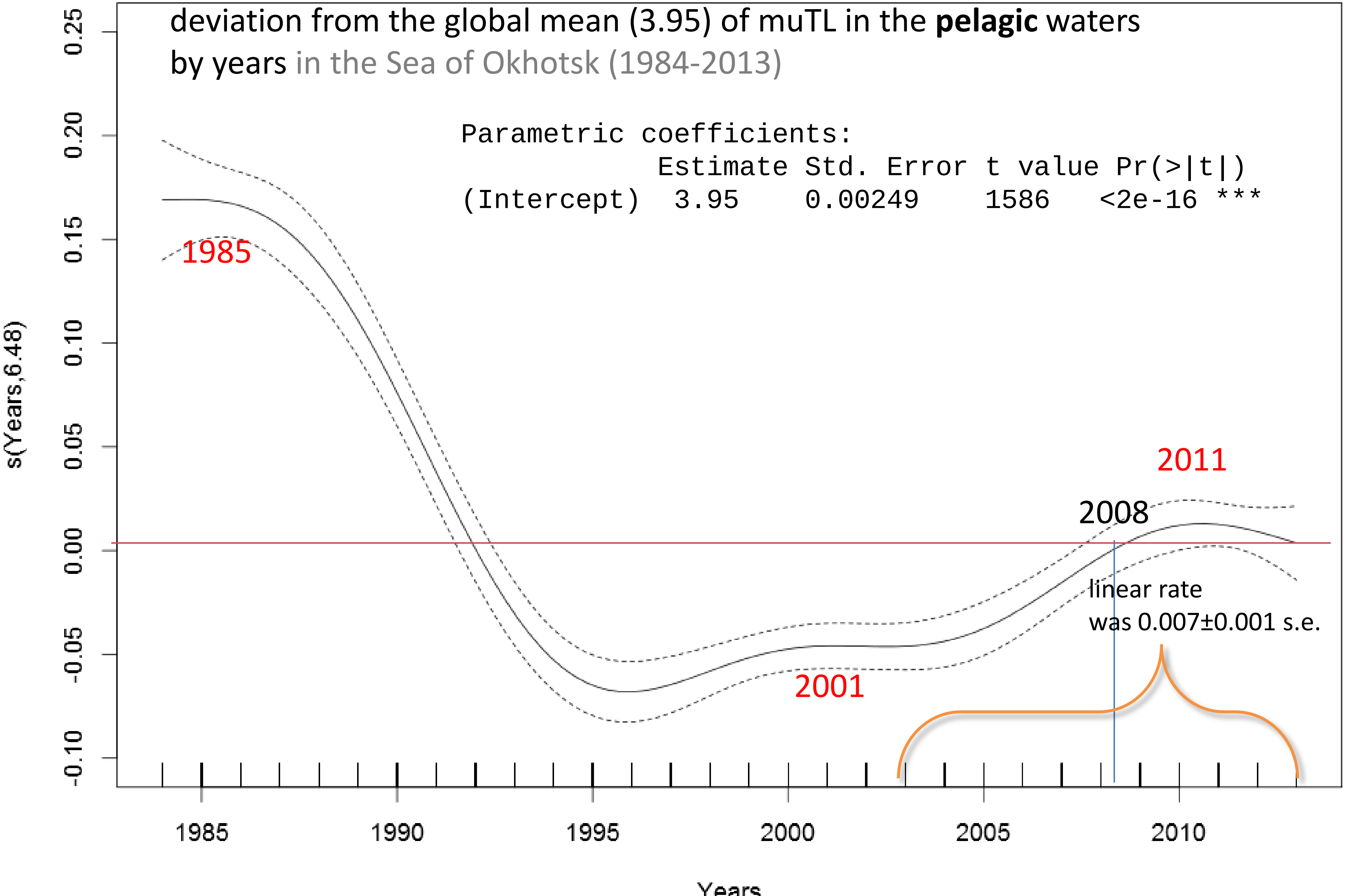


Finally we estimated muTL from 9926 trawls (with 1 cm mesh)
in the pelagic waters (in 1984-2013)
and
from 6321 bottom trawls (in 1977-2010).

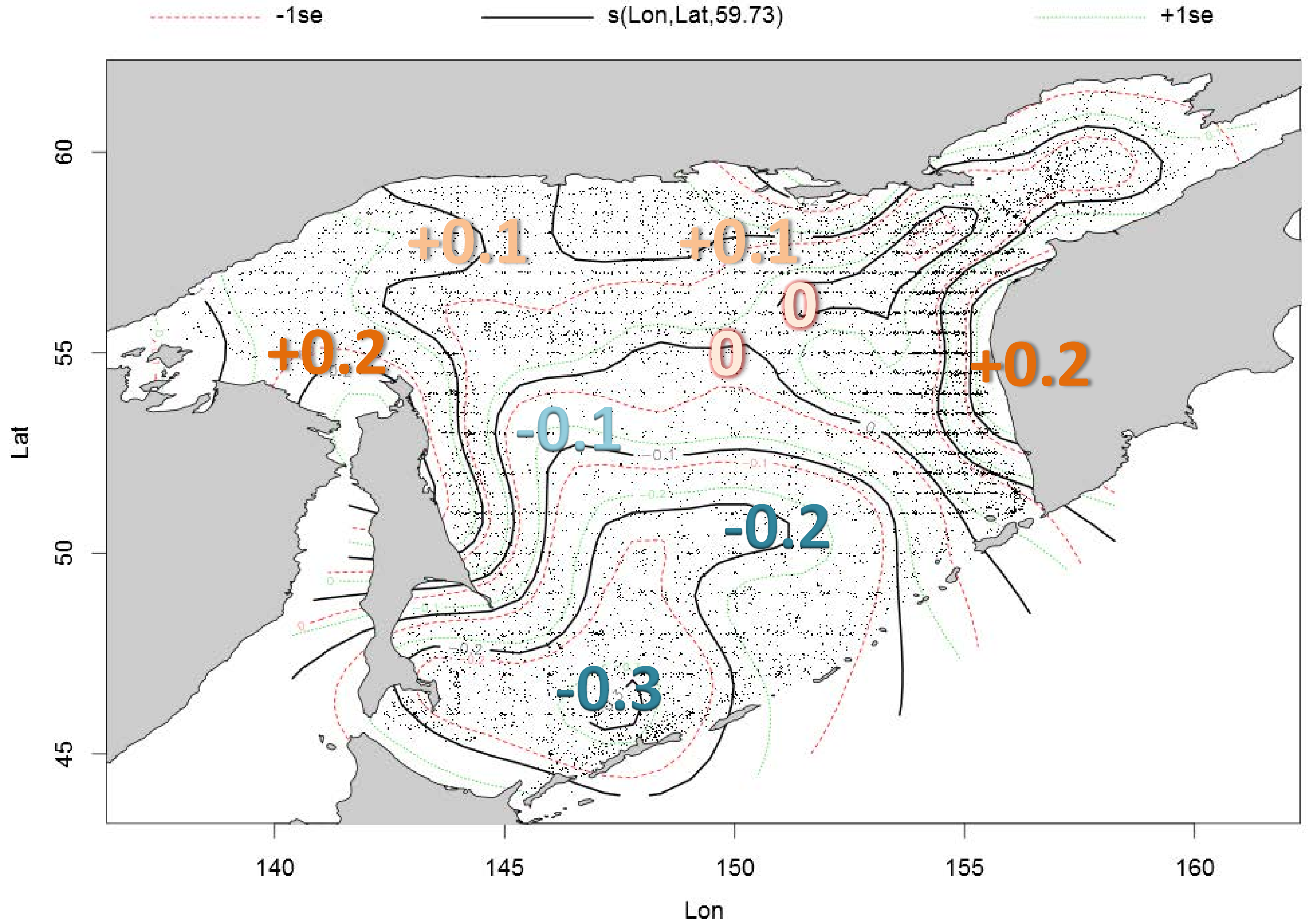
muTL was weighted by kg per square km average of TL in each trawl catch.

We analyzed spatial and temporal variation of muTL
using Generalized Additive Models with splines on coordinates, horizon of trawling, years and months
(gam function from the mgcv package of R language,
finally, with Gaussian errors).

muTL in the trawls in the **pelagial**

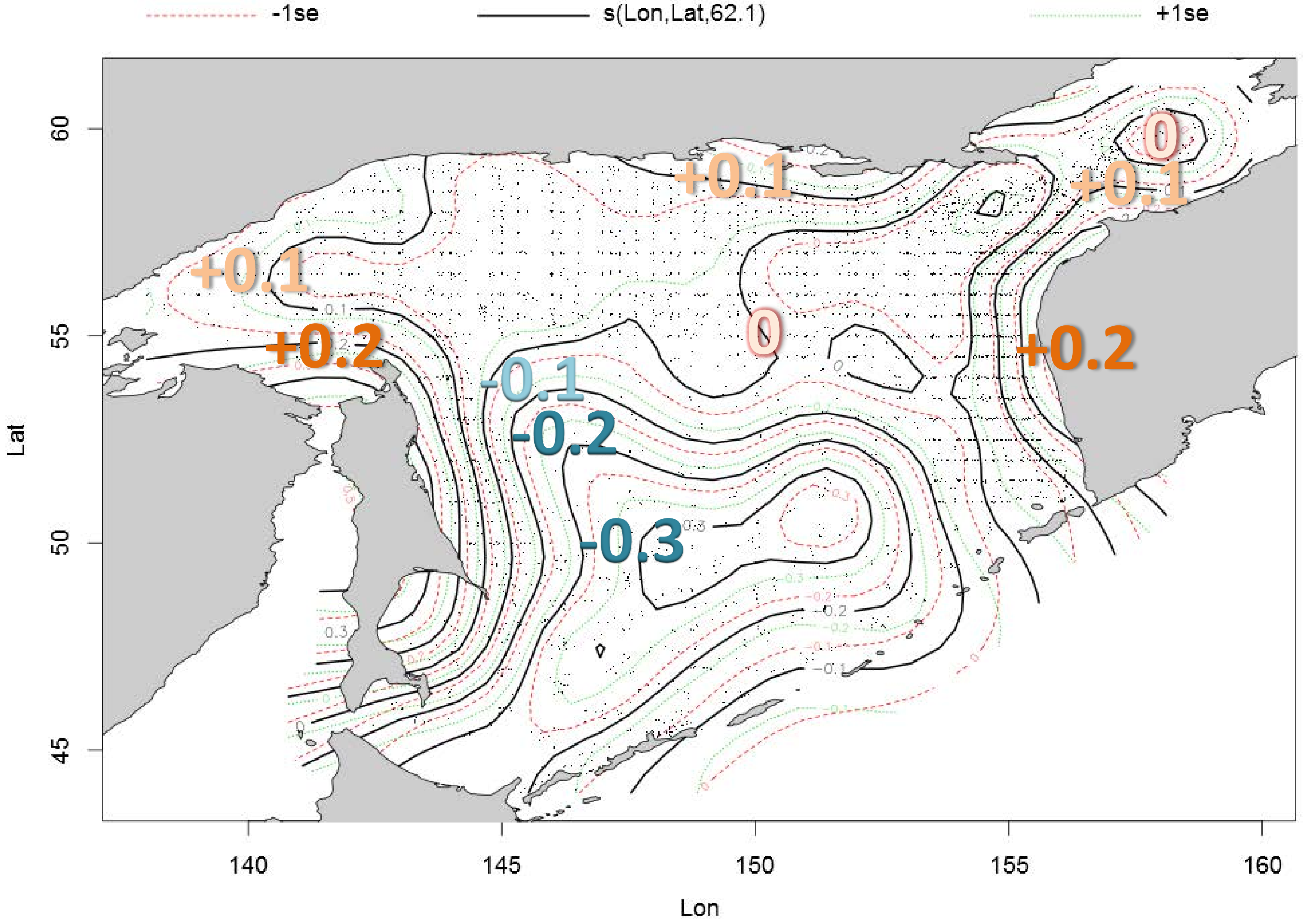


muTL in the **pelagic** waters in the space as deviation from the global mean (3.95)
in the Sea of Okhotsk (1984-2013)

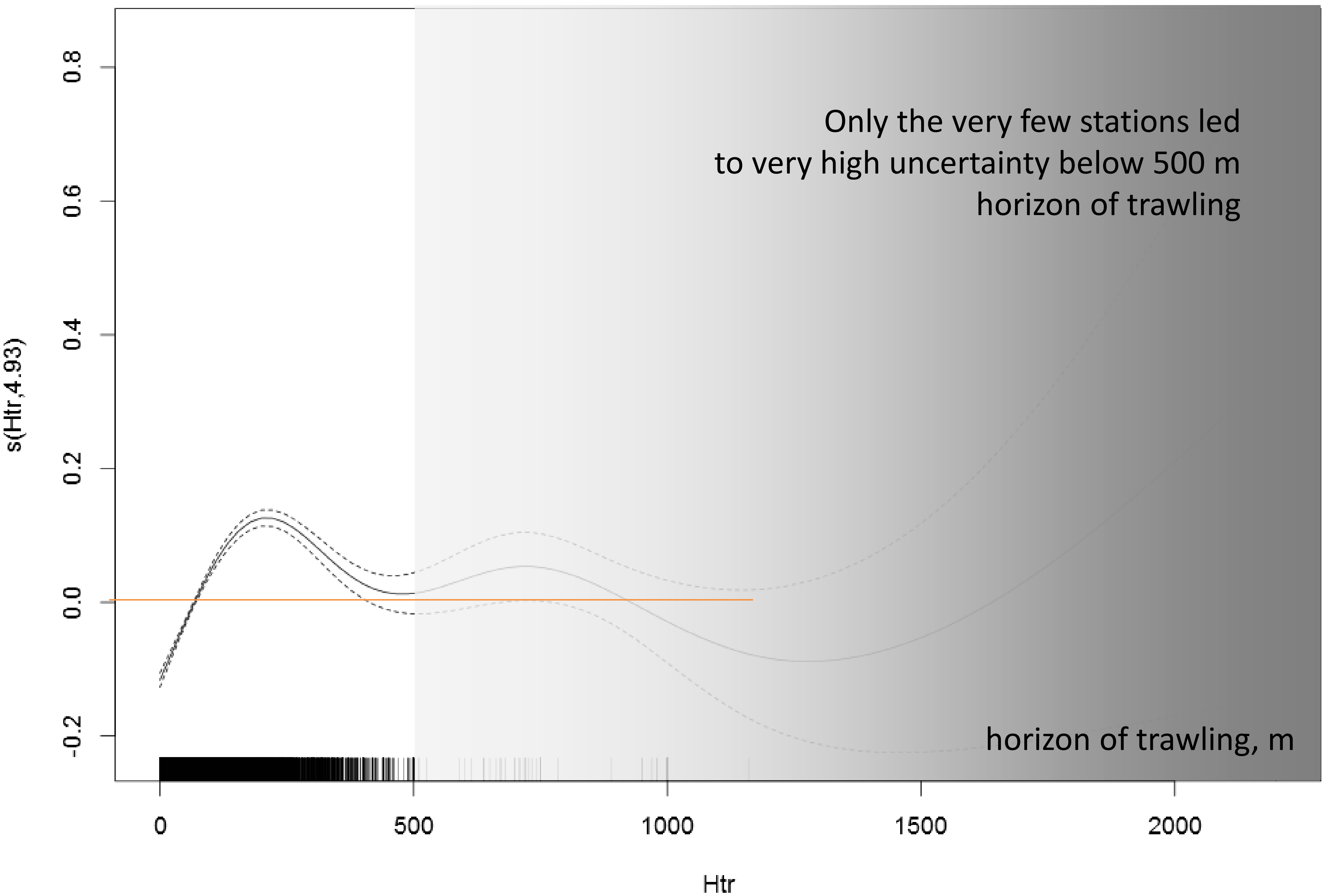


muTL in the **pelagic** waters in the space as deviation from the global mean (2004-2013)

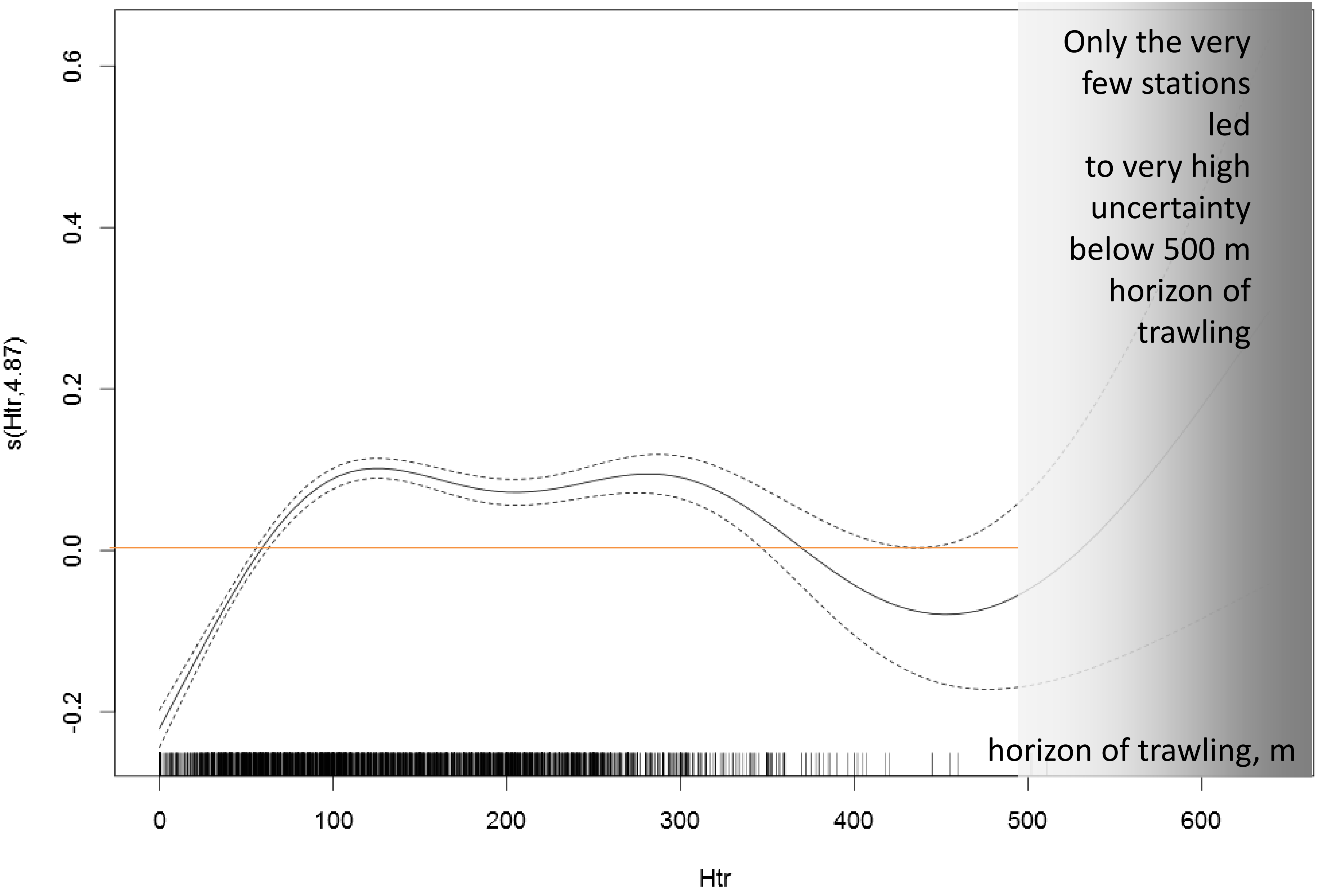
in the Sea of Okhotsk considering increase by 0.007 to be linear



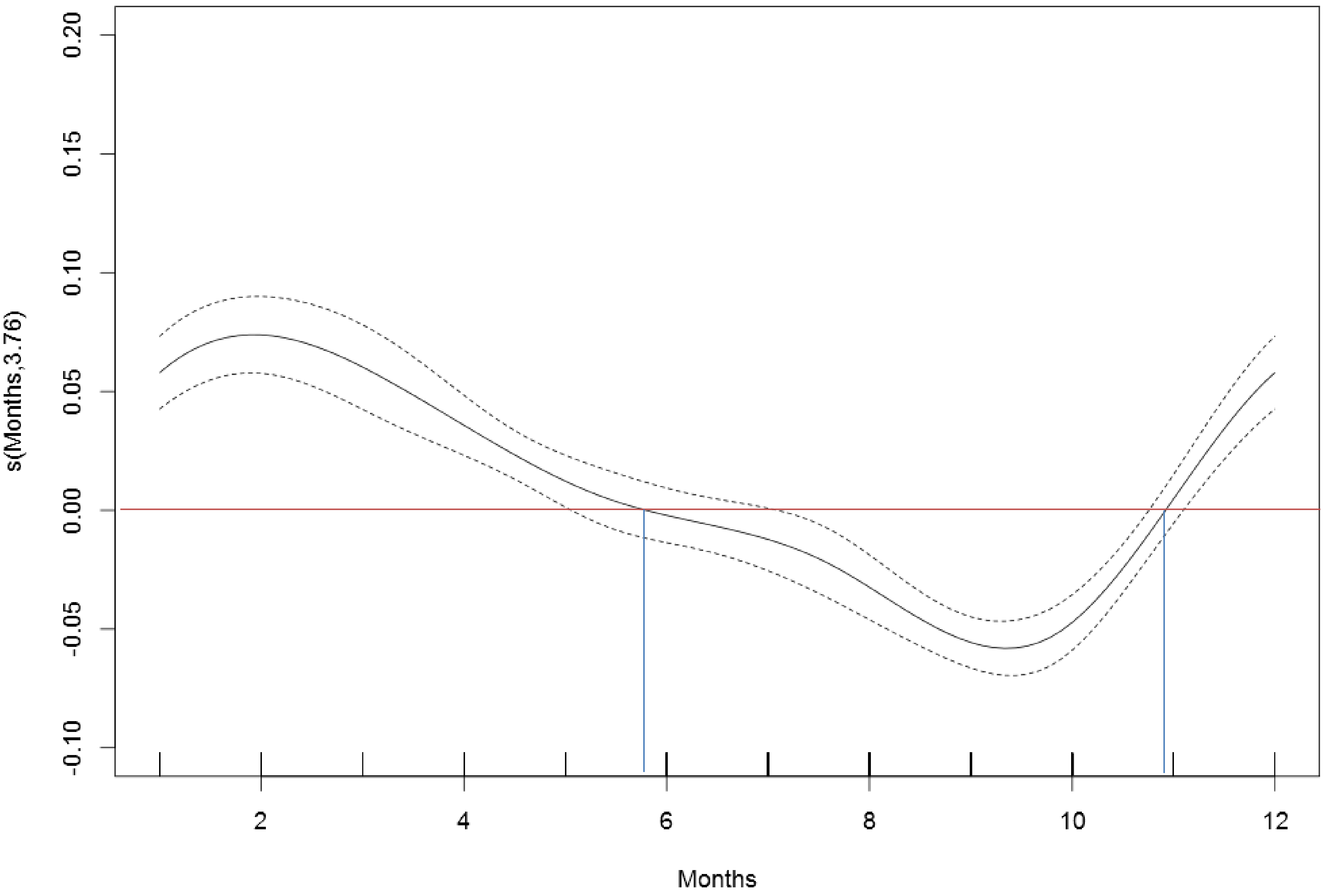
deviation from the global mean (3.95) of muTL in the **pelagic** waters
depending on the horizon of trawling in the Sea of Okhotsk (1984-2013)



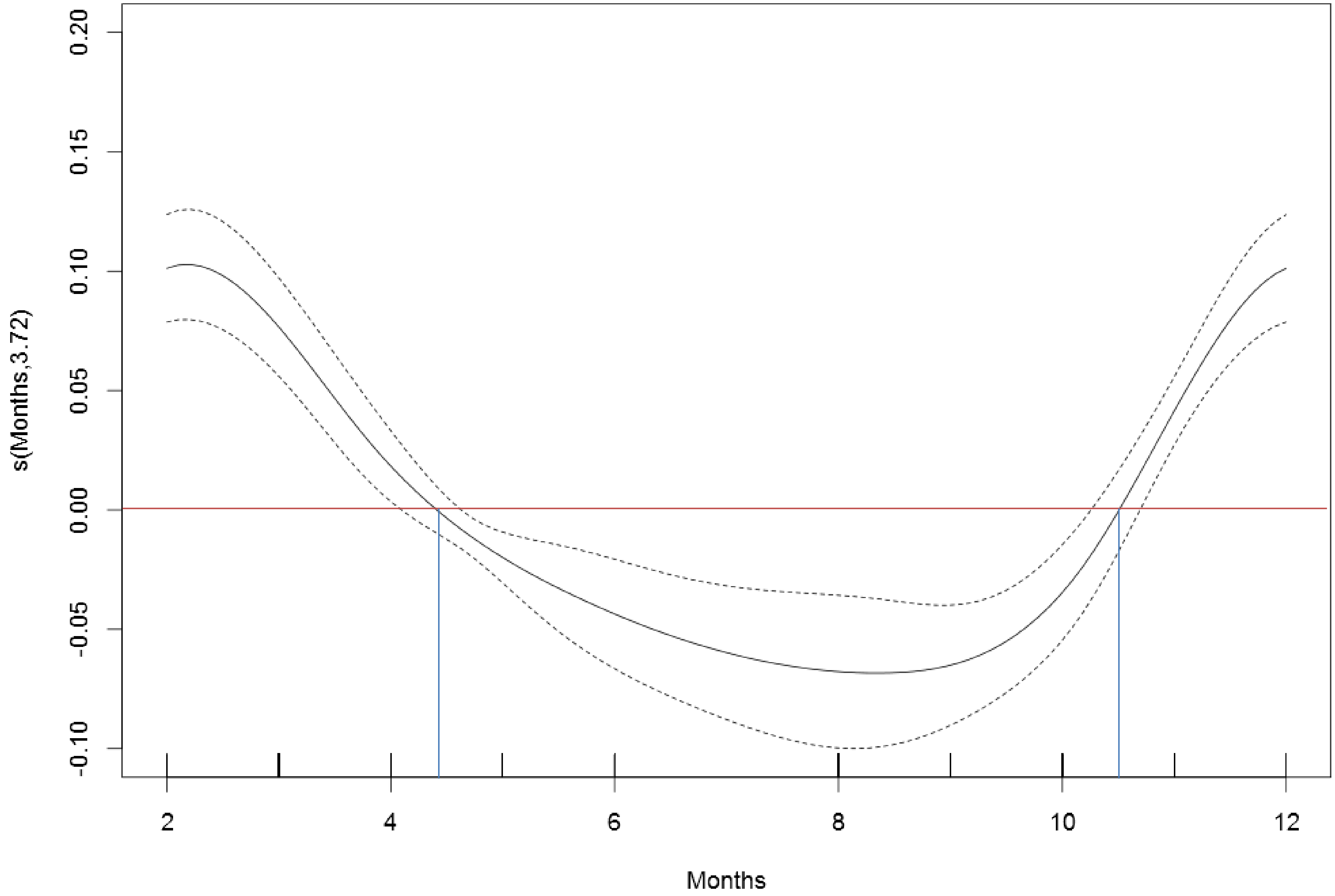
deviation from the global mean of muTL in the **pelagic** waters (2004-2013)
depending on the horizon of trawling in the Sea of Okhotsk



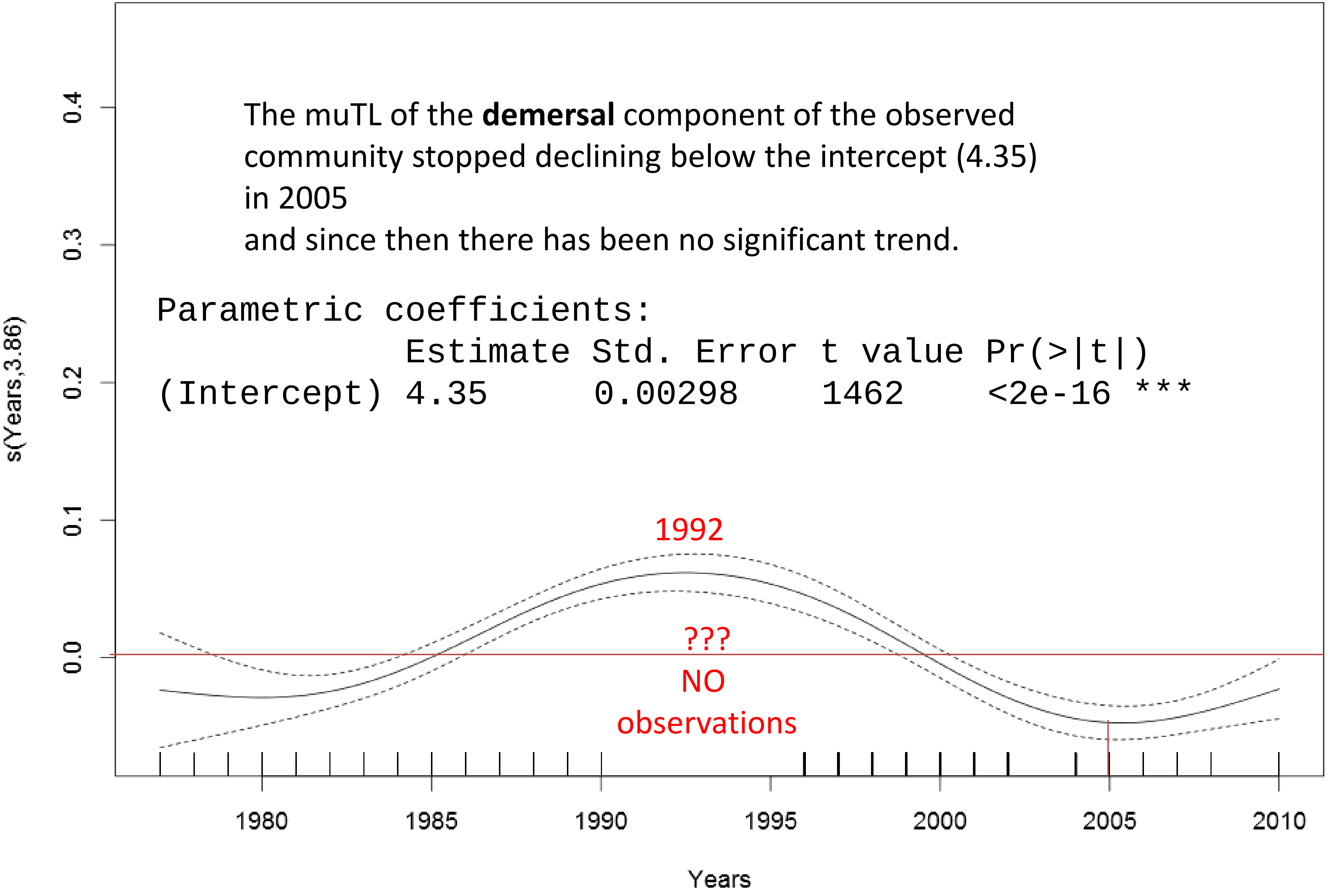
deviation from the global mean (3.95) of muTL in the **pelagic** waters
depending on the number of month in a year in the Sea of Okhotsk (1984-2013)



deviation from the global mean of muTL in the **pelagic** waters (2004-2013)
depending on the number of month in a year in the Sea of Okhotsk

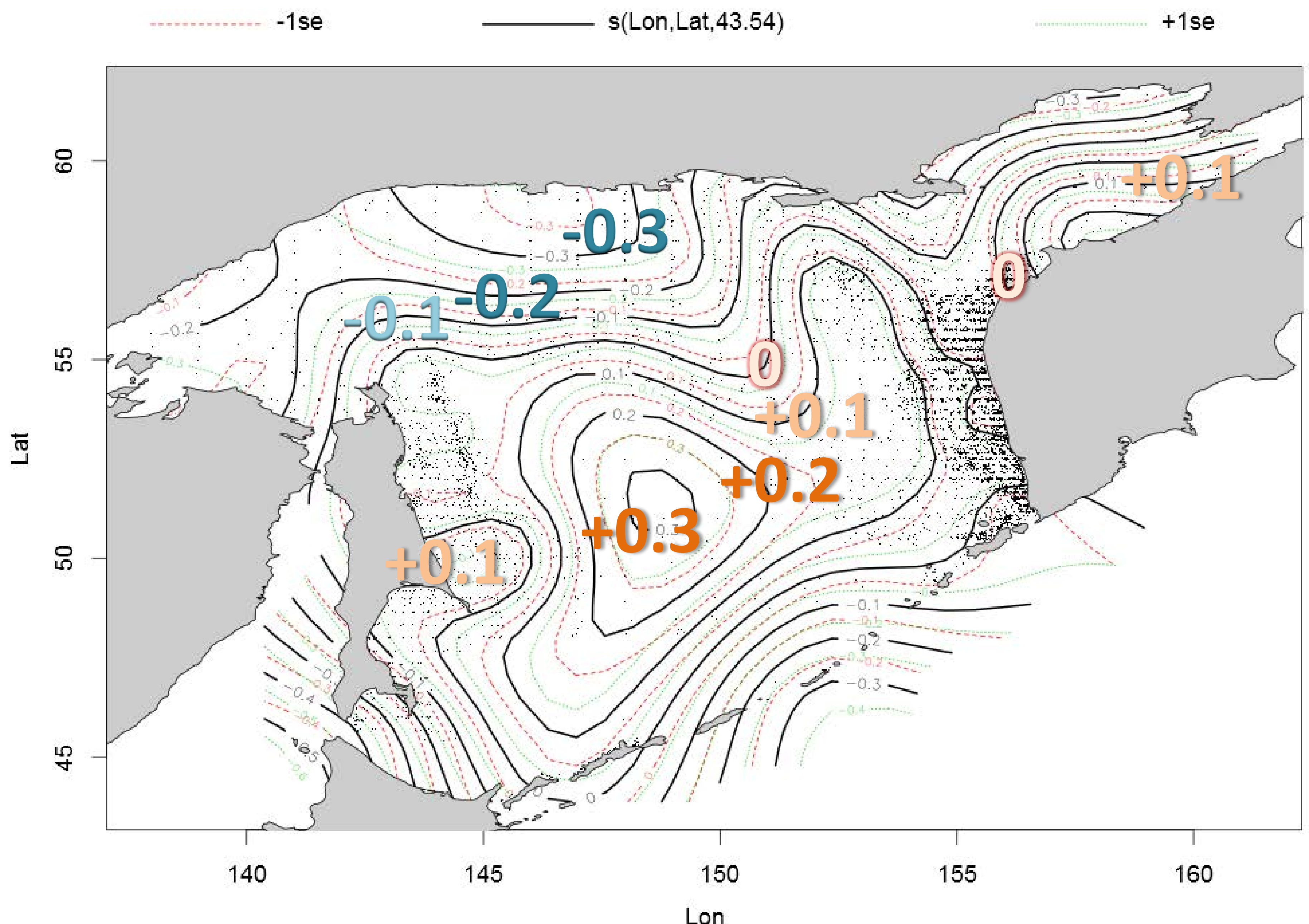


muTL in the **bottom** trawls in the Sea of Okhotsk (1977-2010)

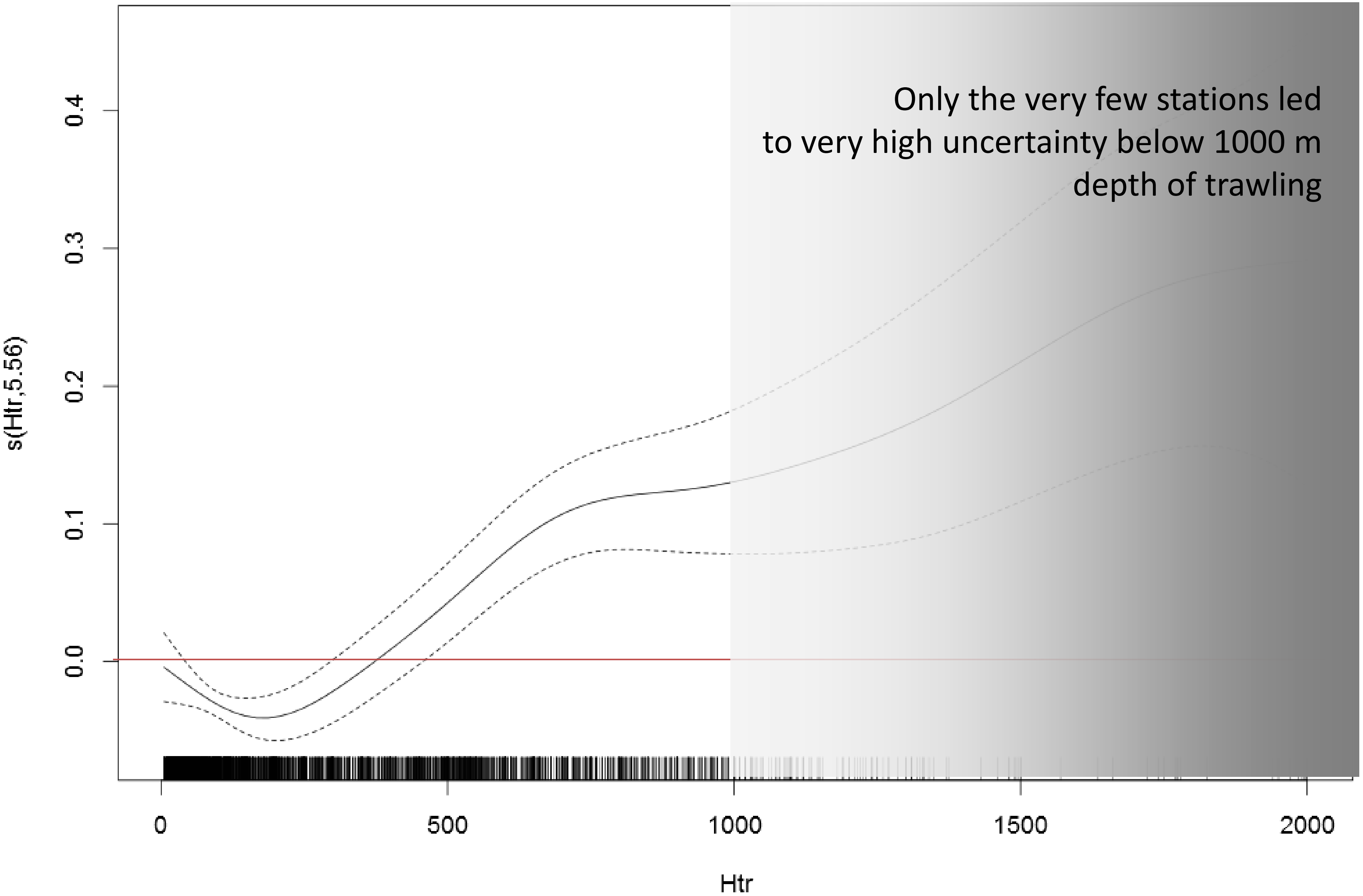


muTL in the **bottom** trawls in the space as deviation from the global mean (4.35)

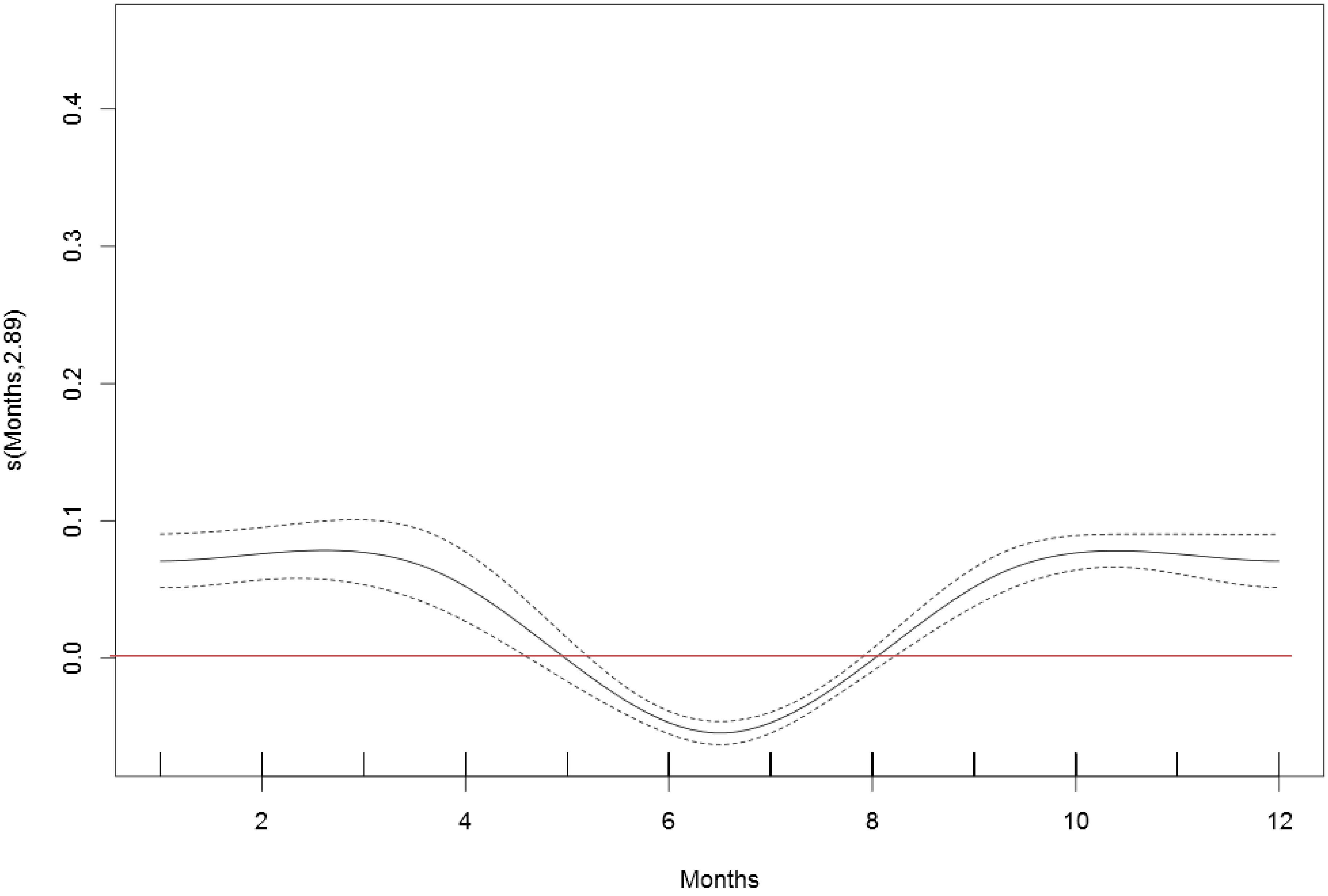
in the Sea of Okhotsk (1977-2010)



deviation from the global mean (4.35) of muTL in the **bottom** trawls
depending on the horizon of trawling in the Sea of Okhotsk (1977-2010)



deviation from the global mean (4.35) of muTL in the **bottom** trawls
depending on the number of month in a year in the Sea of Okhotsk (1977-2010)



Conclusion

Stable isotope ratio of nitrogen ($^{15}N/^{14}N$) allowed us to explore muTL
of animals bigger than 1 cm in catches of the trawls
including nonlinear connections in space and time as the part of a model.

Based on these annual estimates, we conclude that:

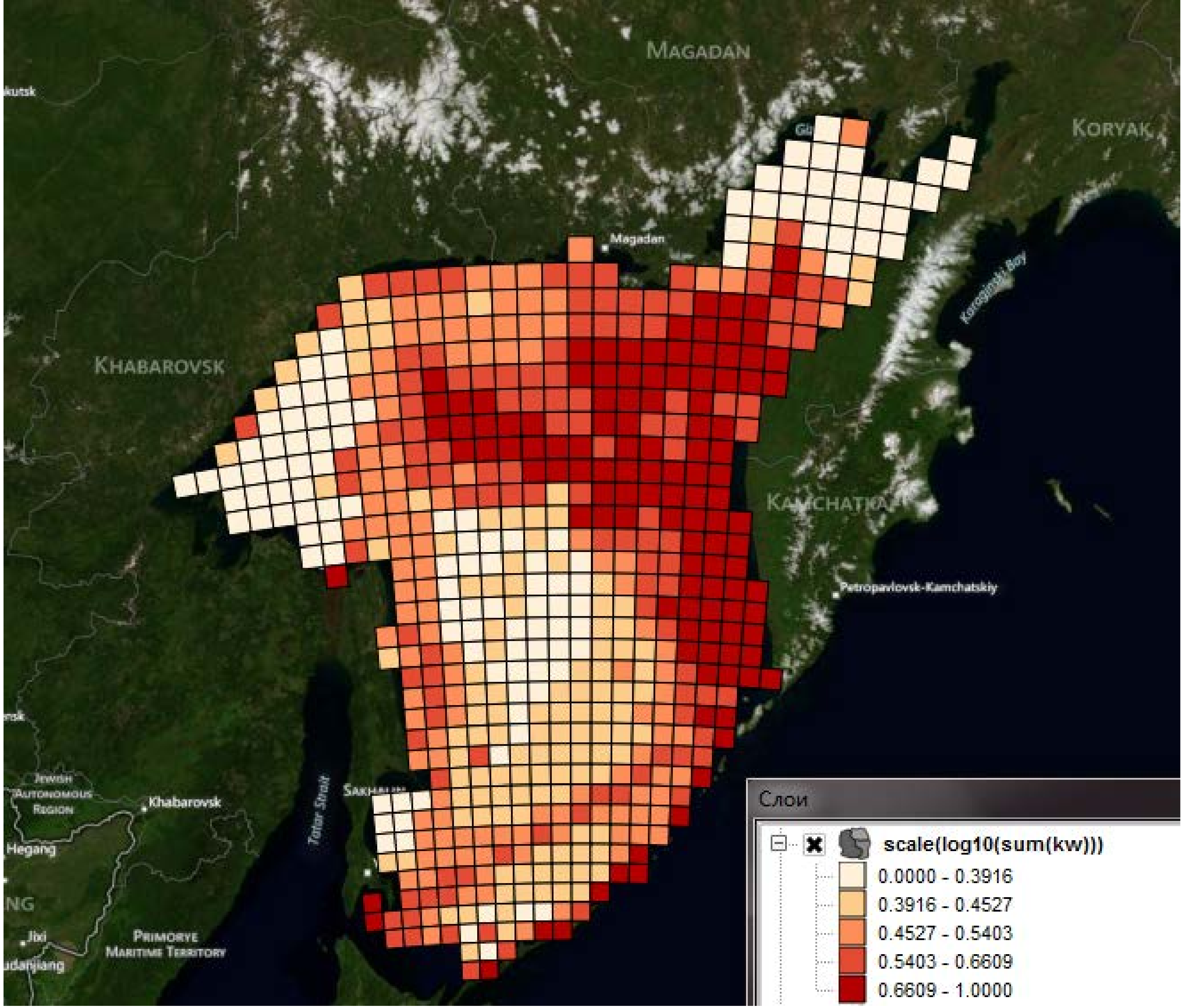
muTL over the last 10 years increased significantly
(the rate was about 0.007 per year on the linear scale)
in the **pelagic** waters and it crossed
the intercept = 3.95±0.00249 s.e. in 2008.

The muTL of the **demersal** component
(of the observed community in the bottom trawls)
stopped declining below **the intercept = 4.35±0.00298** s.e.
in 2005 and since then there has been no significant trend.

Further work connected with the ToR of the WG-28:

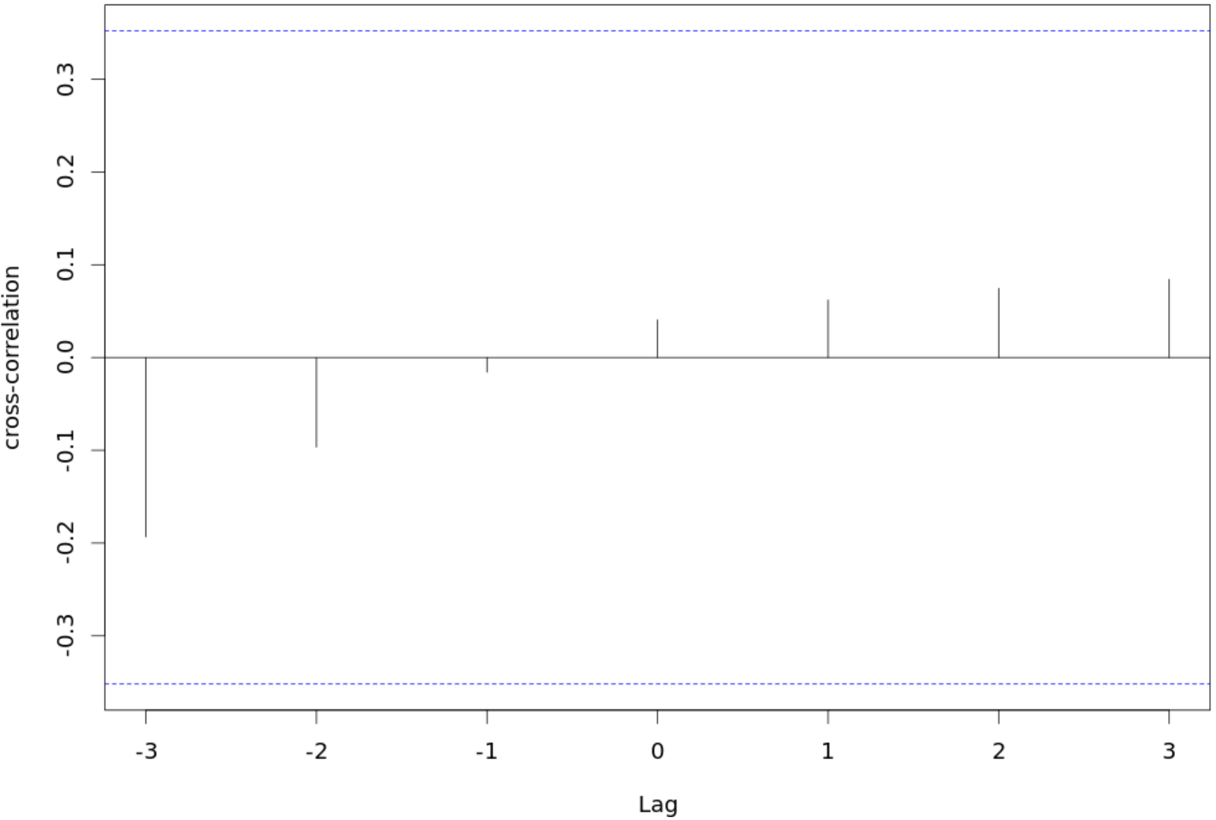
Fisheries is considered to be the most important anthropogenic stressor.

So, can annual total catch be statistically connected with presented variation of muTL?



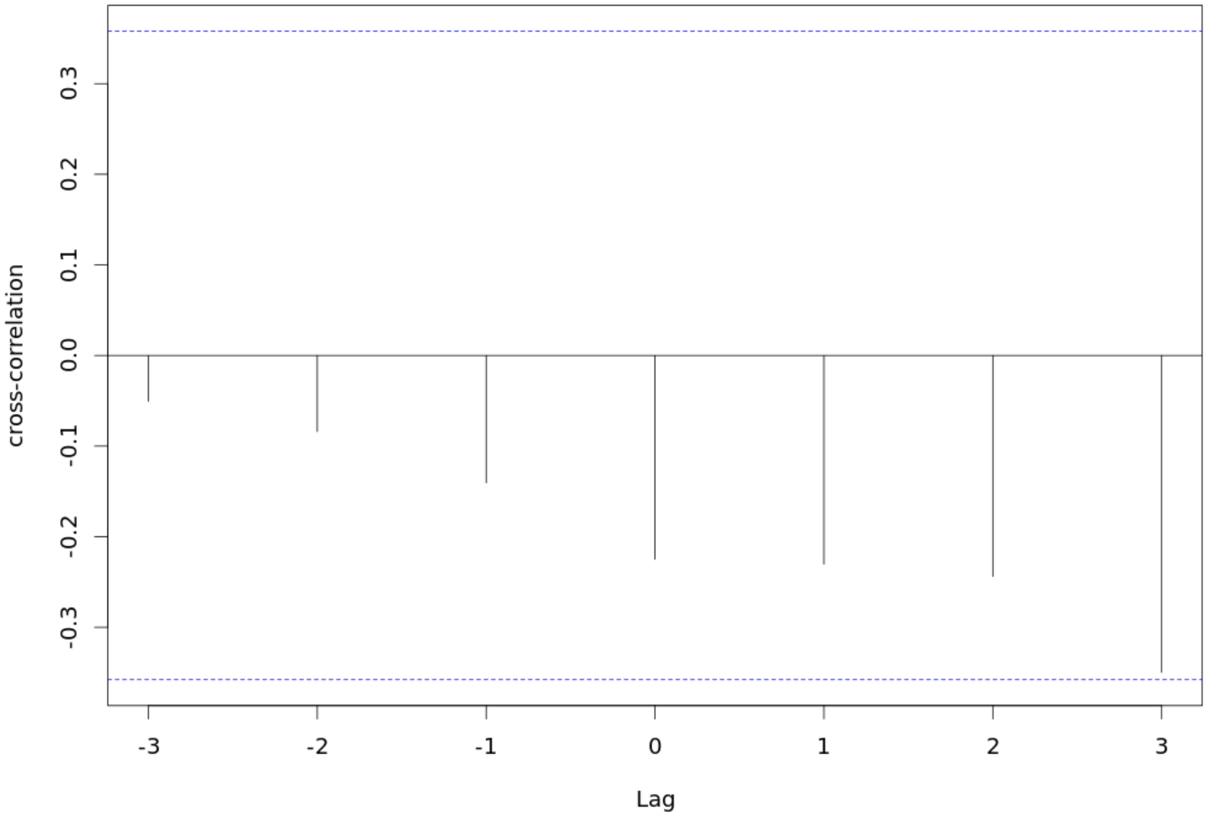
Bottom catch cross-correlated with muTL
at the bottom is insignificant (with up to 3 years lag):

-3	-2	-1	0	1	2	3
-0.193	-0.097	-0.016	0.041	0.062	0.075	0.084



Pelagic catch cross-correlated with muTL
In the pelagial is also insignificant (with up to 3 years lag):

-3	-2	-1	0	1	2	3
-0.051	-0.084	-0.140	-0.225	-0.230	-0.244	-0.350



Thank you for attention !!!

Special thanks to R Core Team for the work on
“**R**: A Language and Environment for Statistical Computing”
and author of mgcv Wood, S.N.