

Nutrient limitation analysis

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**Quarterly Review Meeting
August 10, 2016**

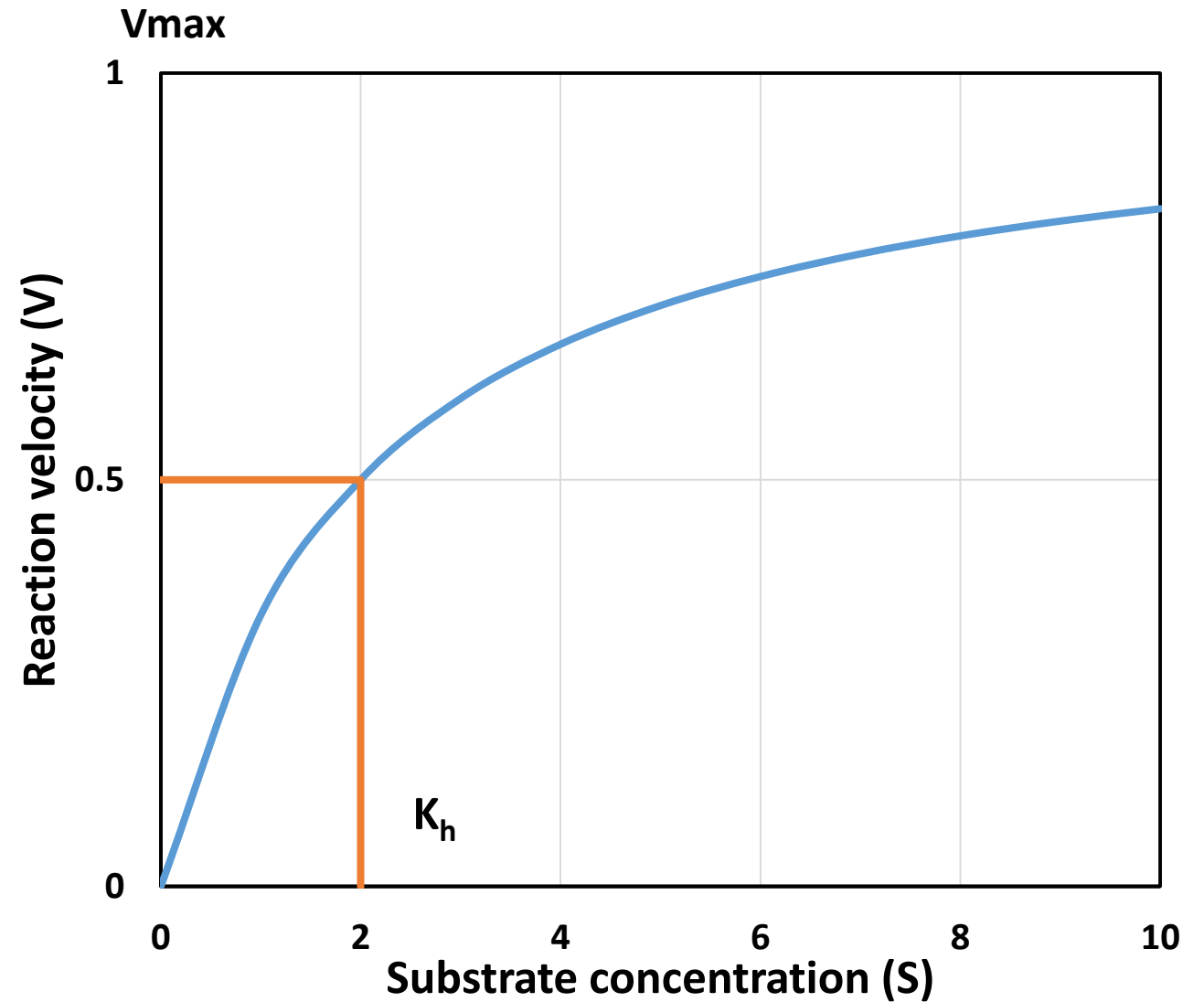
OUTLINE

- **History and determination**
- **Light limitation factor**
- **Bio-assay result summary from literature**
- **Nutrient limitation based on data**
- **Modeled nutrient limitation from CH3D-ICM**

Nutrient limitation and determination

- Liebig law of minimum (1842)
- Bioassay to determine nutrient limitation
- Michealis-Menten function (1913):

$$f(N) = \frac{N}{N + K_h}$$

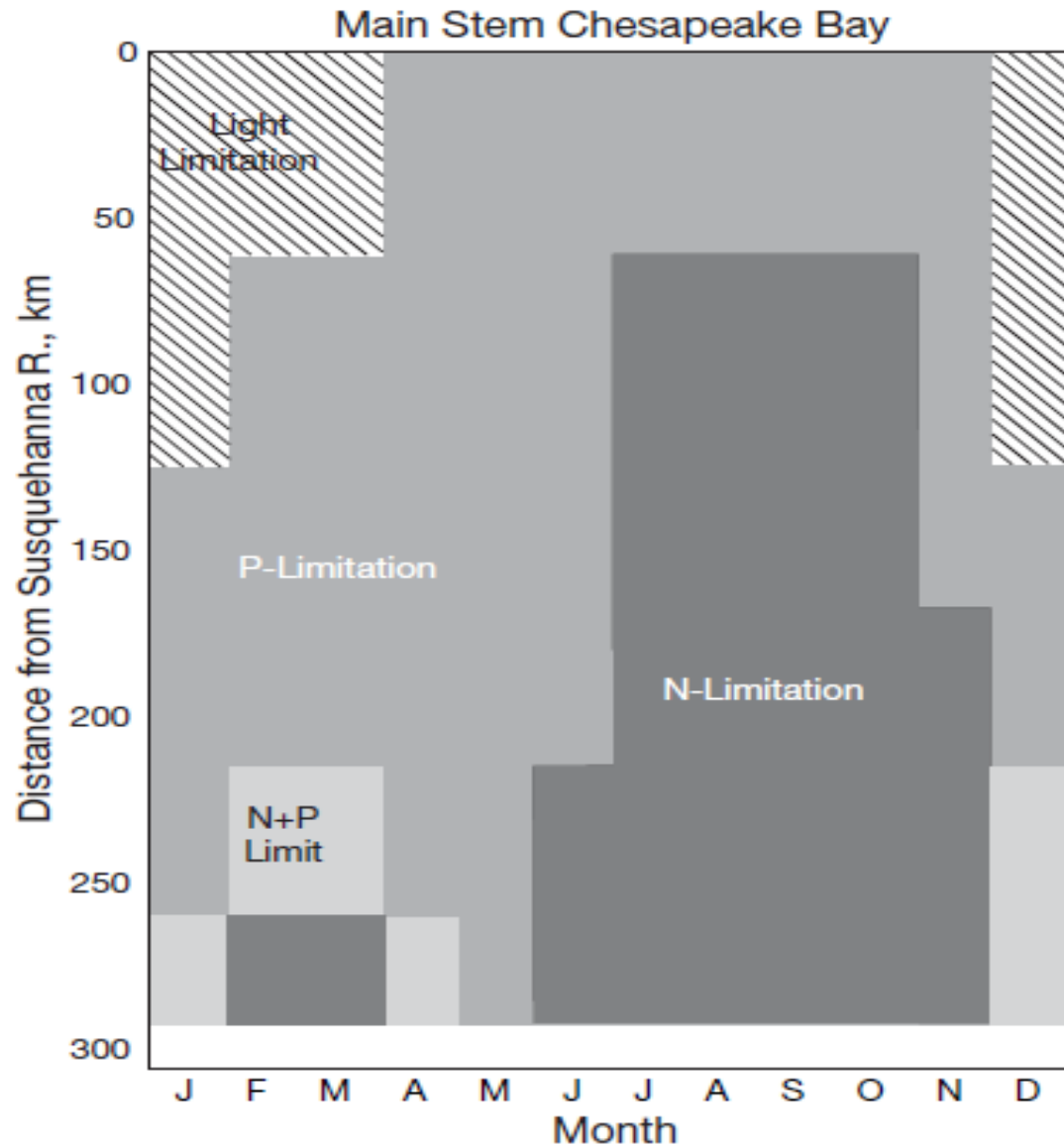


Application in biological growth rate

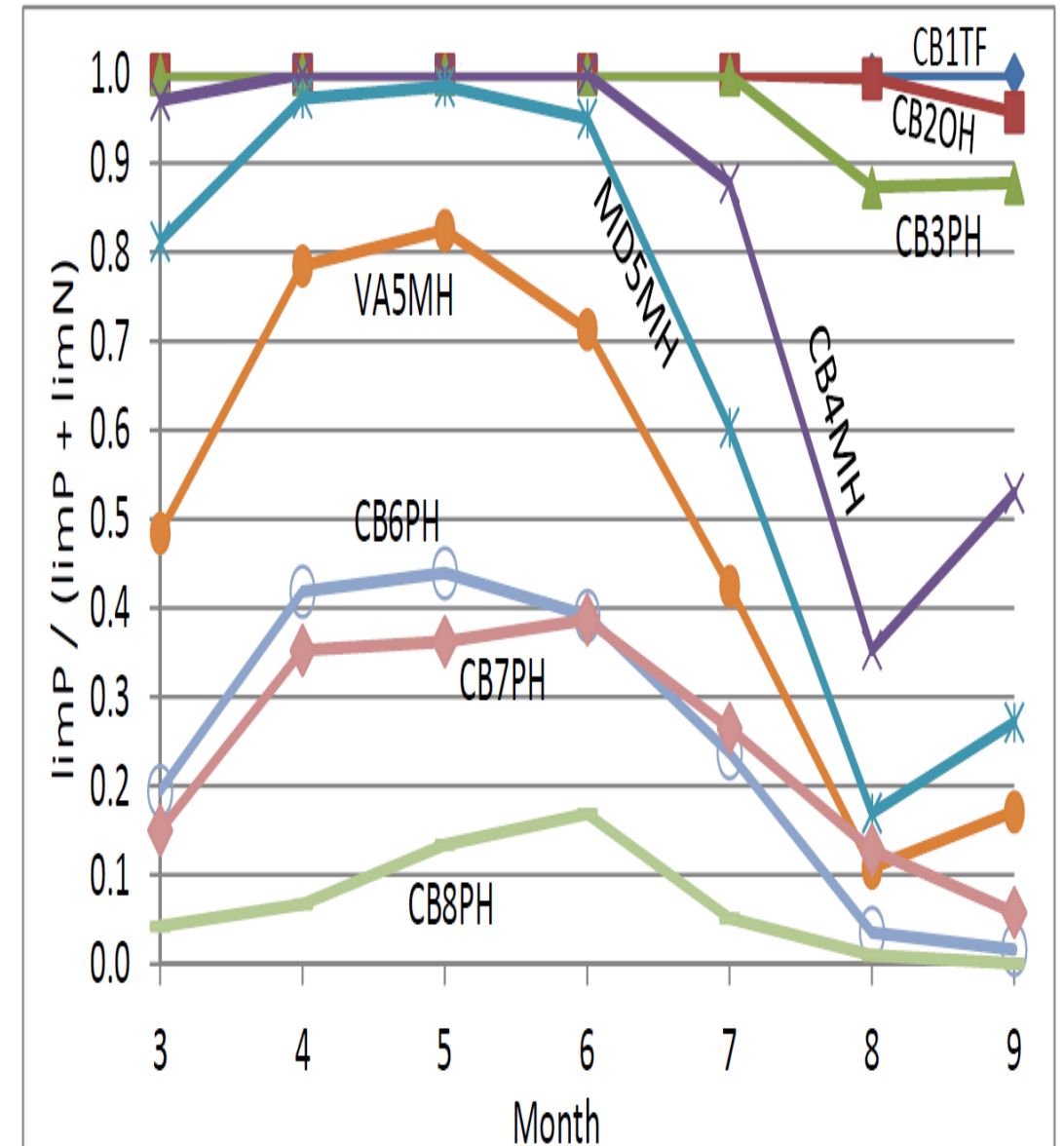
- Monod equation (1941)
- Disc function (1959)
- Application in nutrient (Dugdale, 1967)
- Light limitation: Michealis-Menten and Smith:

$$f(I) = \frac{I}{\sqrt{I^2 + I_h^2}}$$

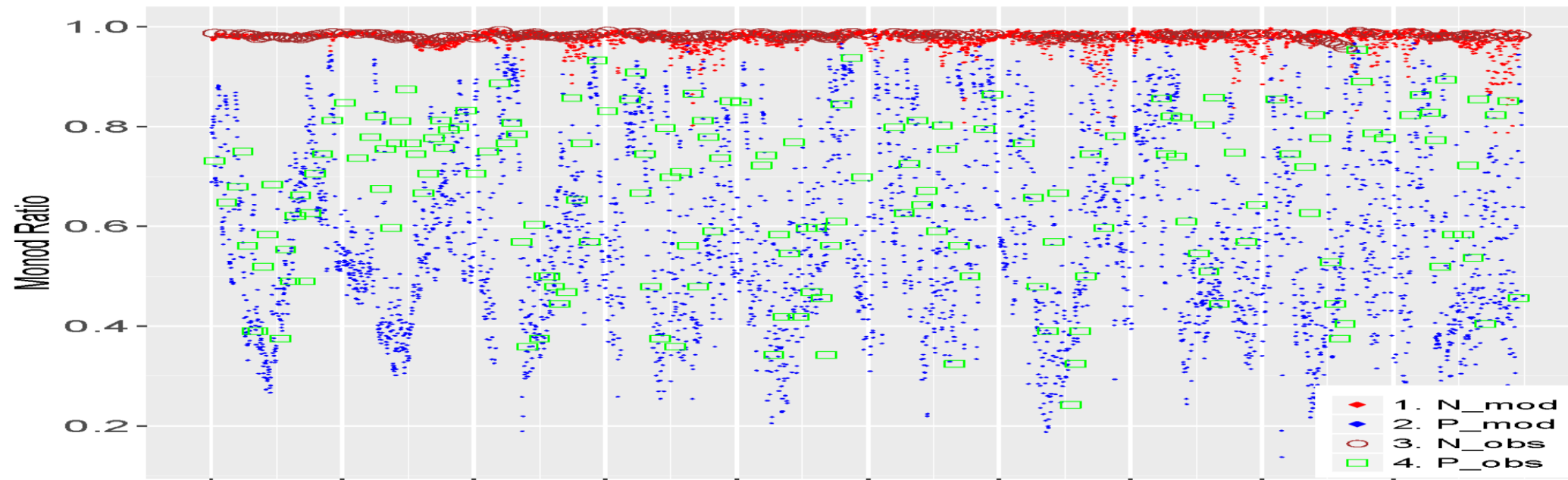
Spatio-temporal N-P limitation based on bioassay (Kemp, Fisher)



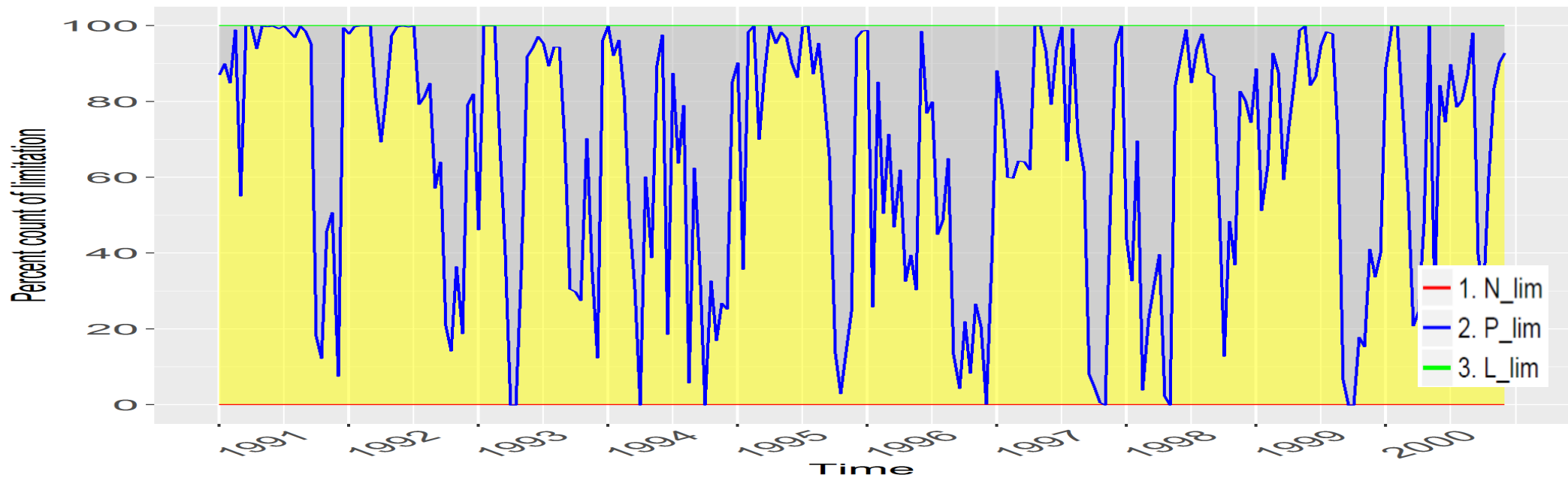
Spatio-temporal N-P limitation based on P532 model prediction



**Data-model
comparison
of N-P
limitation at
CB1.1**



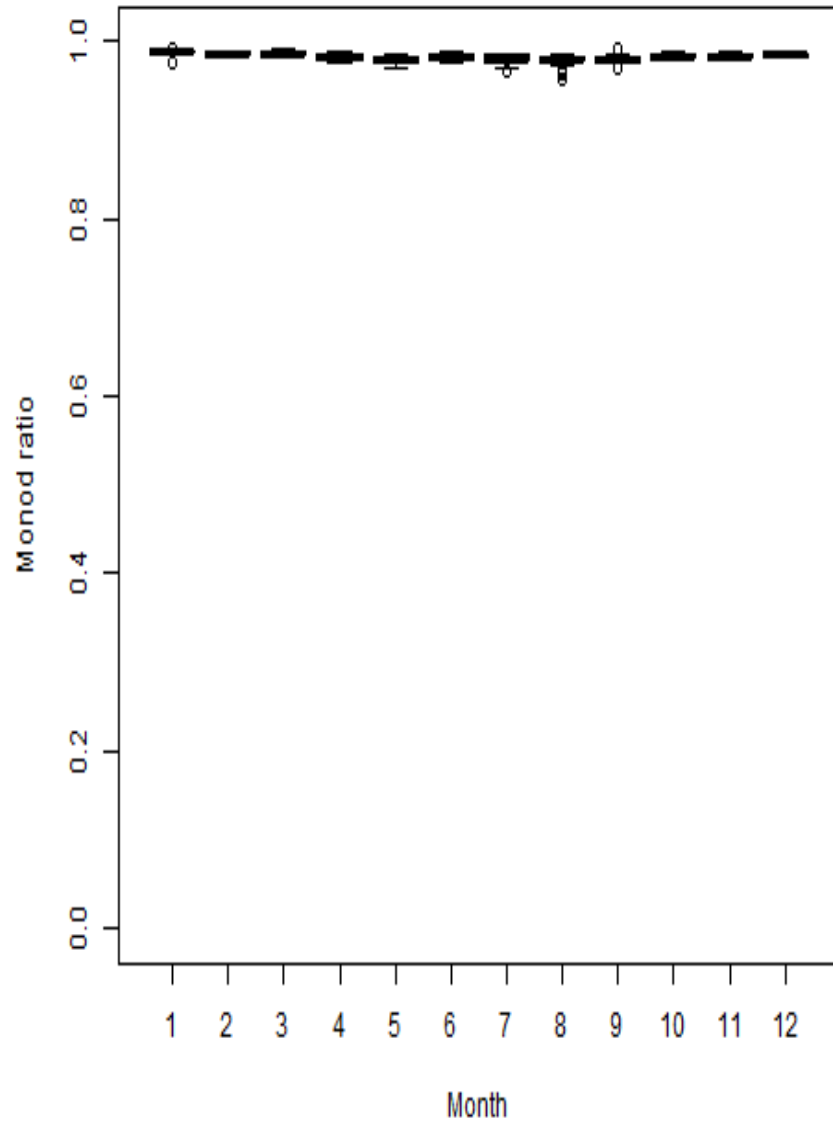
**P532 model
prediction
of relative
N-P-Light
limitation in
CB1 (TF)**



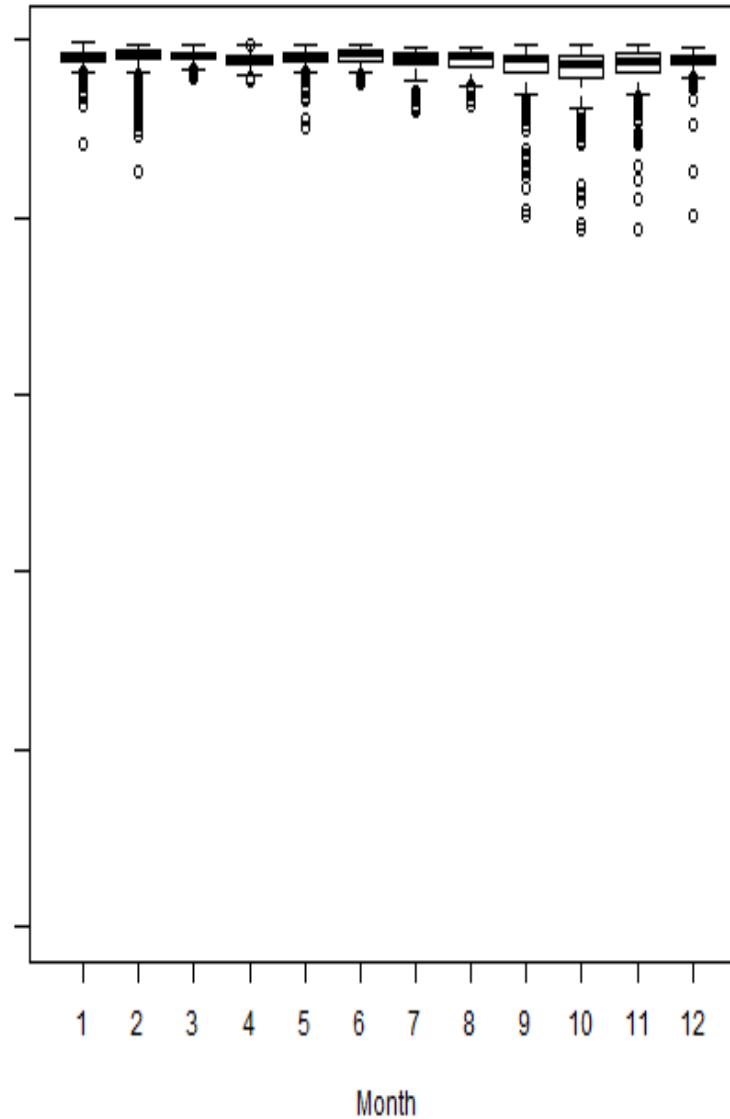
Relative counts of cell & day in every 15 days that had stronger limitation

P532 and Beta2 comparison of N-limitation at CB1.1

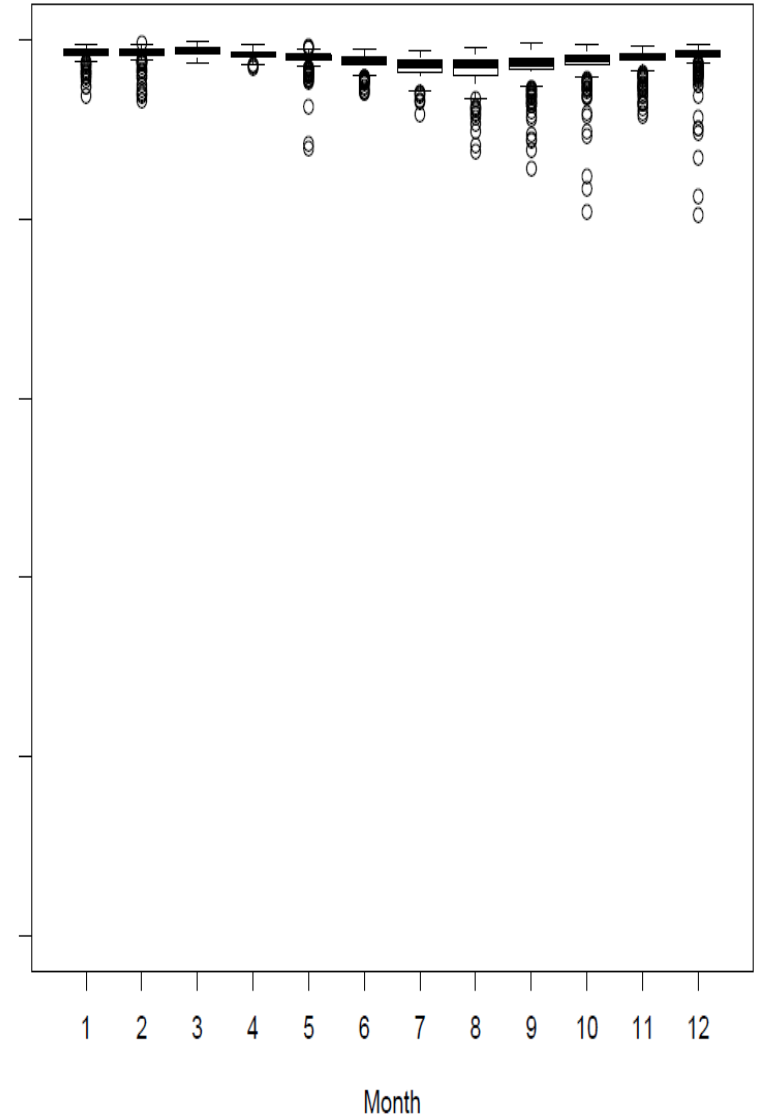
Observed



P532

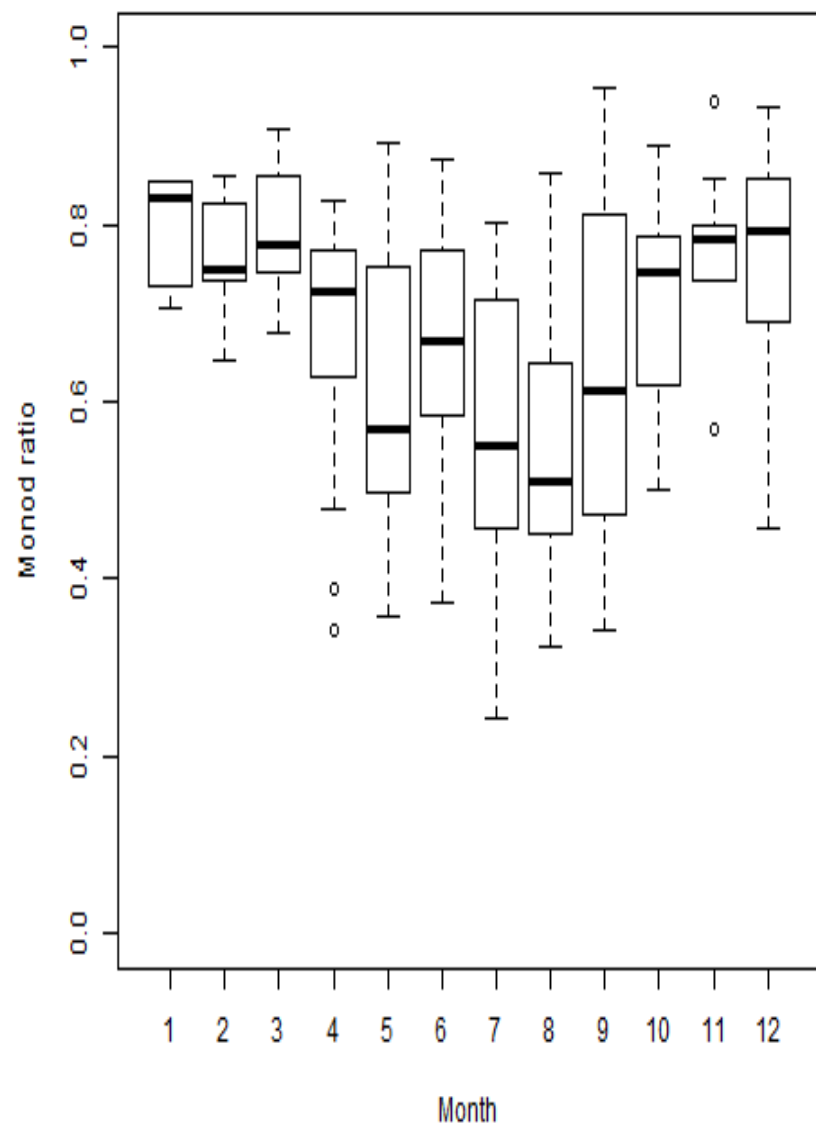


Beta2

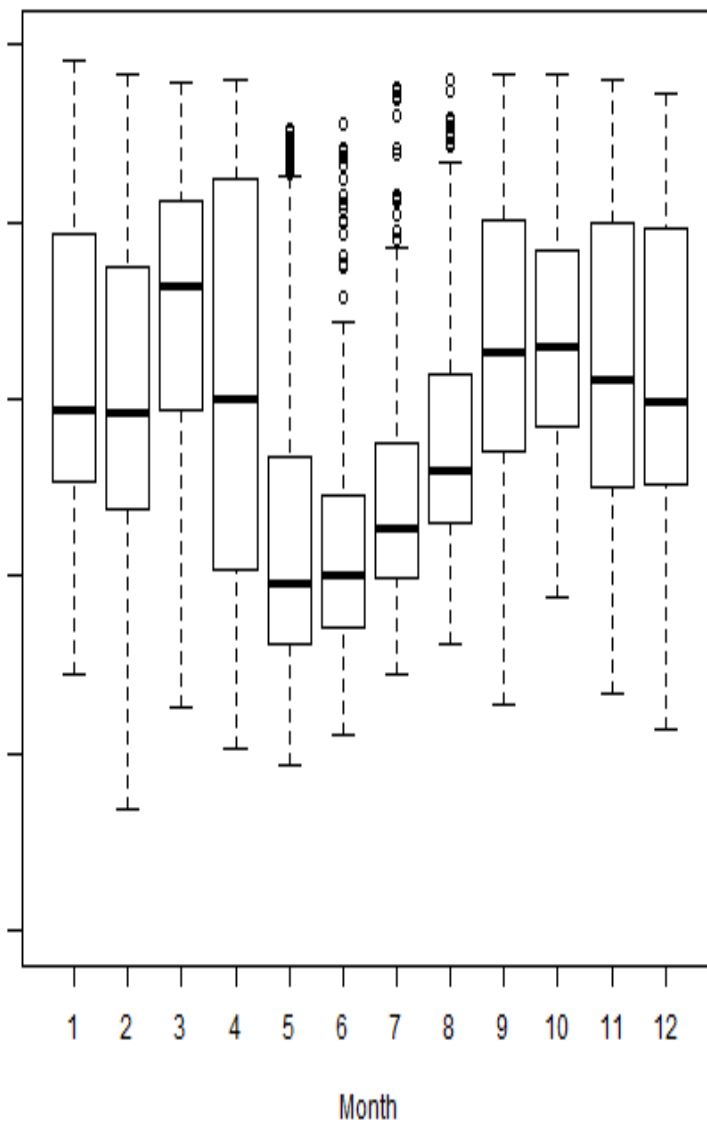


P532 and Beta2 comparison of P-limitation CB1.1

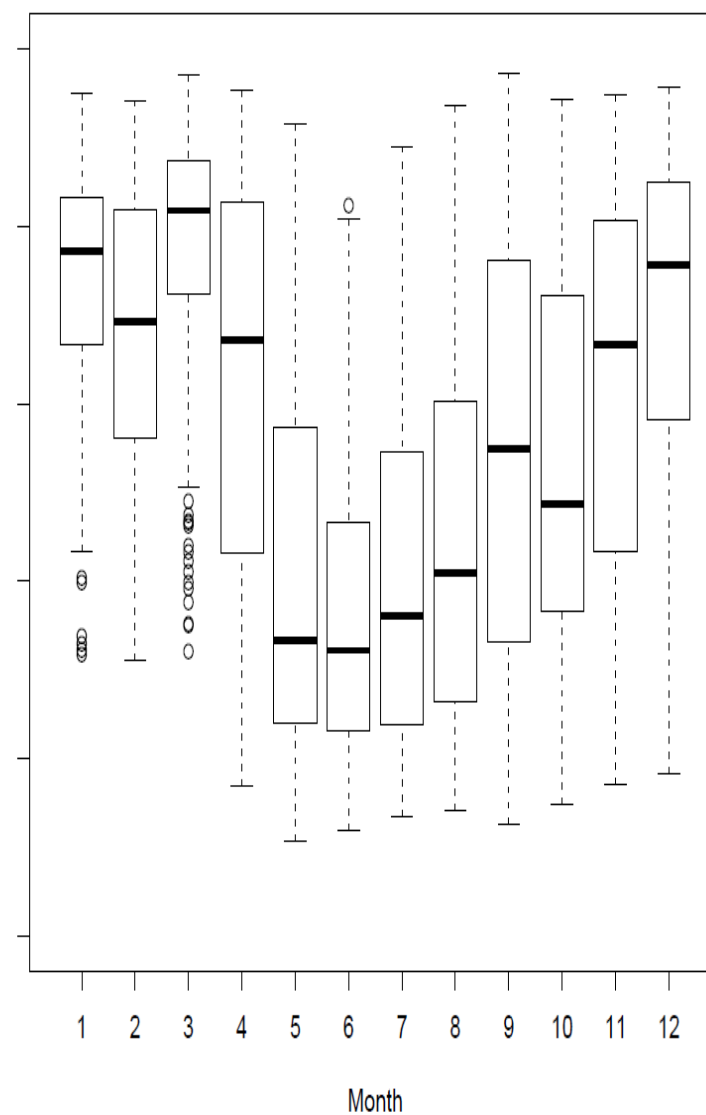
Observed



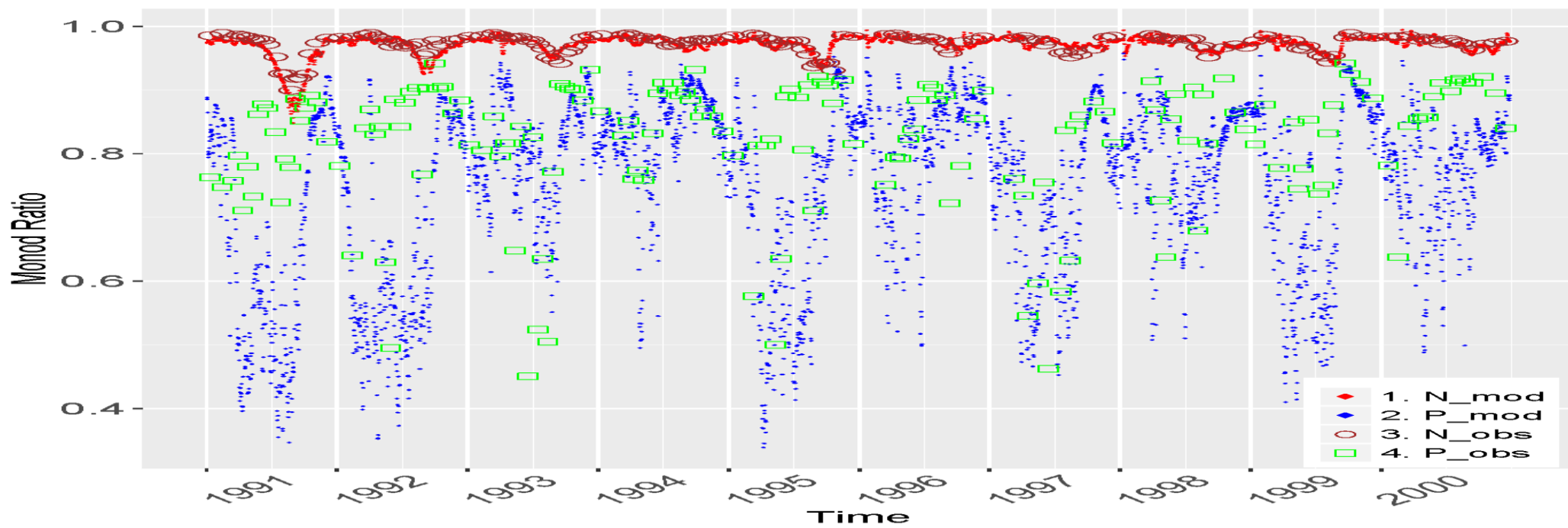
P532



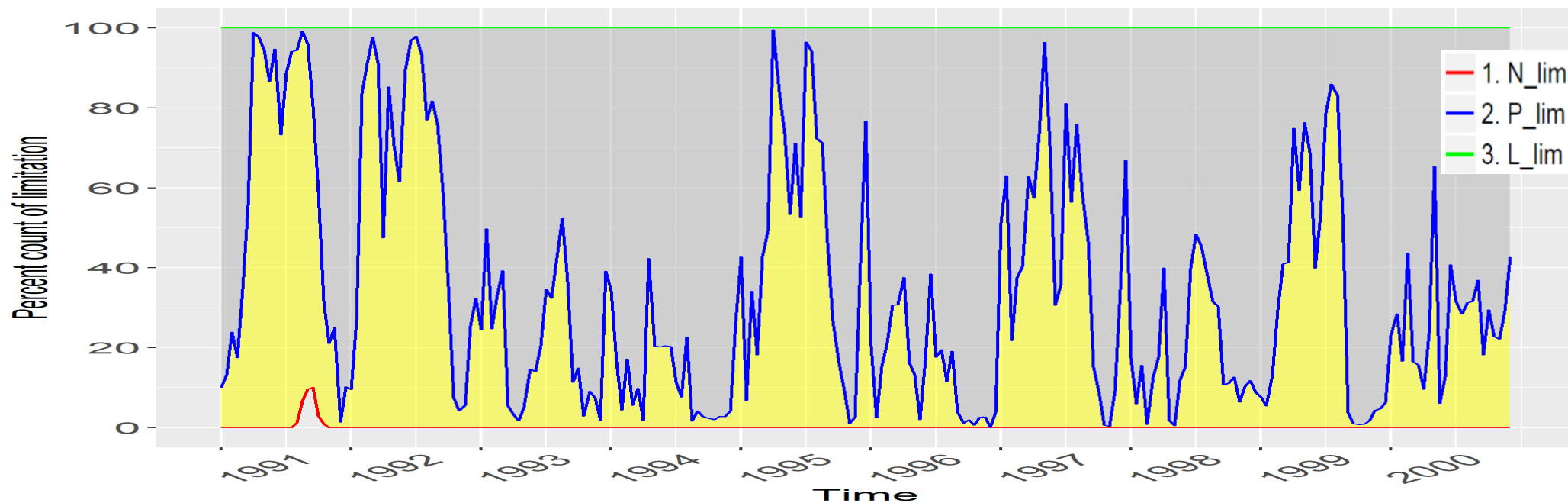
Beta2



**Data-model
comparison
of N-P
limitation at
CB2.2**

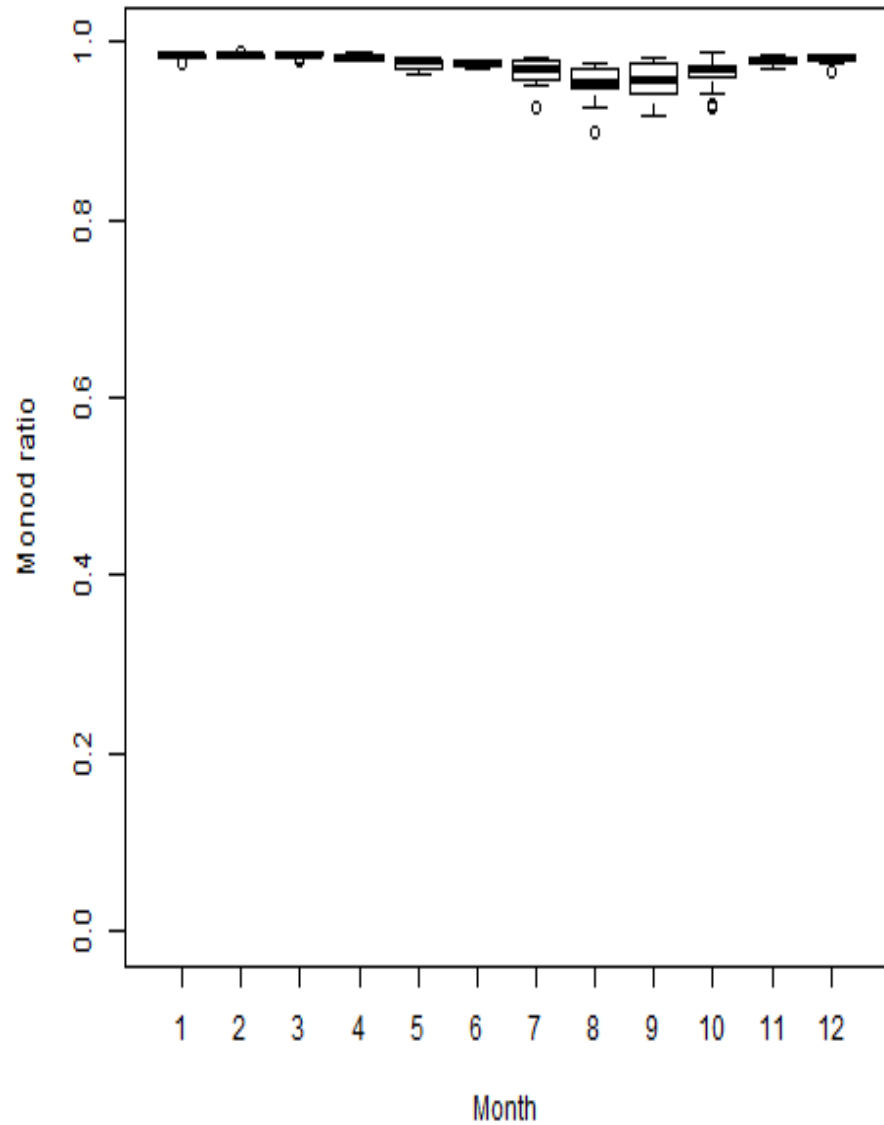


**P532 model
prediction
of relative
N-P-Light
limitation at
CB2 (OH)**

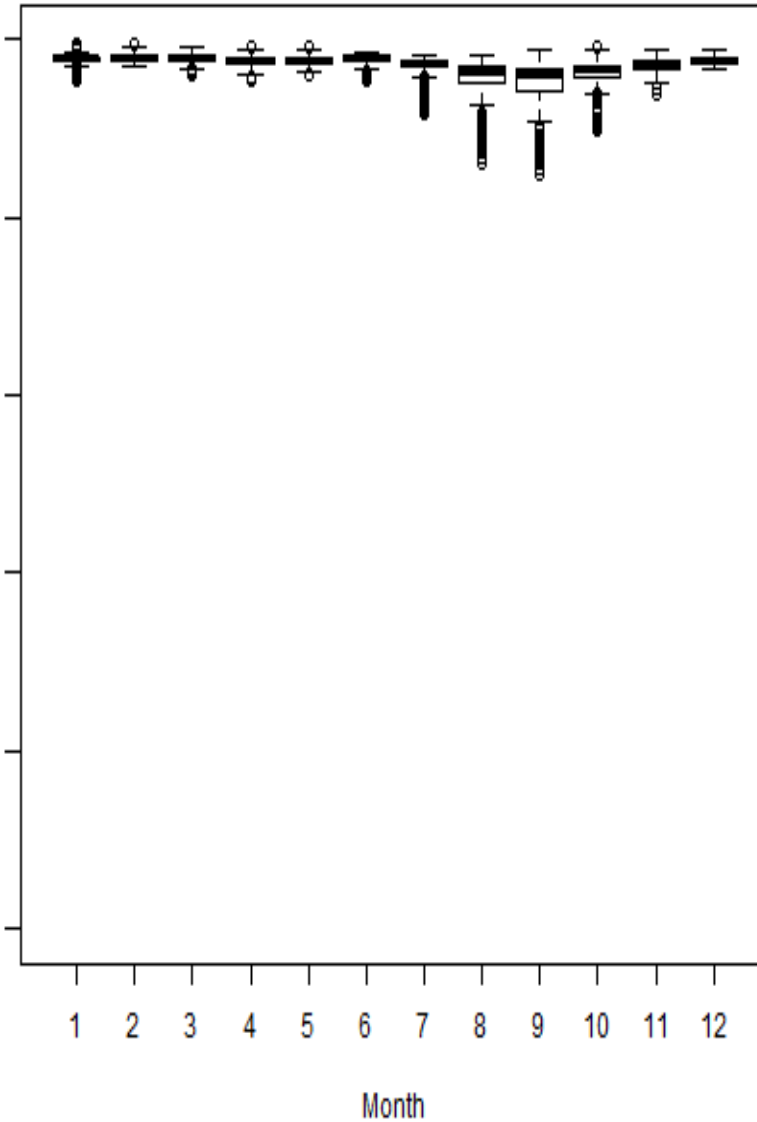


P532 and Beta2 comparison of N-limitation at CB2.2

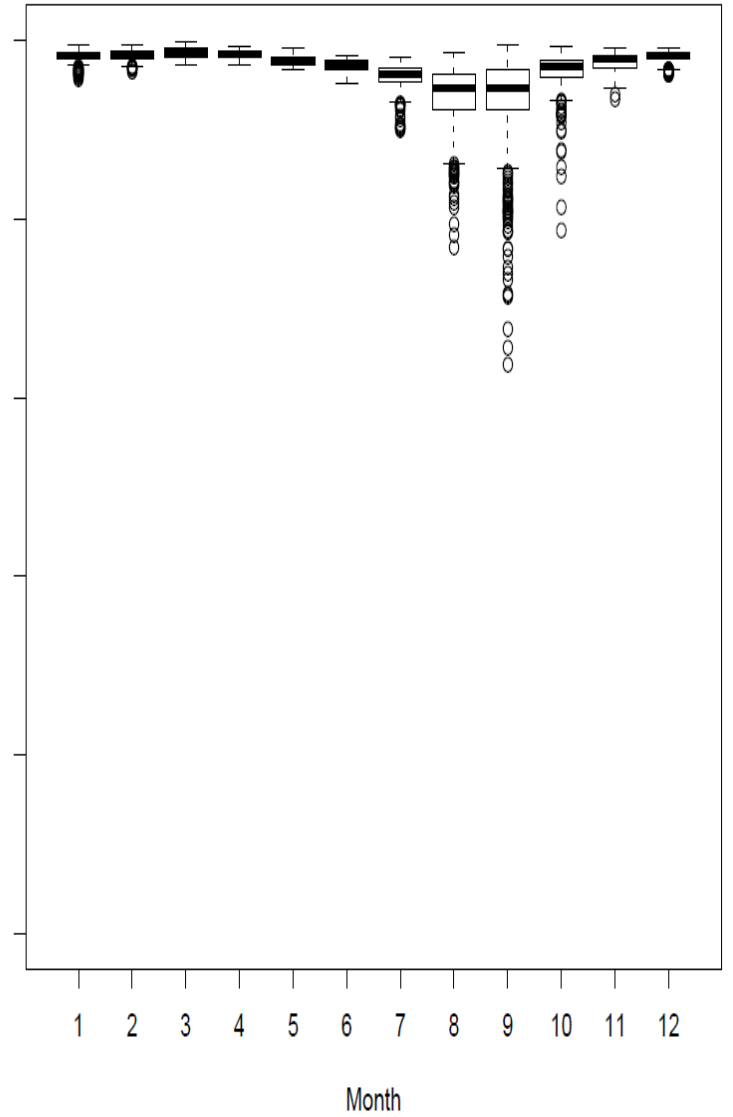
Observed



P532

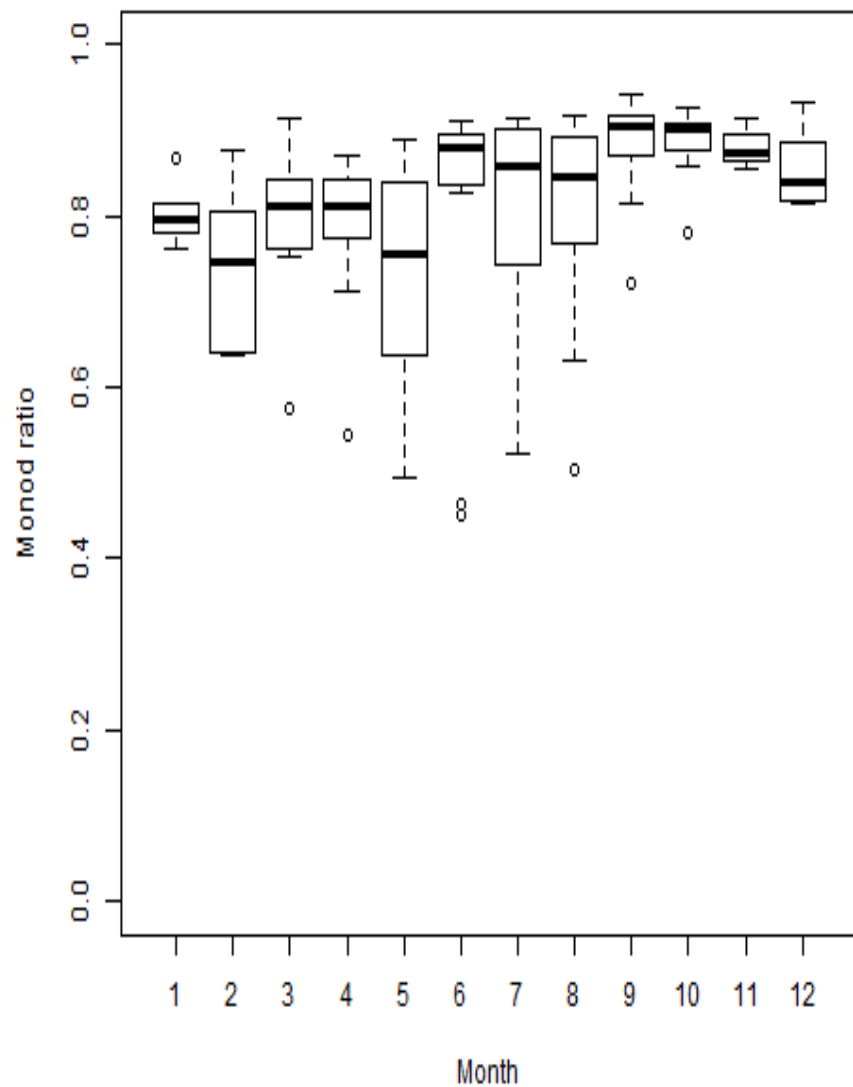


Beta2

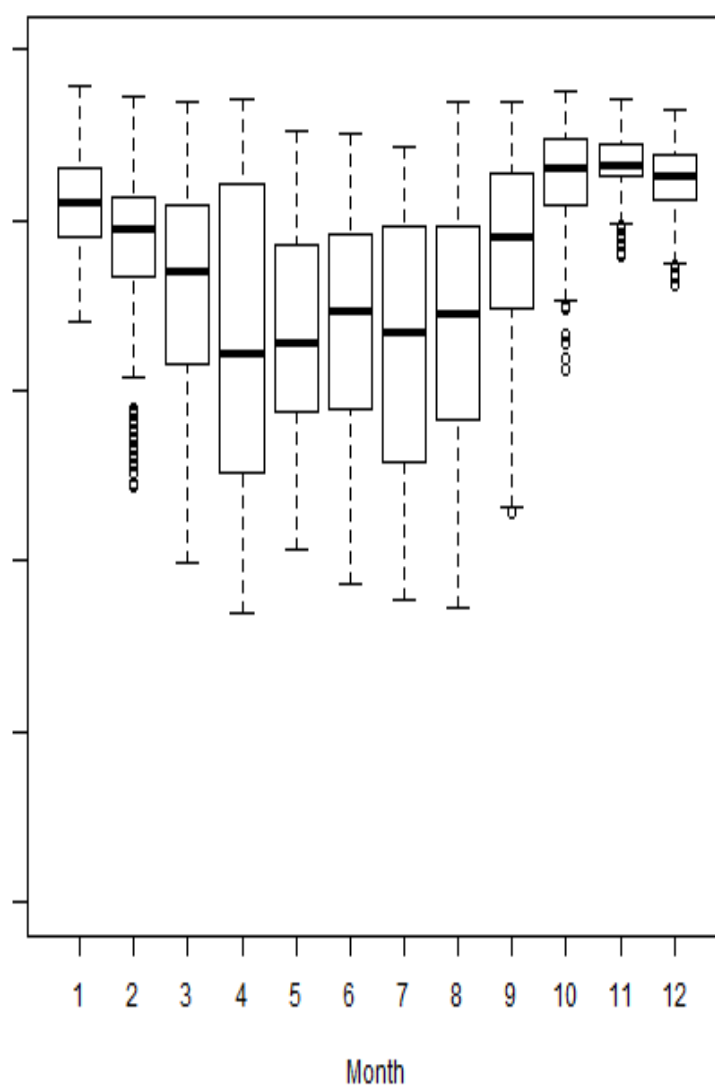


P532 and Beta2 comparison of P-limitation at CB2.2

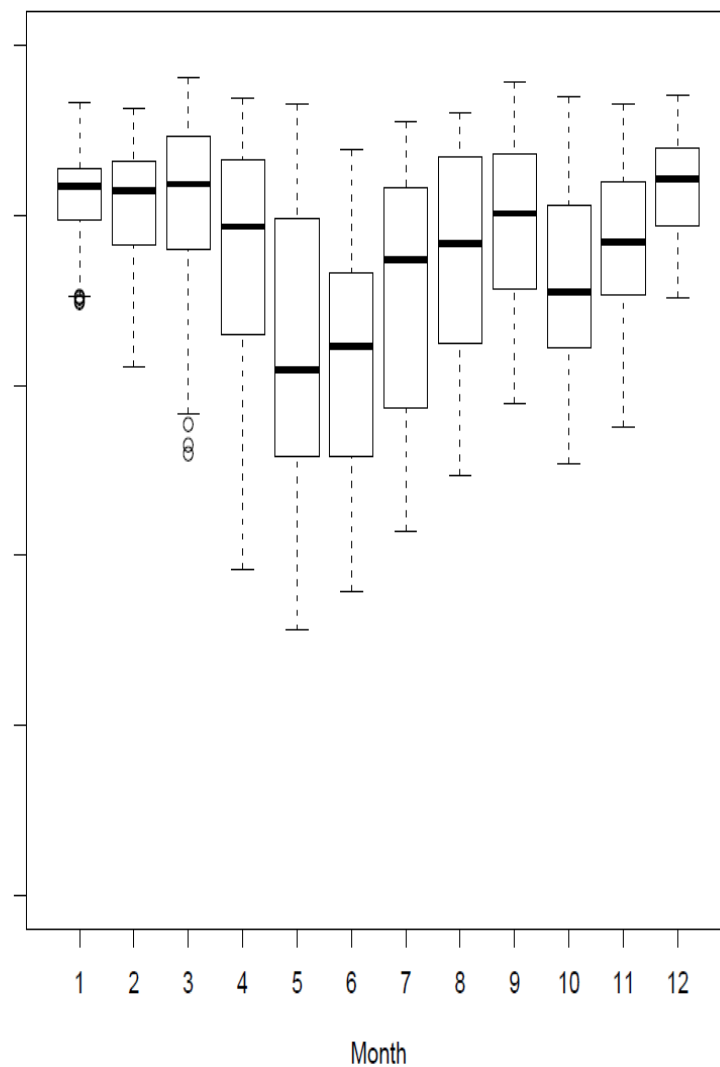
Observed



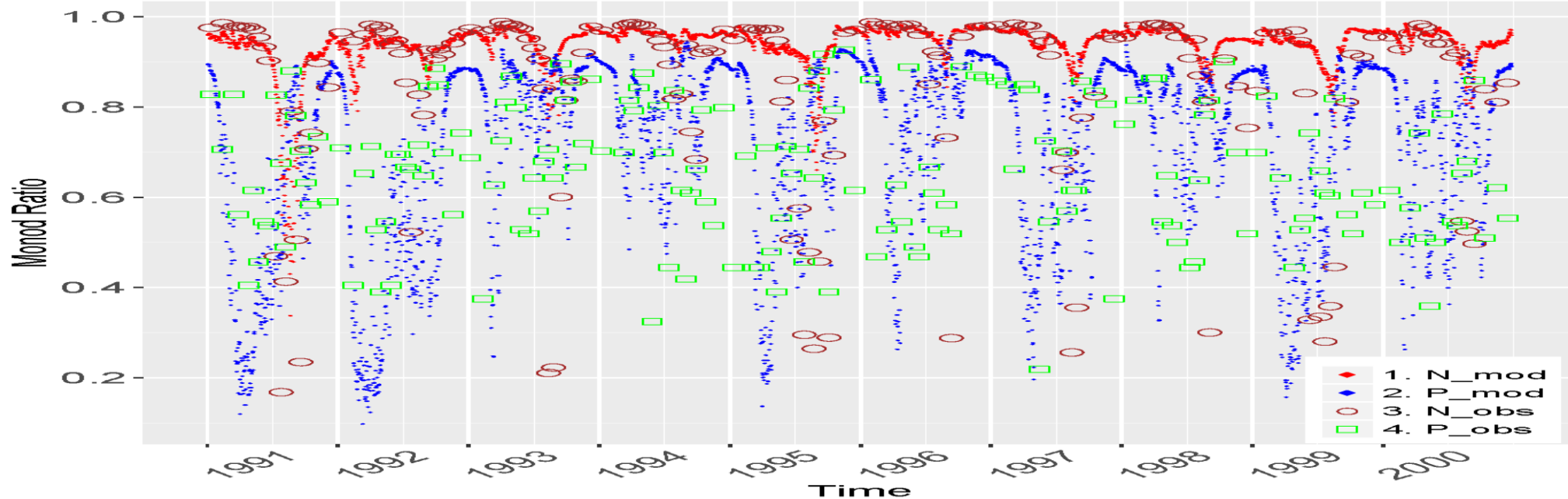
P532



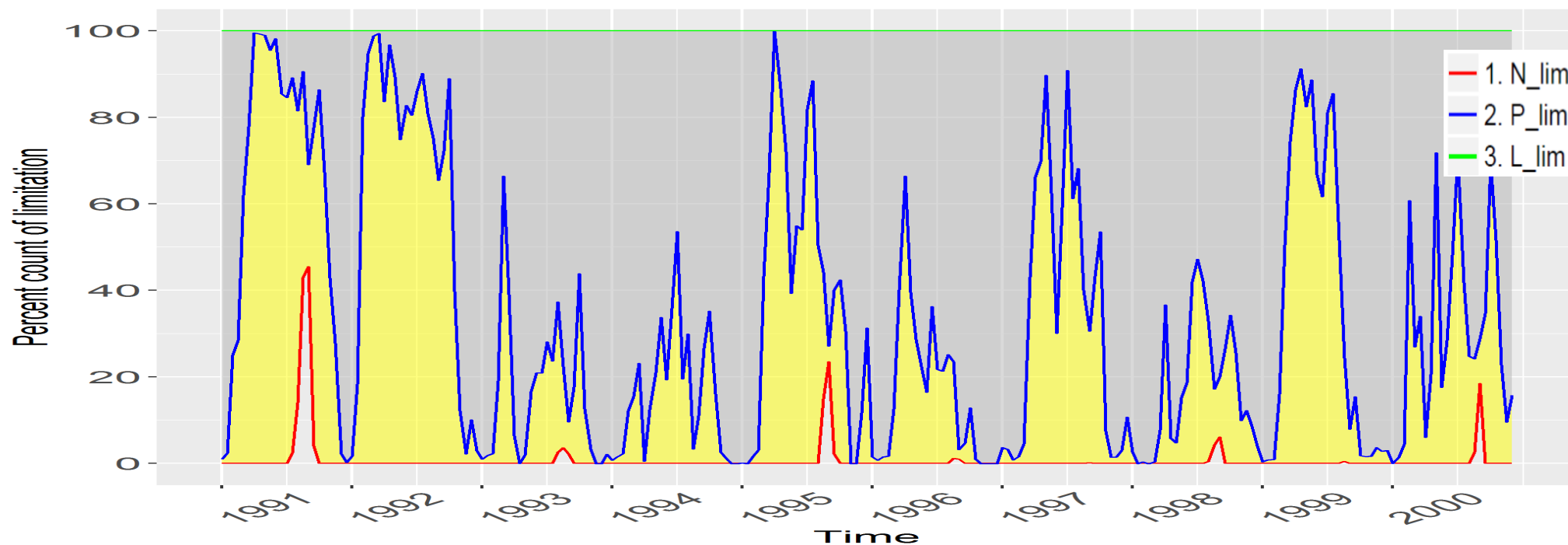
Beta2



**Data-model
comparison
of N-P
limitation at
CB3.2**

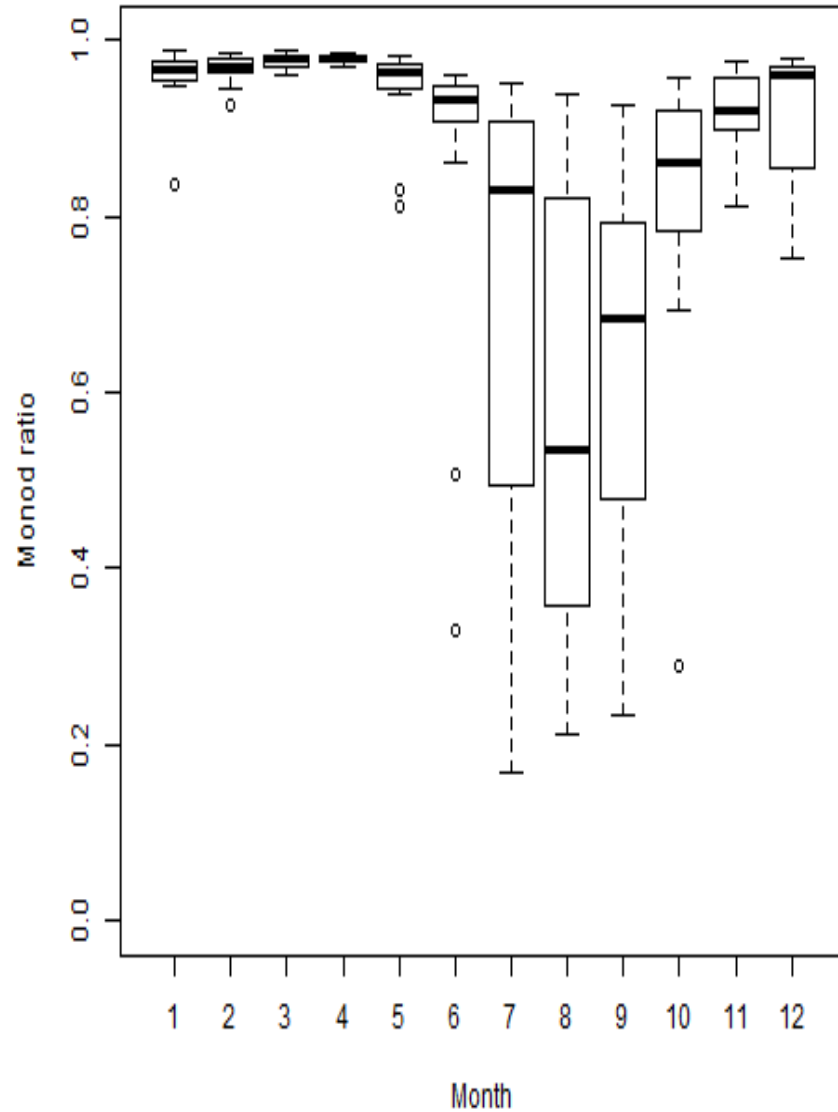


**P532 model
prediction
of relative
N-P-Light
limitation in
CB3 (MH)**

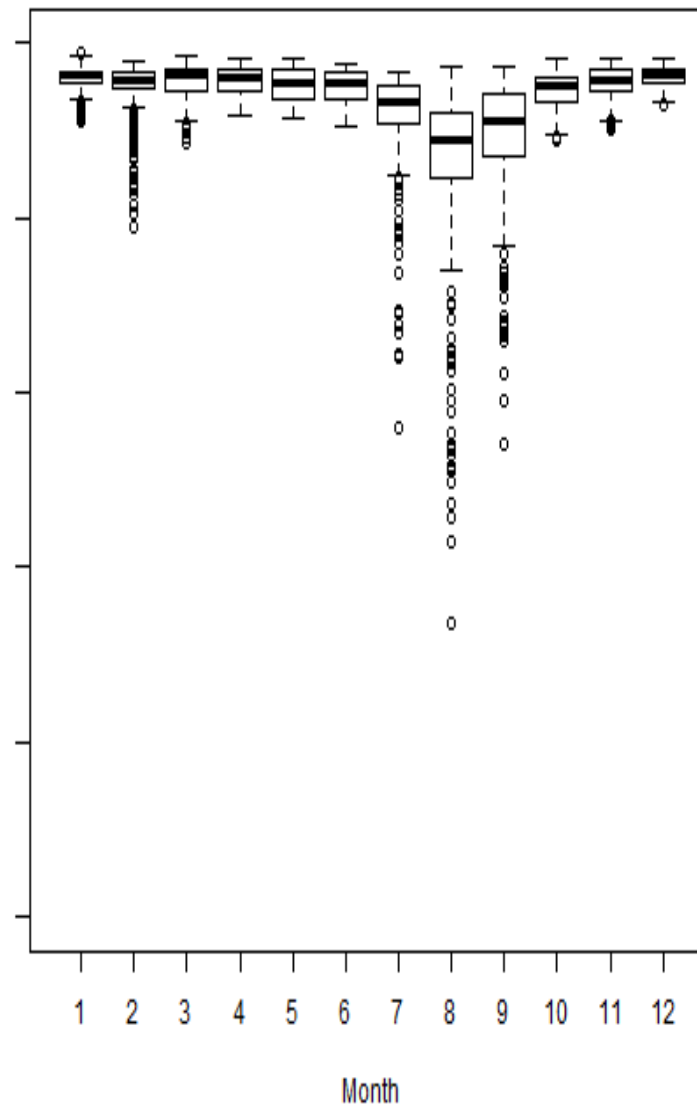


P532 and Beta2 comparison of N-limitation at CB3.2

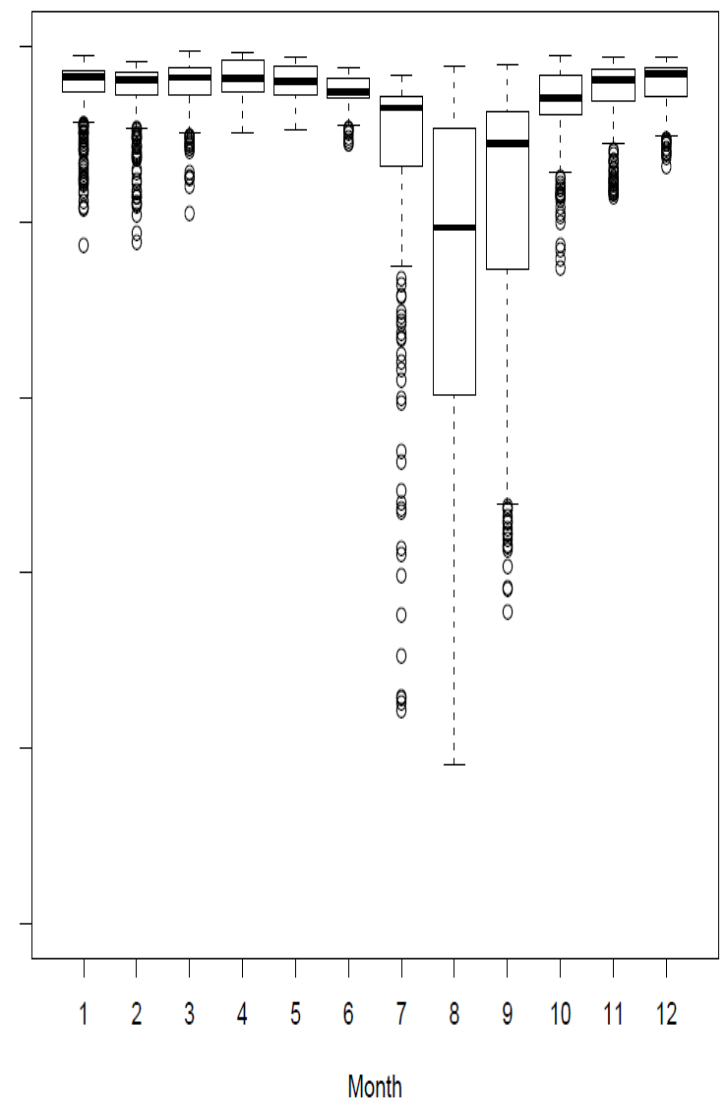
Observed



P532

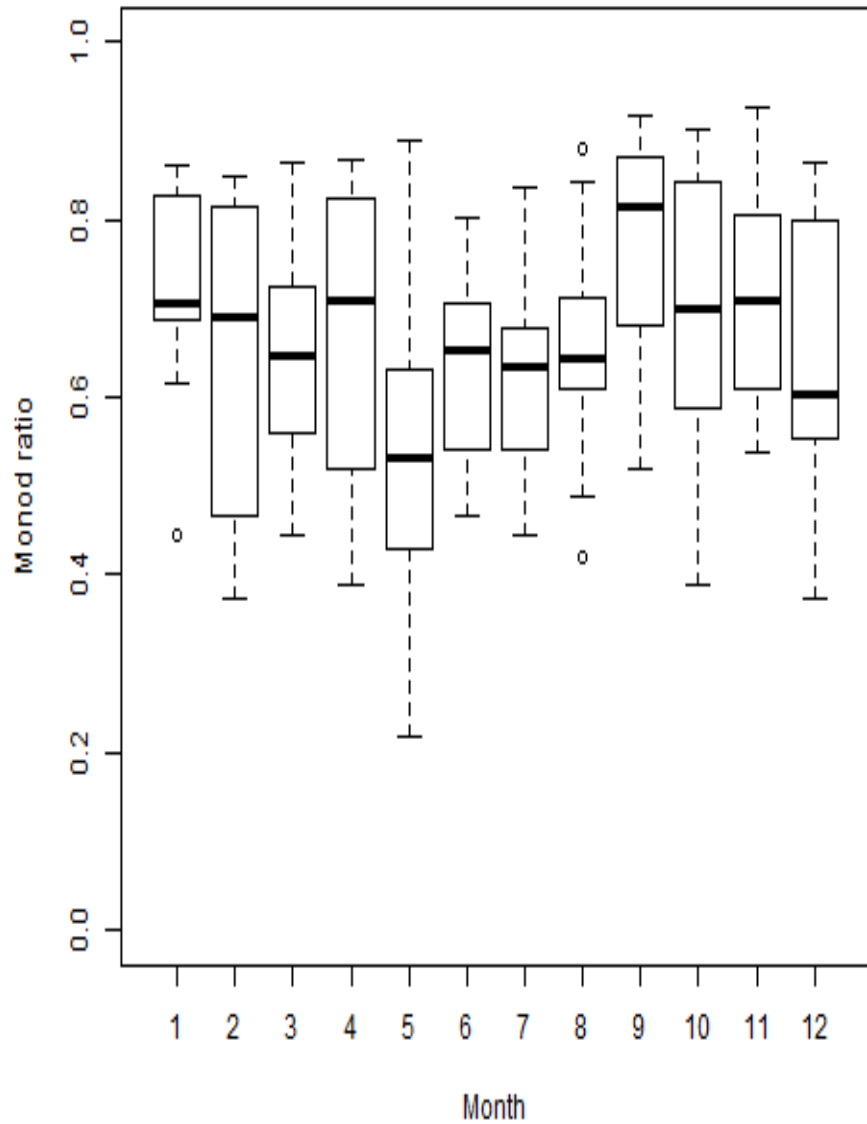


Beta2

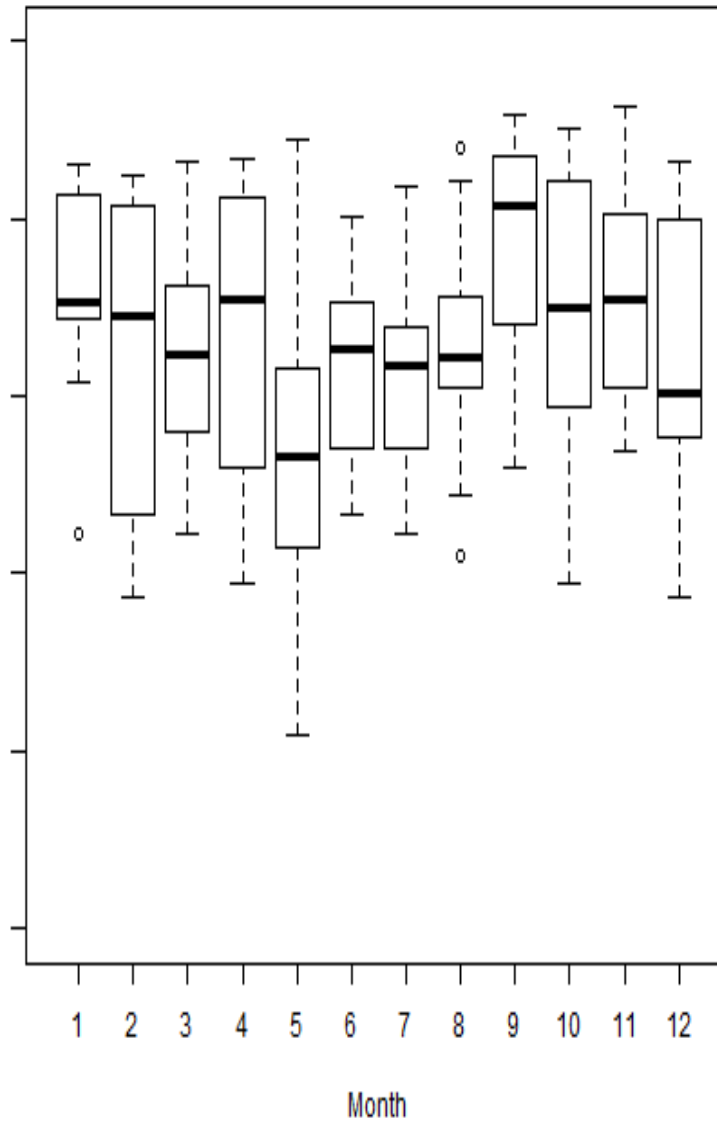


P532 and Beta2 comparison P-limitation at CB3.2

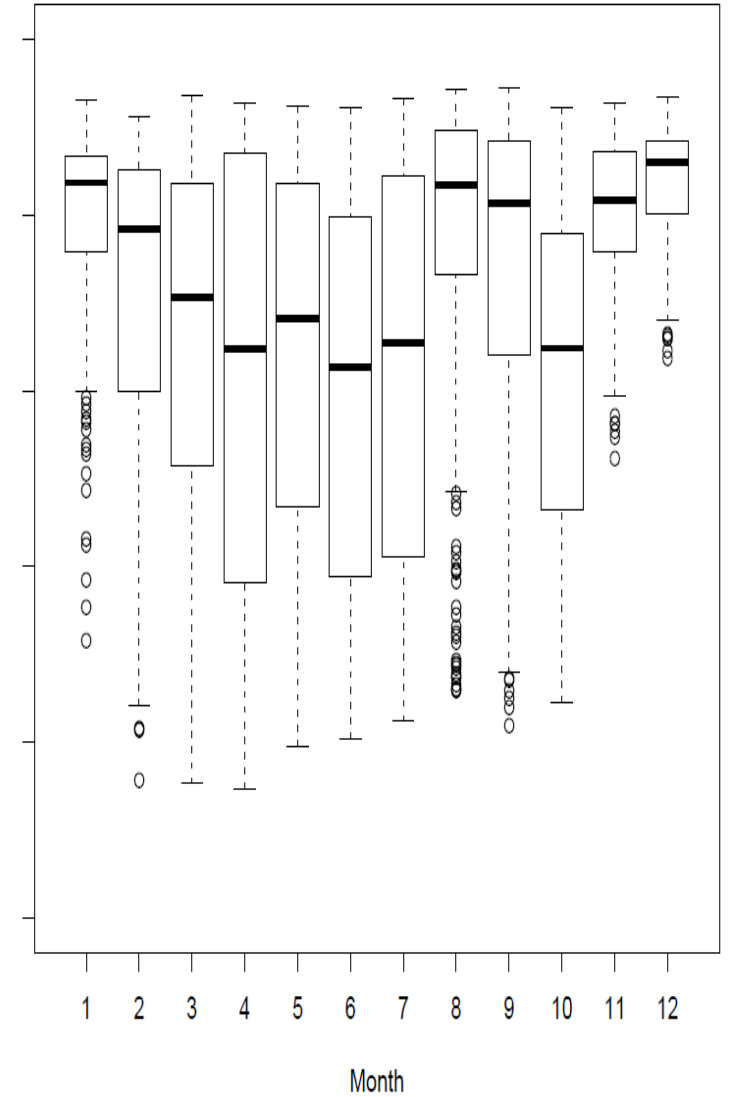
Observed



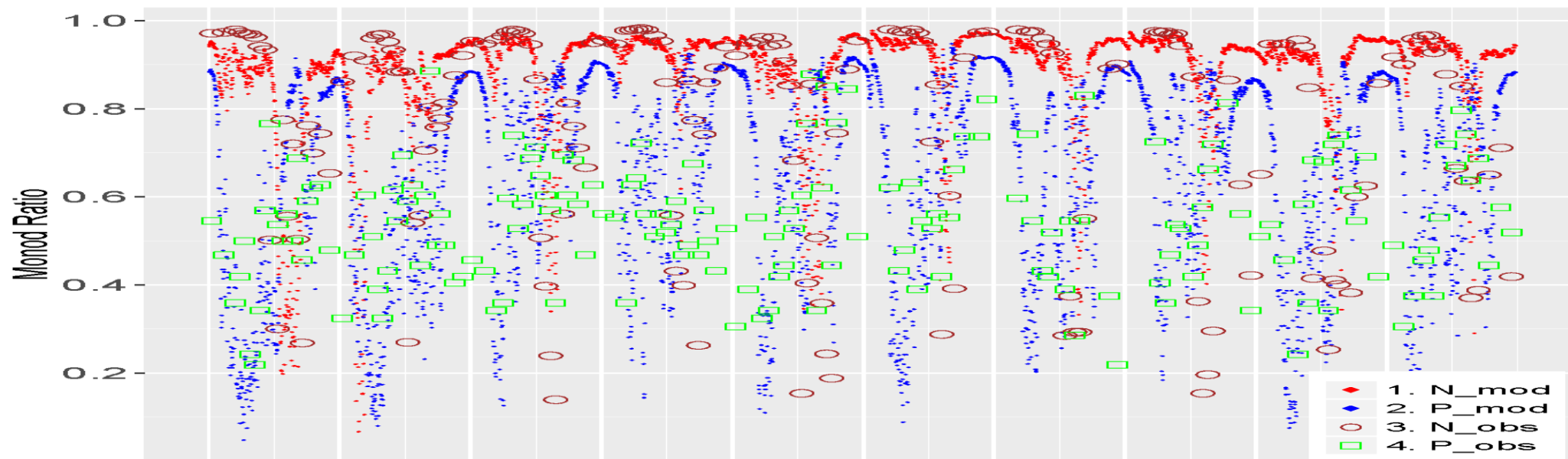
P532



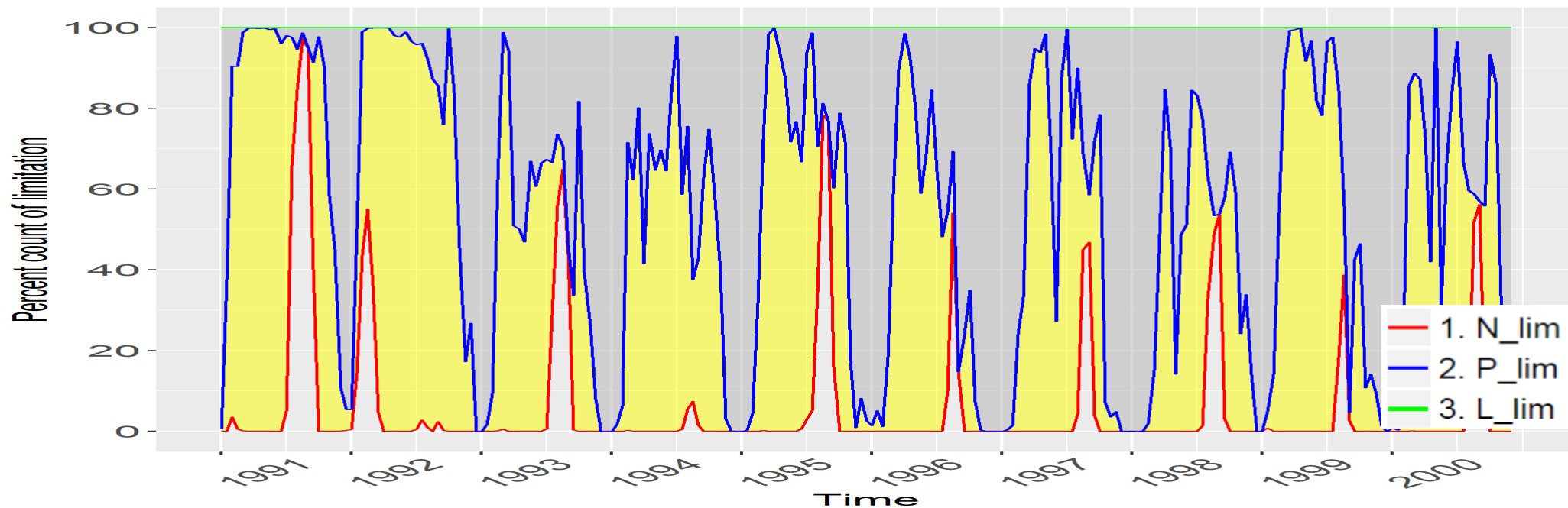
Beta2



**Data-model
comparison
of N-P
limitation at
CB4.2C**

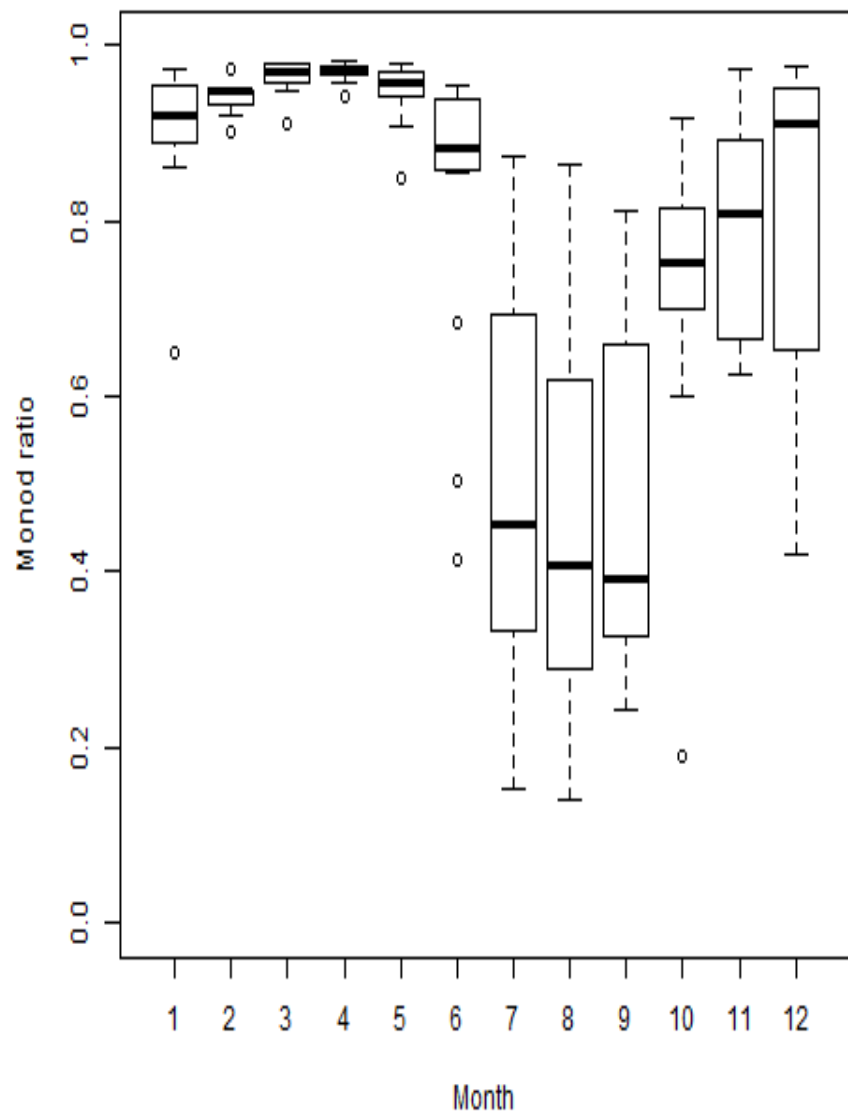


**P532 model
prediction
of relative
N-P-Light
limitation at
CB4 (MH)**

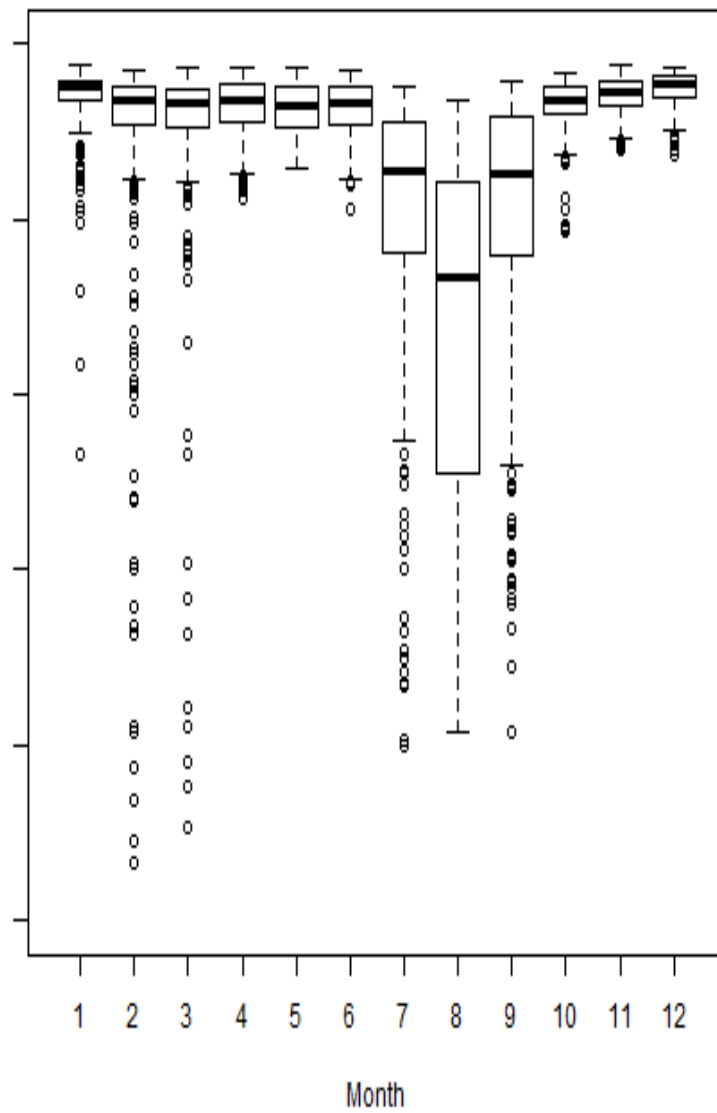


P532 and Beta2 comparison of N-limitation N-limitation at C

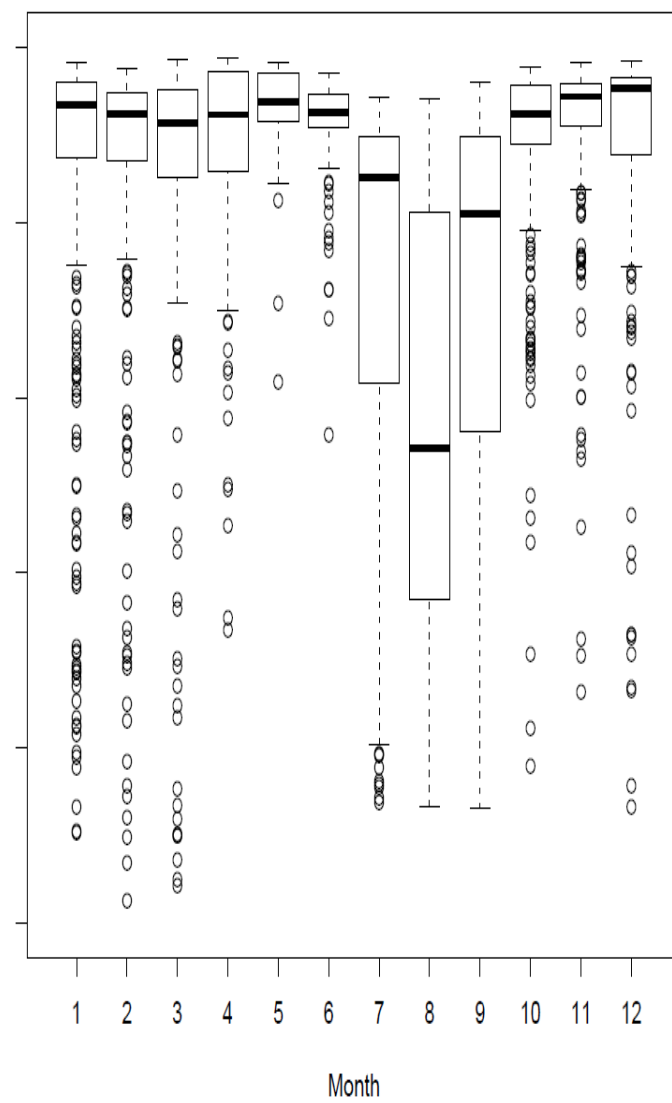
Observed



P532

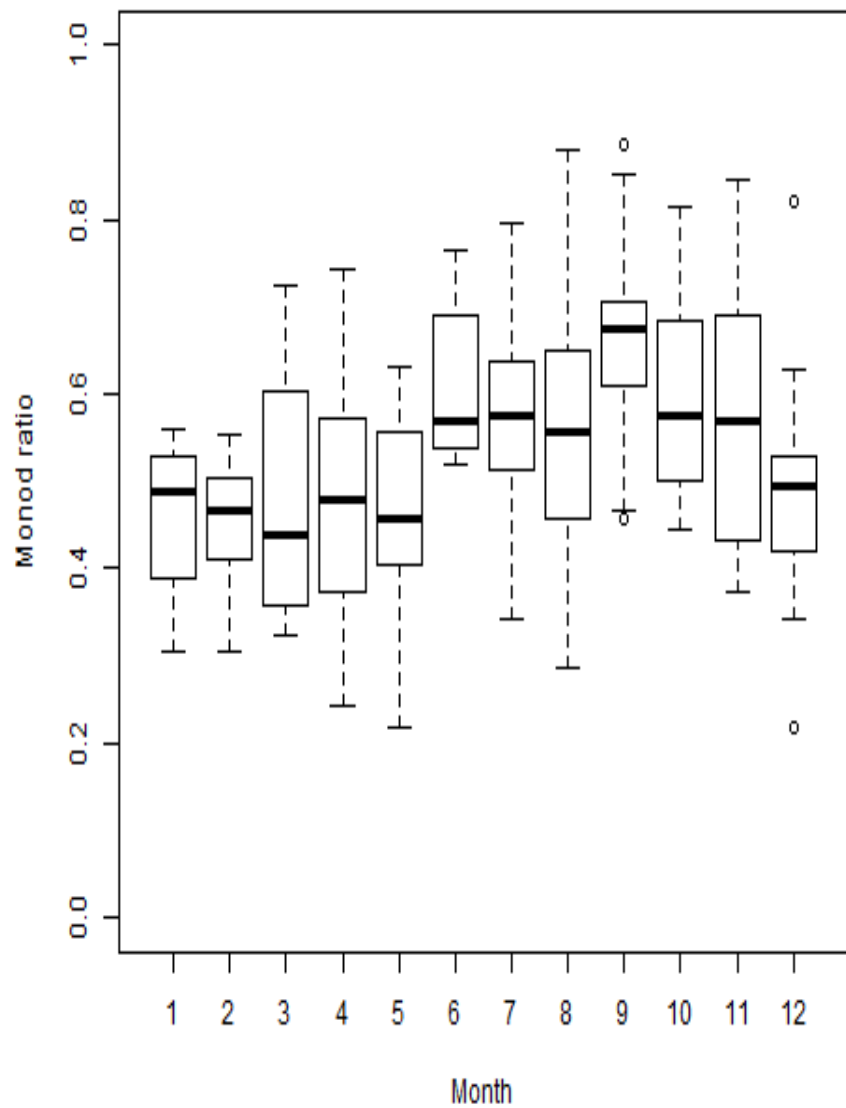


Beta2

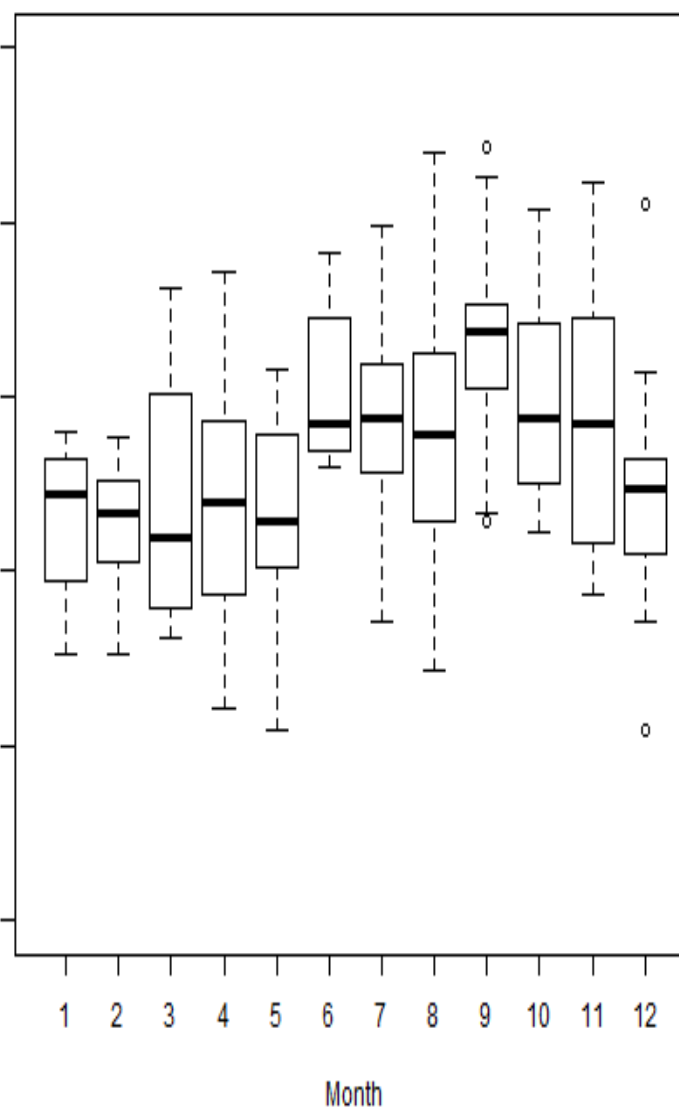


P532 and Beta2 comparison of P-limitation at CB4.2C

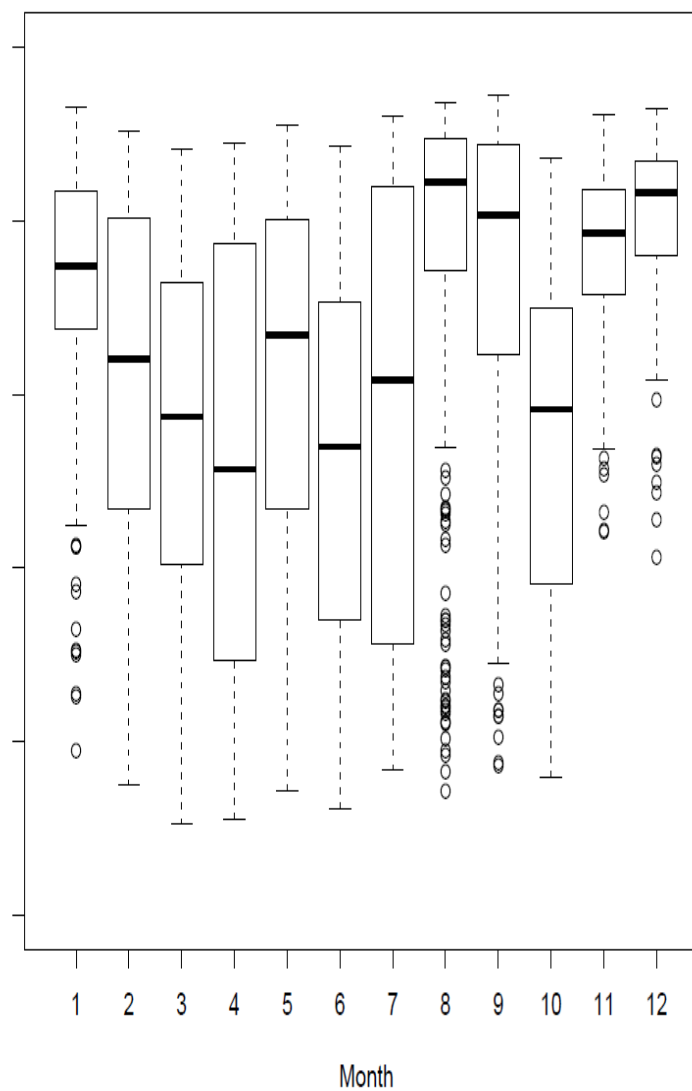
Observed



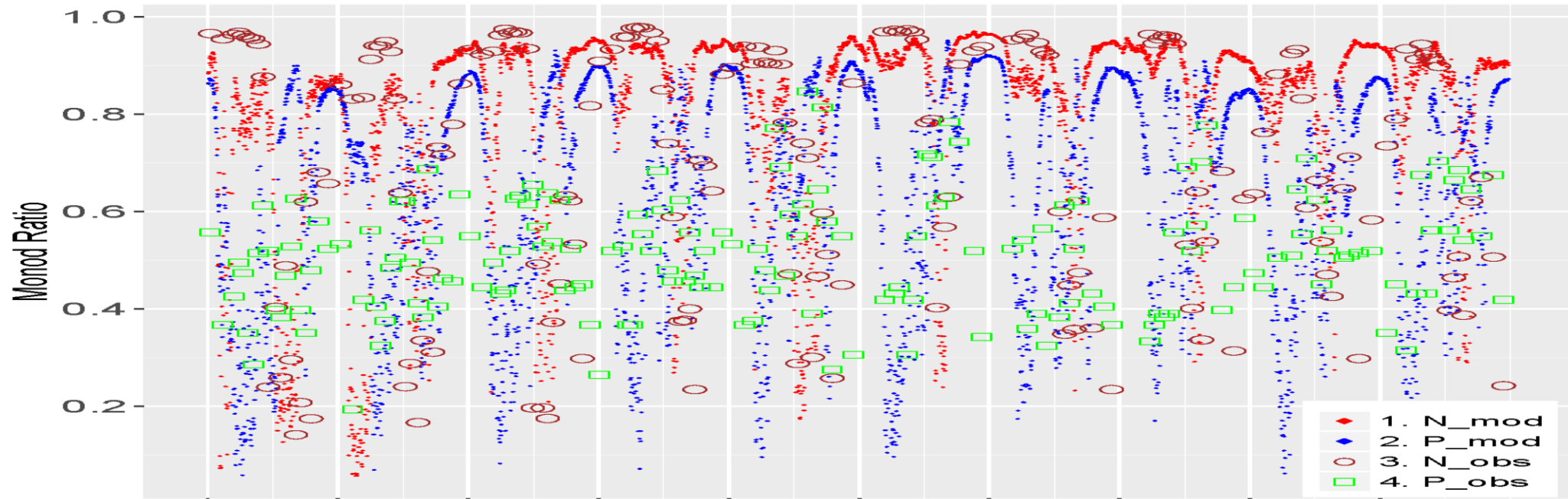
P532



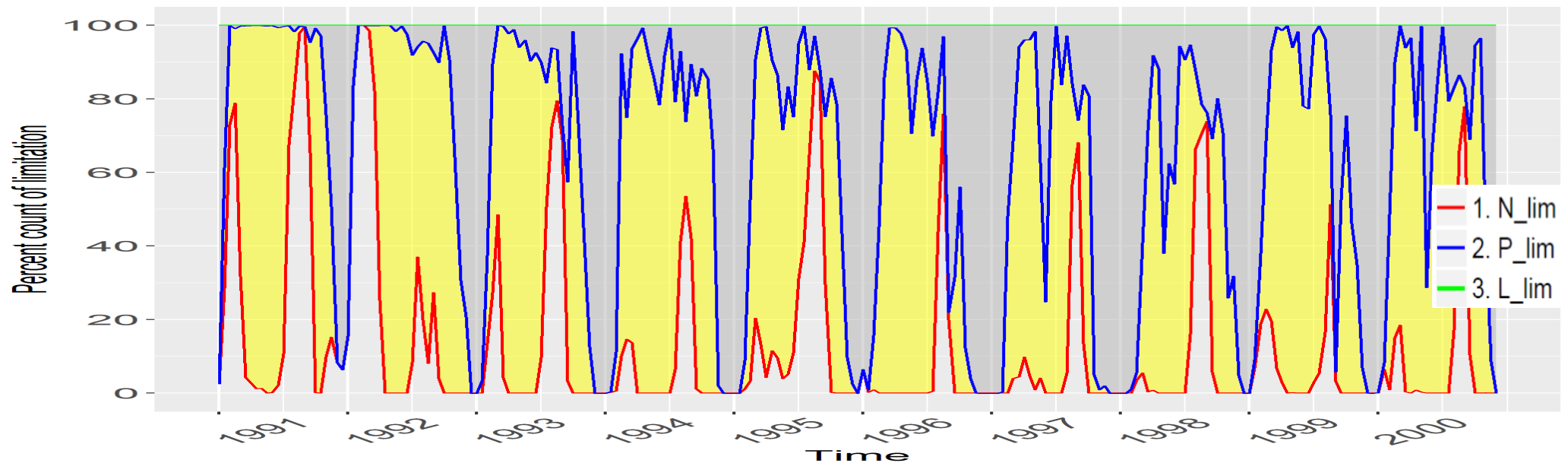
Beta2



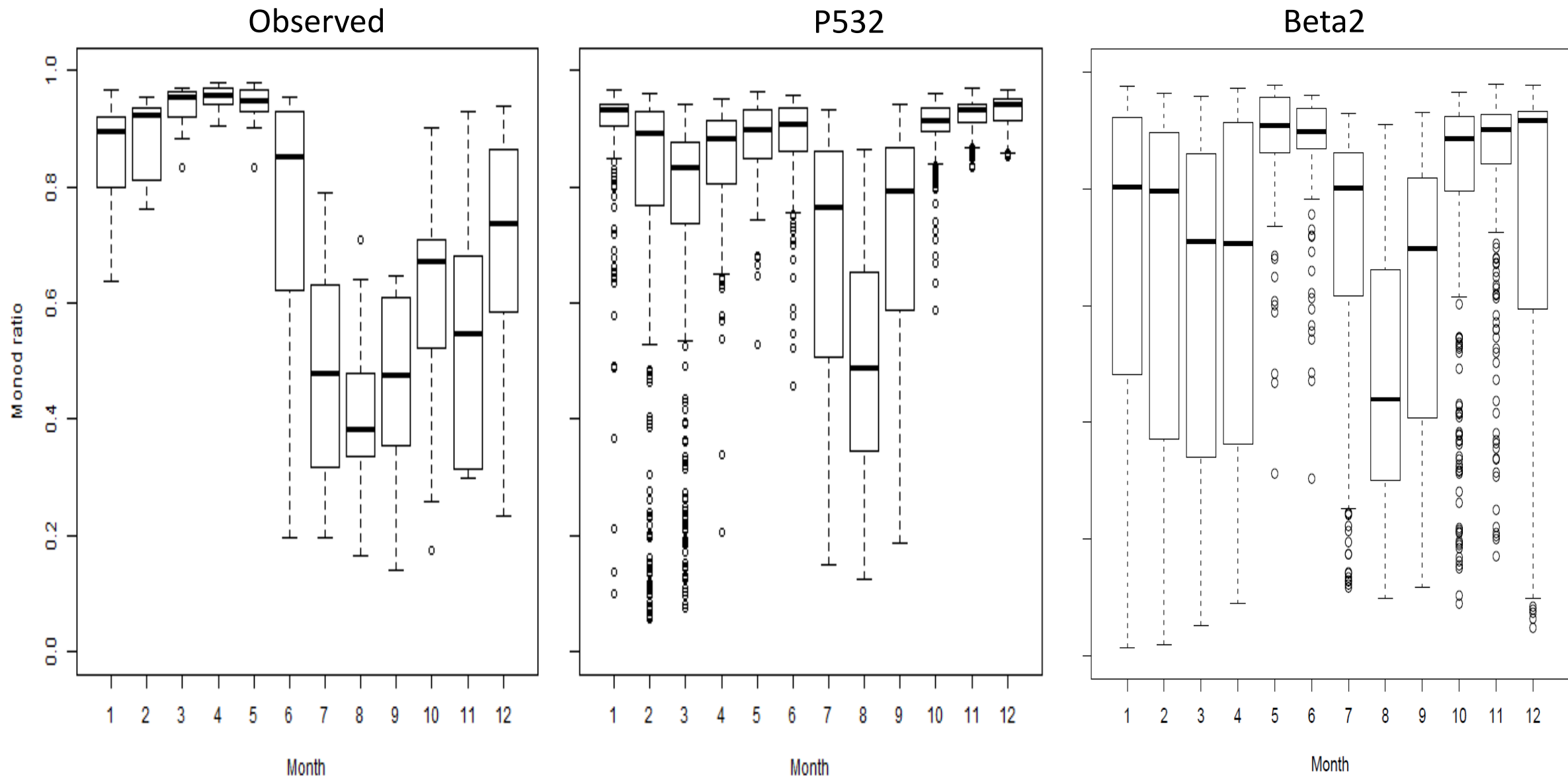
**Data-model
comparison
of N-P
limitation at
CB5.2**



**P532 model
prediction
of relative
N-P-Light
limitation in
CB5 (MD)**

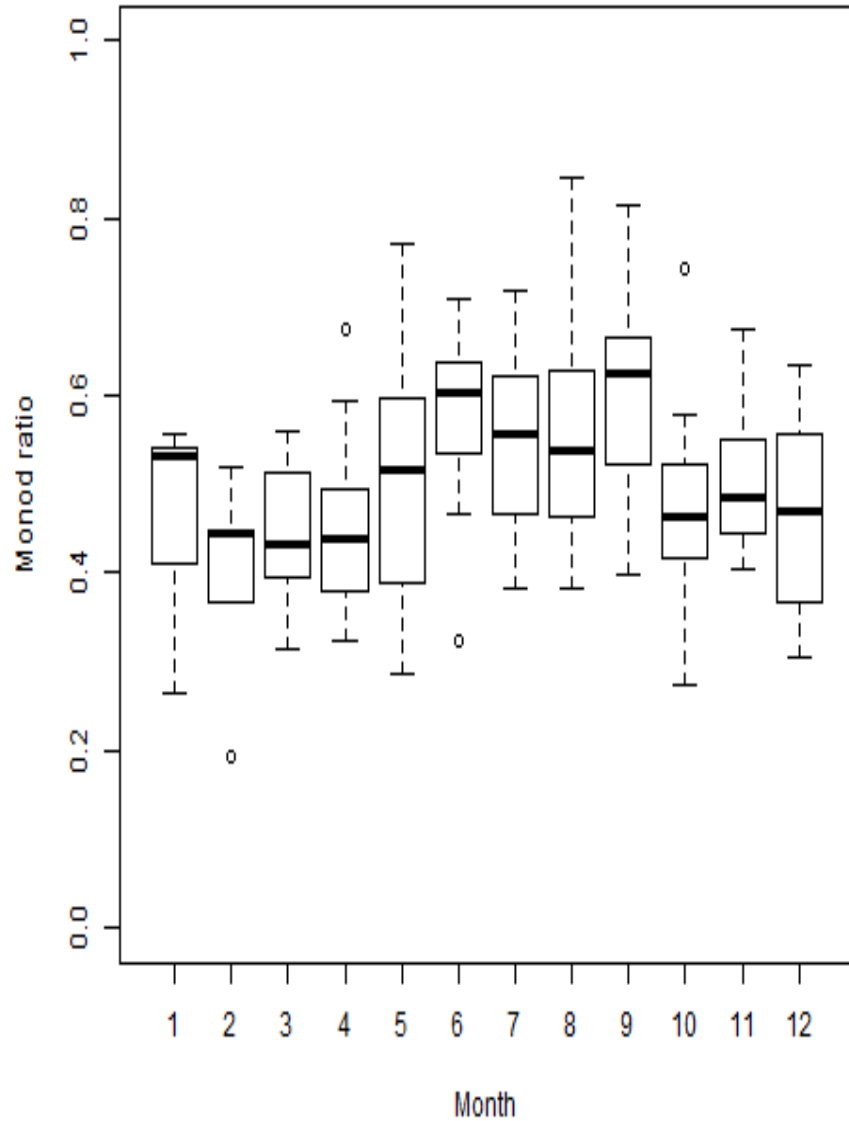


P532 and Beta2 comparison of N-limitation at CB5.2

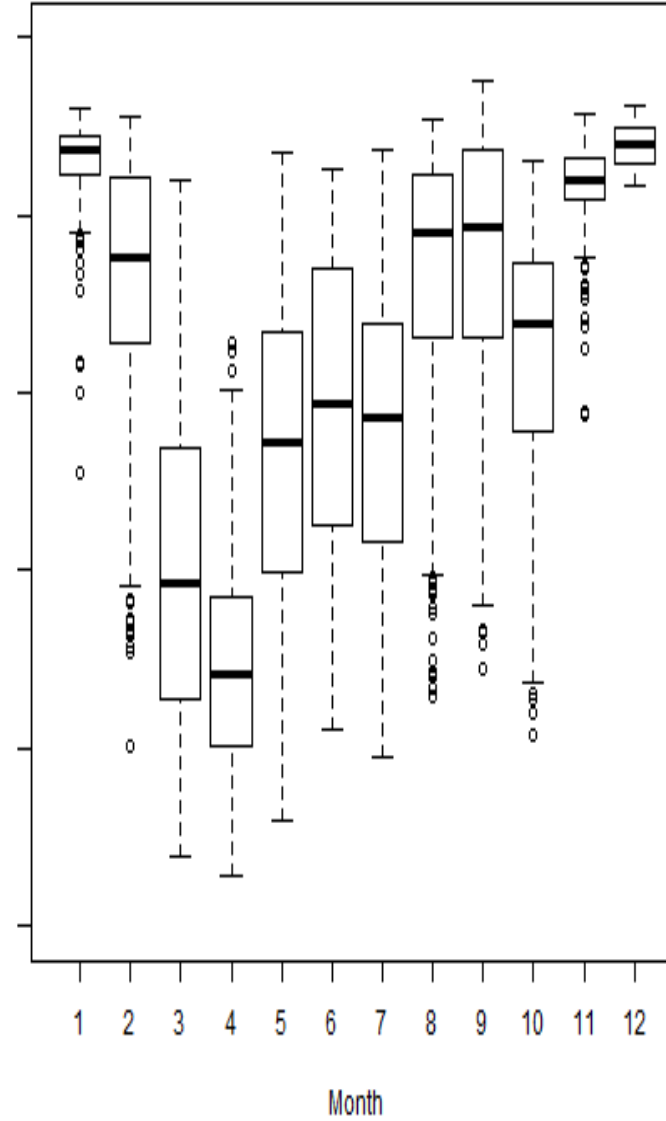


P532 and Beta2 comparison of P-limitation at CB5.2

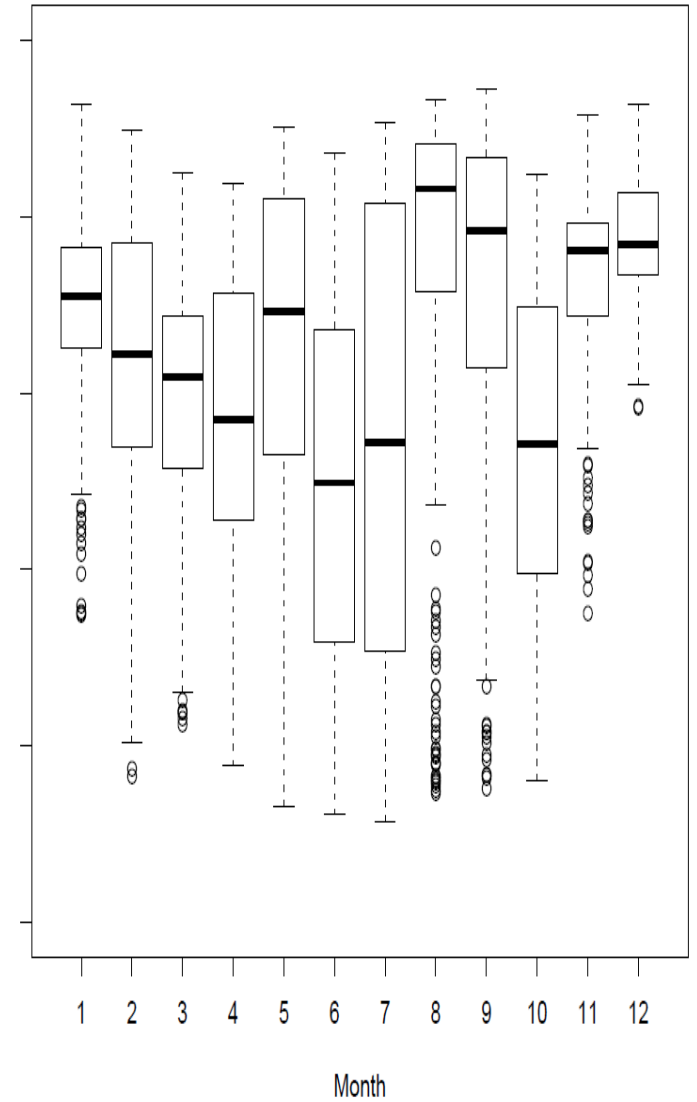
Observed



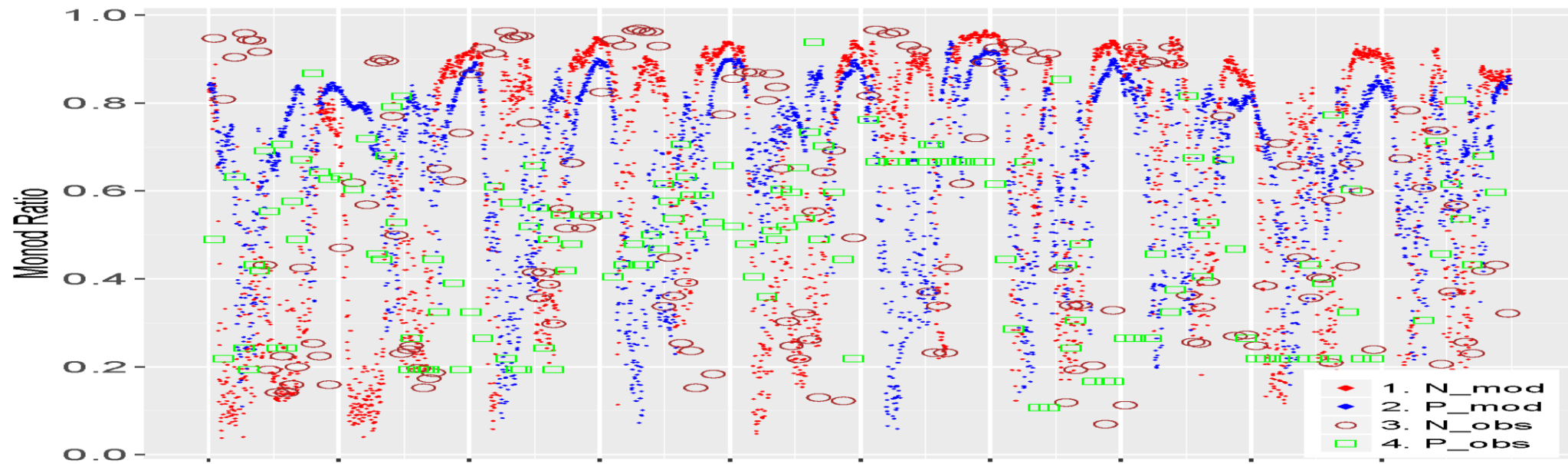
P532



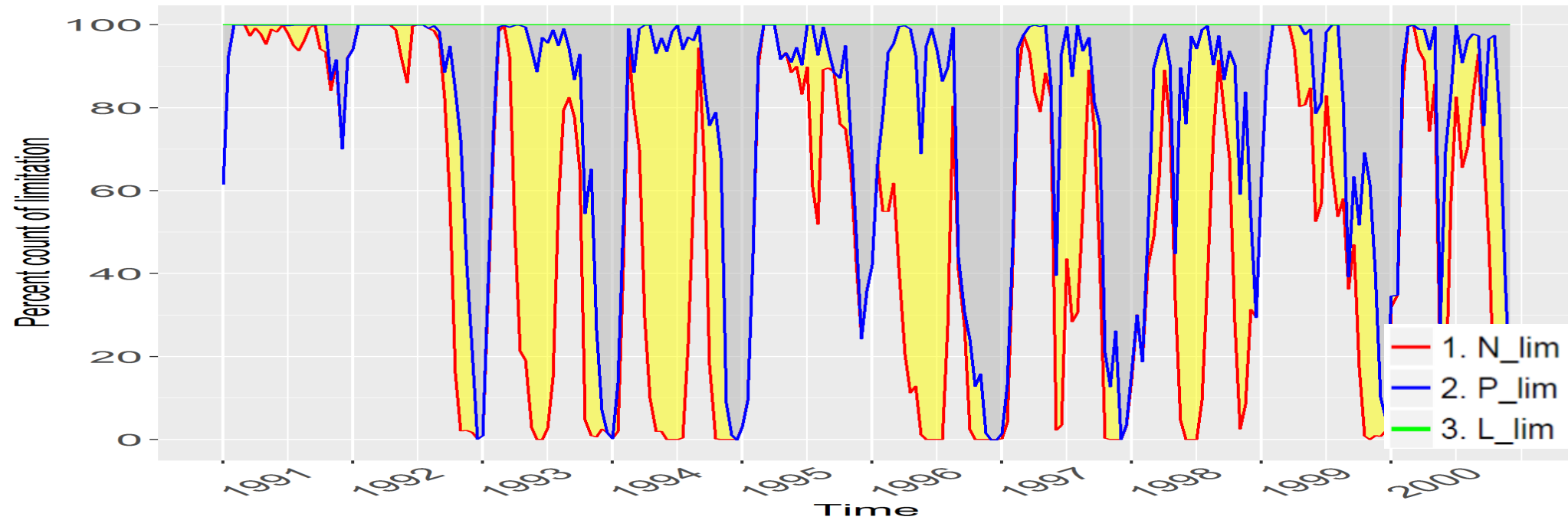
Beta2



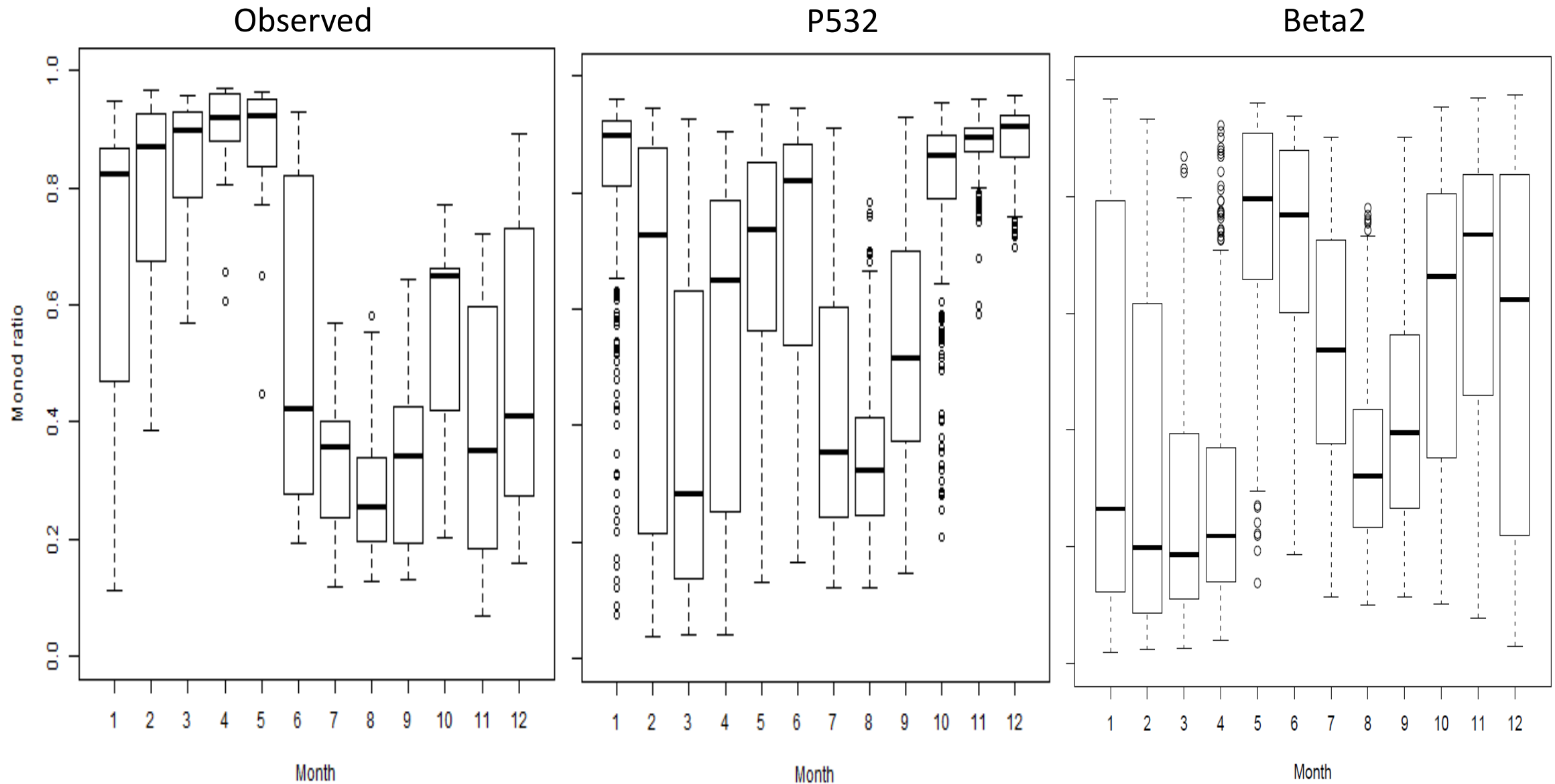
**Data-model
comparison
of N-P
limitation at
CB6.1**



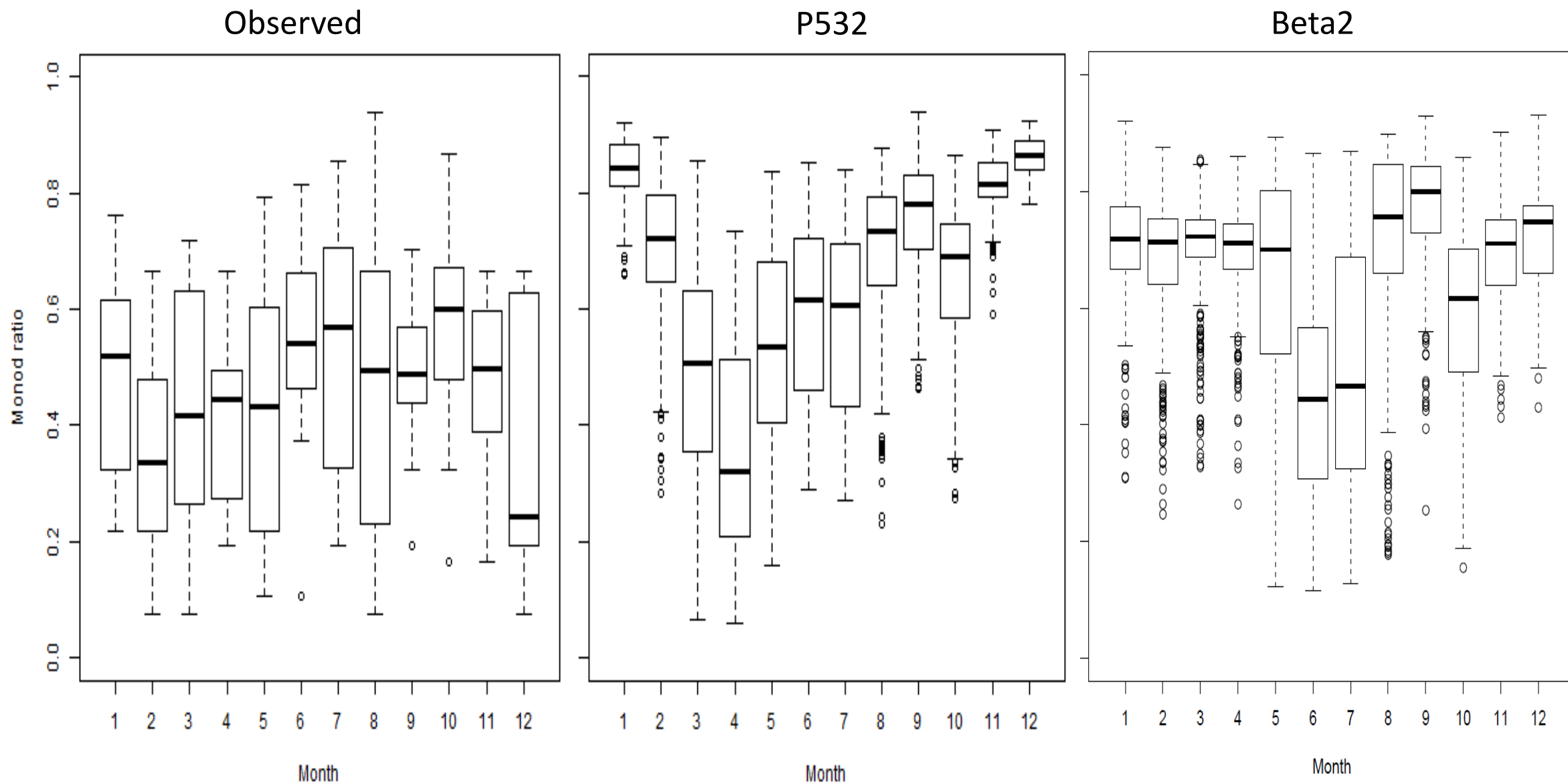
**P532 model
prediction
of relative
N-P-Light
limitation in
CB6 (PH)**



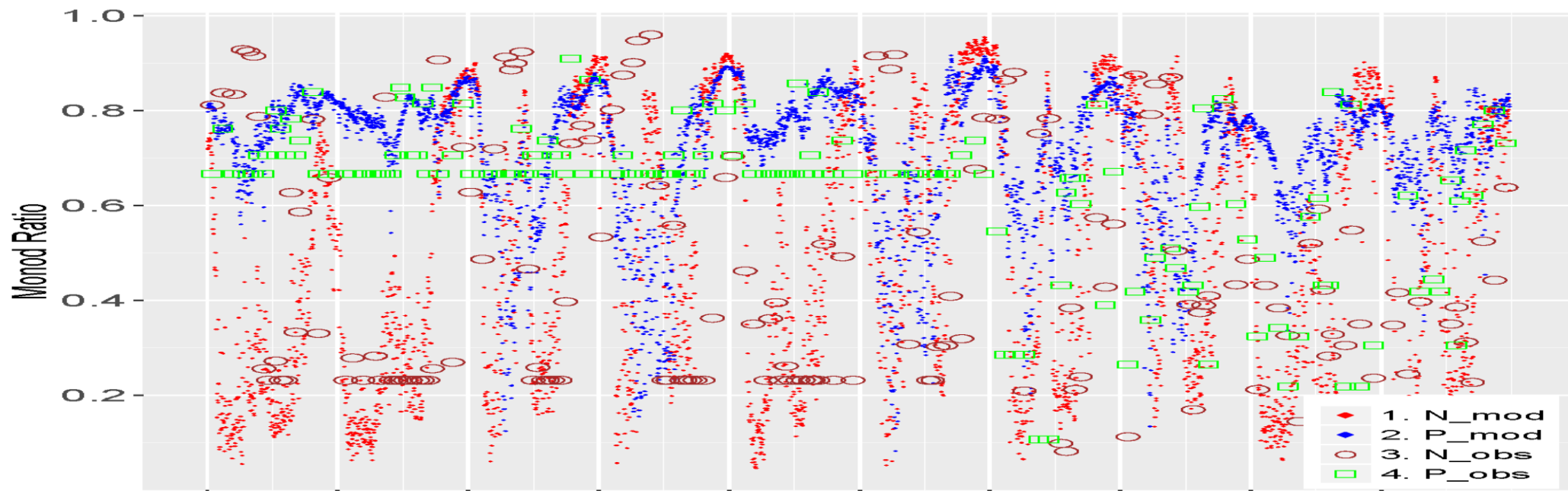
P532 and Beta2 comparison of N-limitation at CB6.1



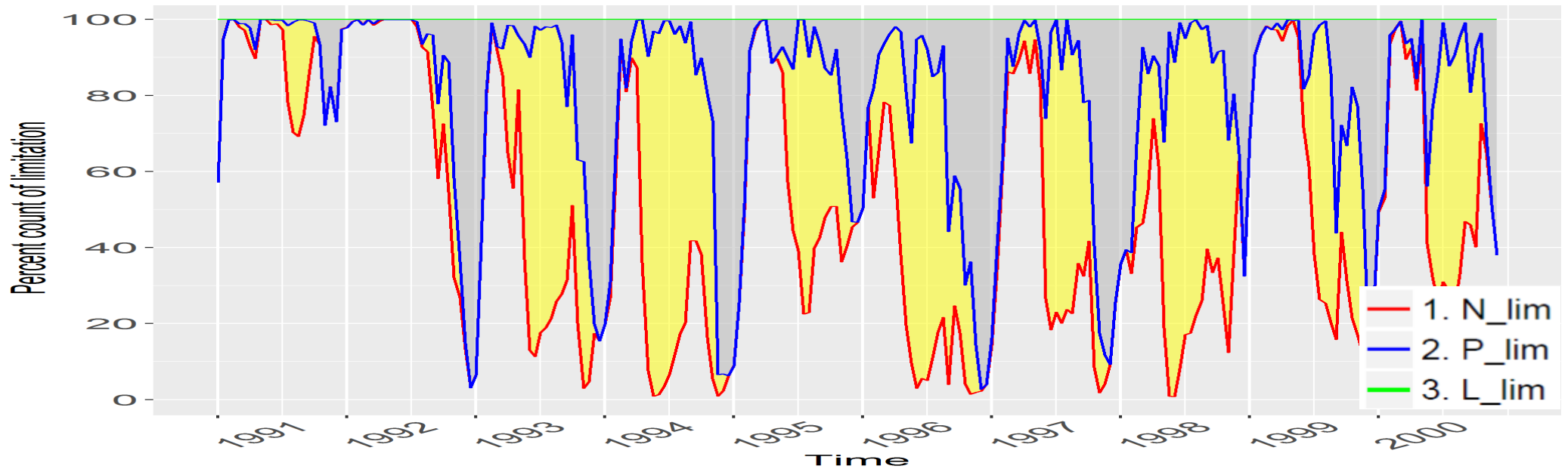
P532 and Beta2 comparison of P-limitation at CB6.1



**Data-model
comparison
of N-P
limitation at
CB7.3**

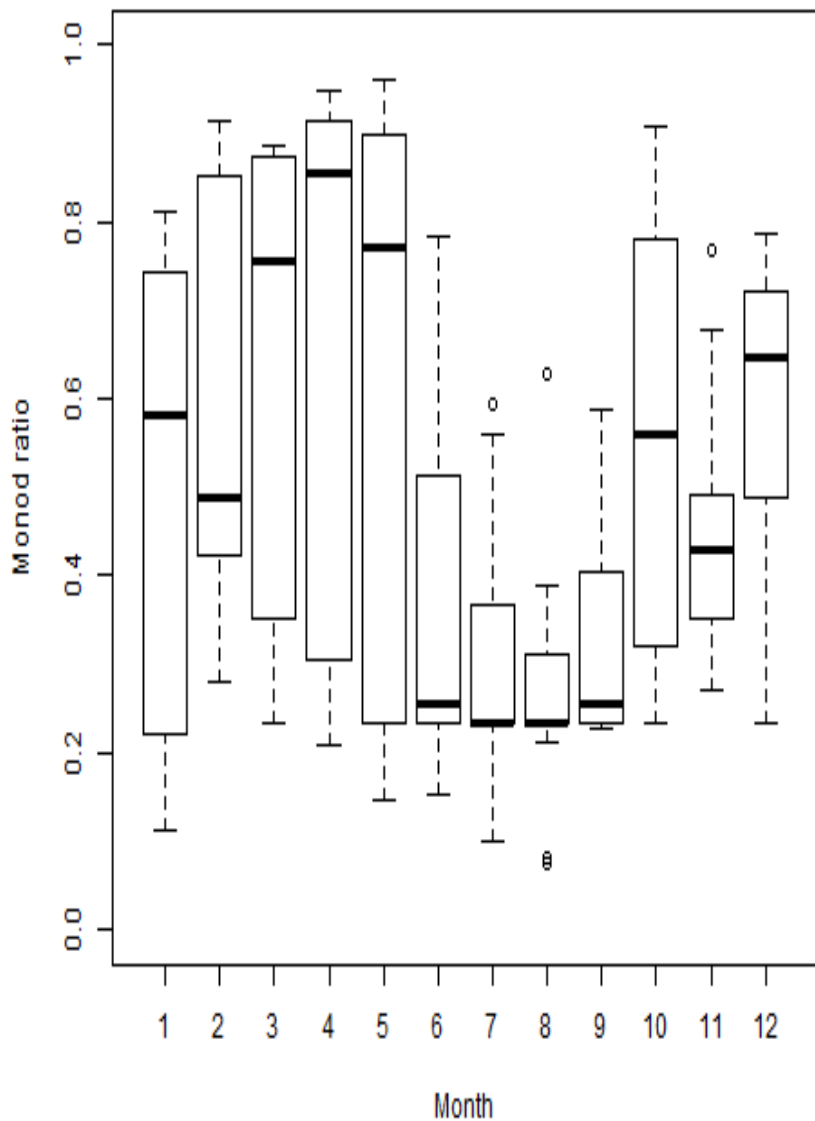


**P532 model
prediction
of relative
N-P-Light
limitation at
CB7**

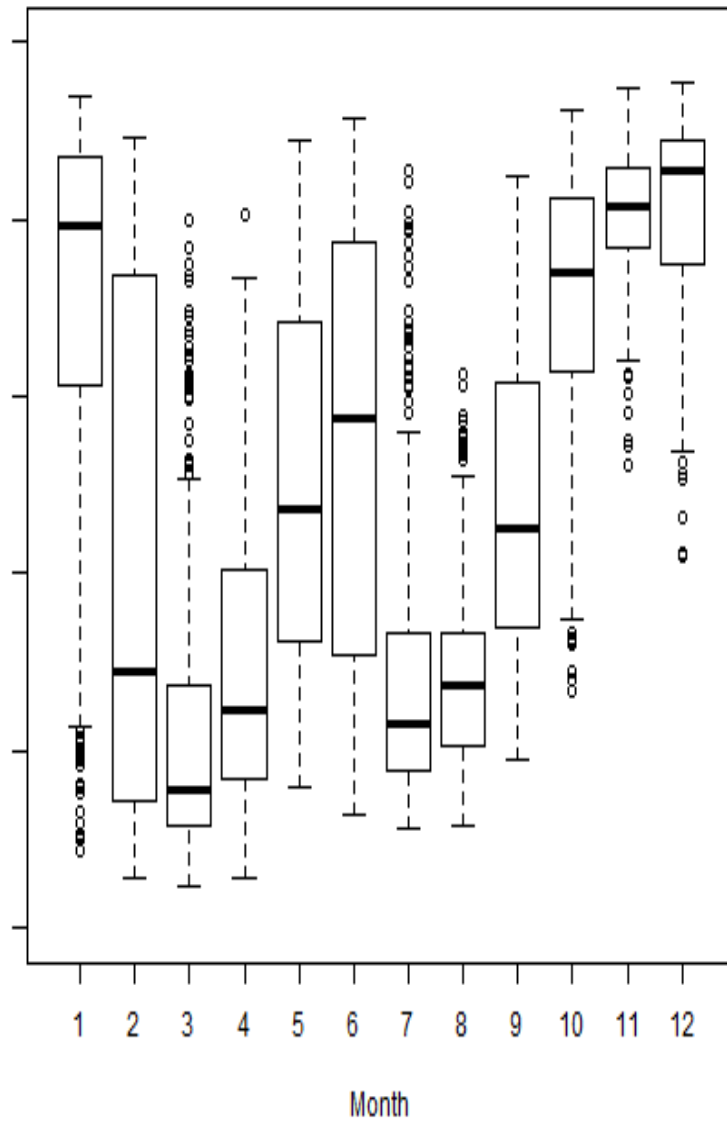


P532 and Beta2 comparison of N-limitation at CB7.3

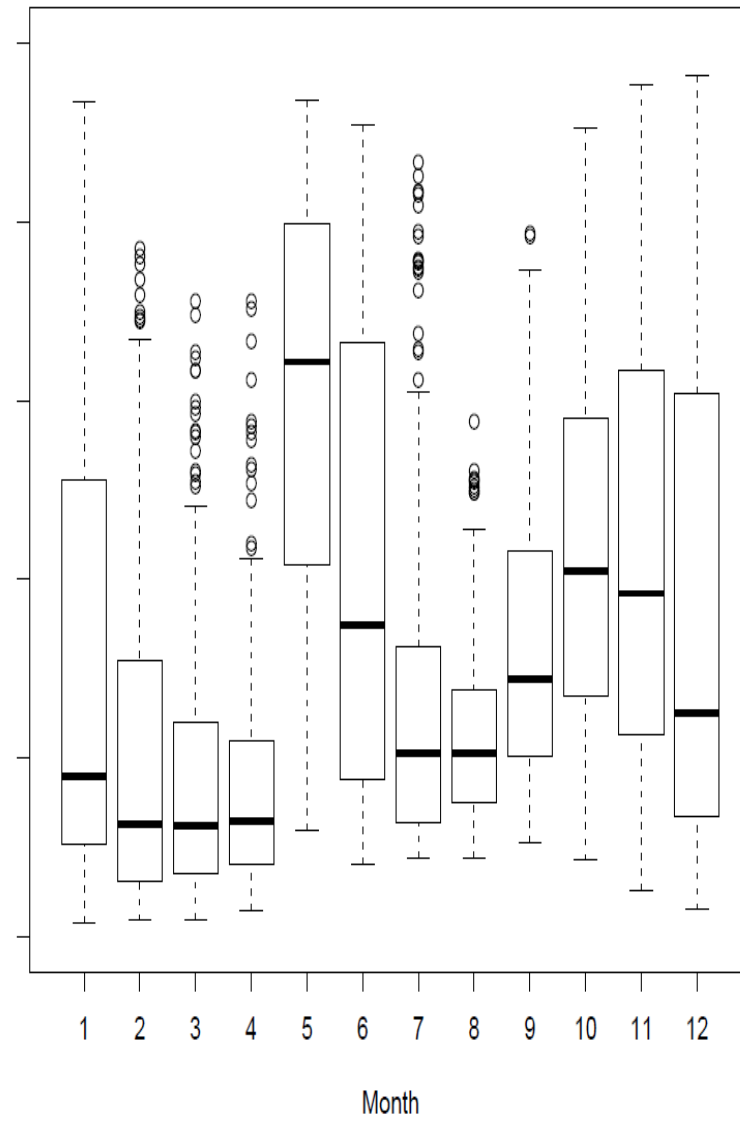
Observed



P532

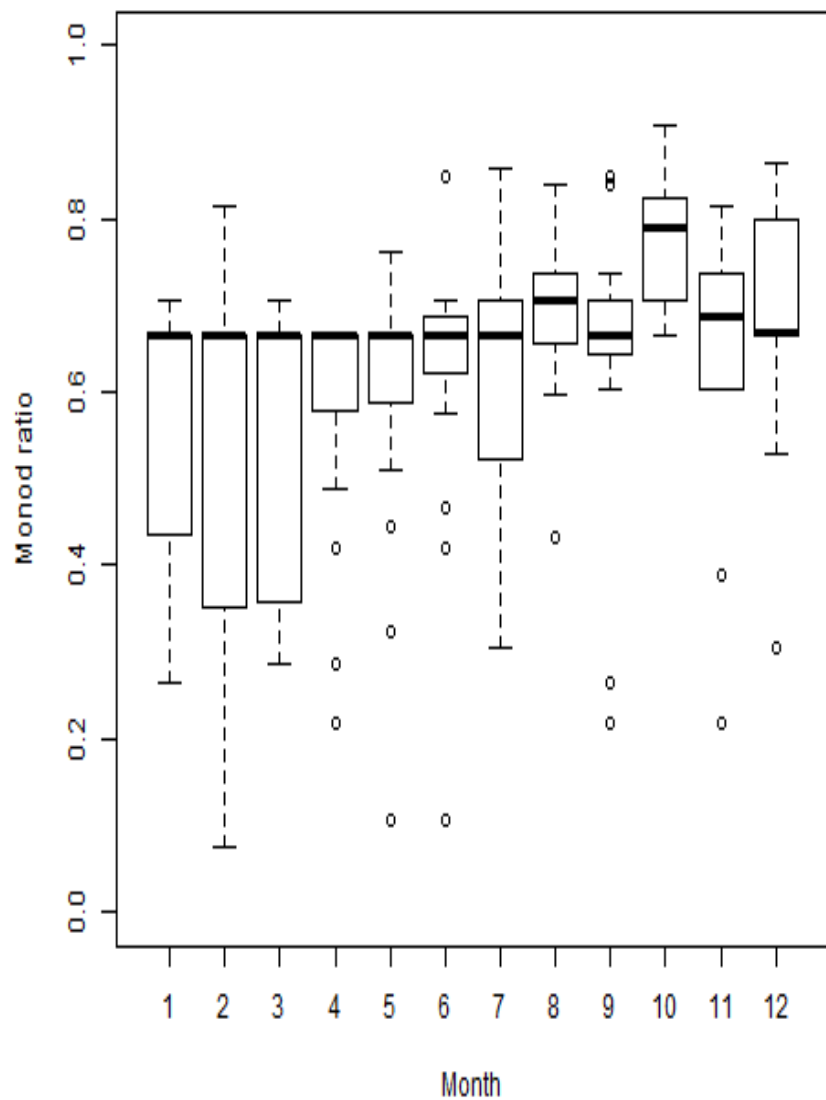


Beta2

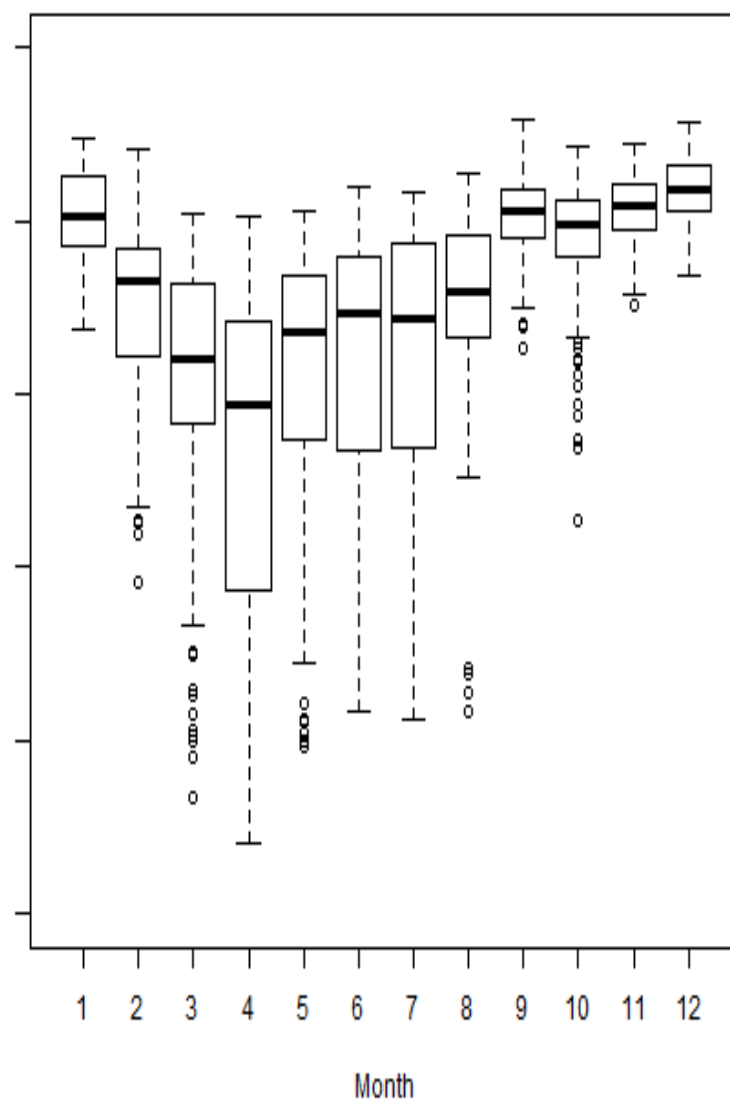


P532 and Beta2 comparison of P-limitation at CB7.3

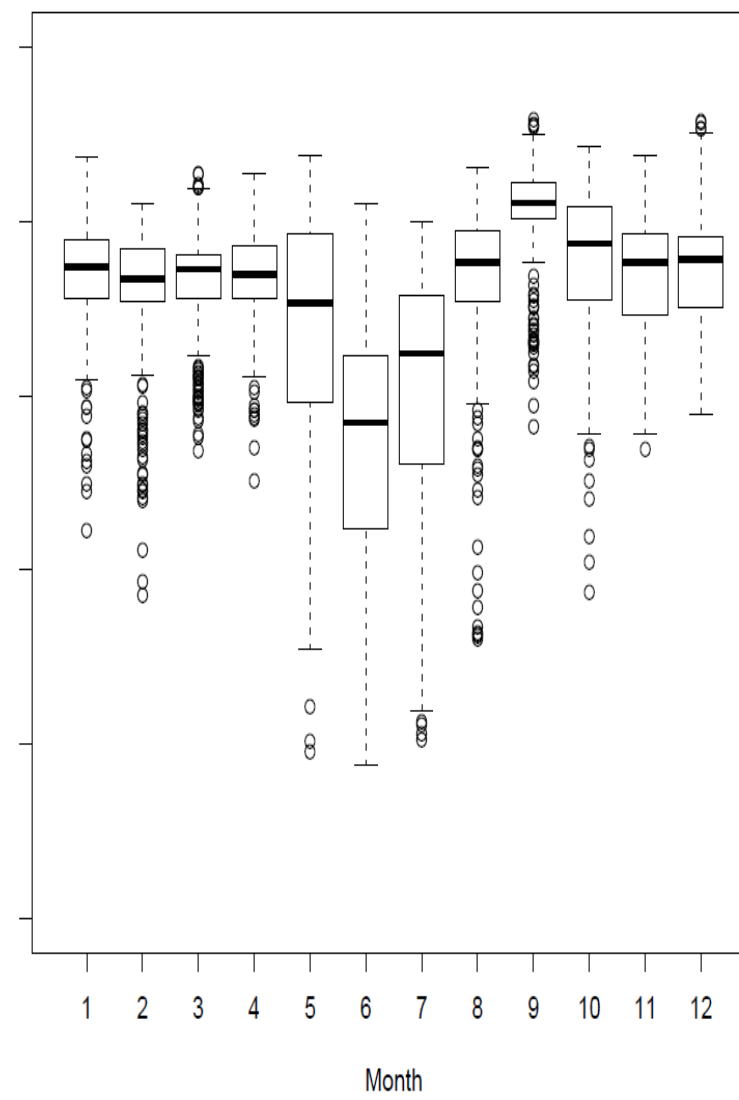
Observed



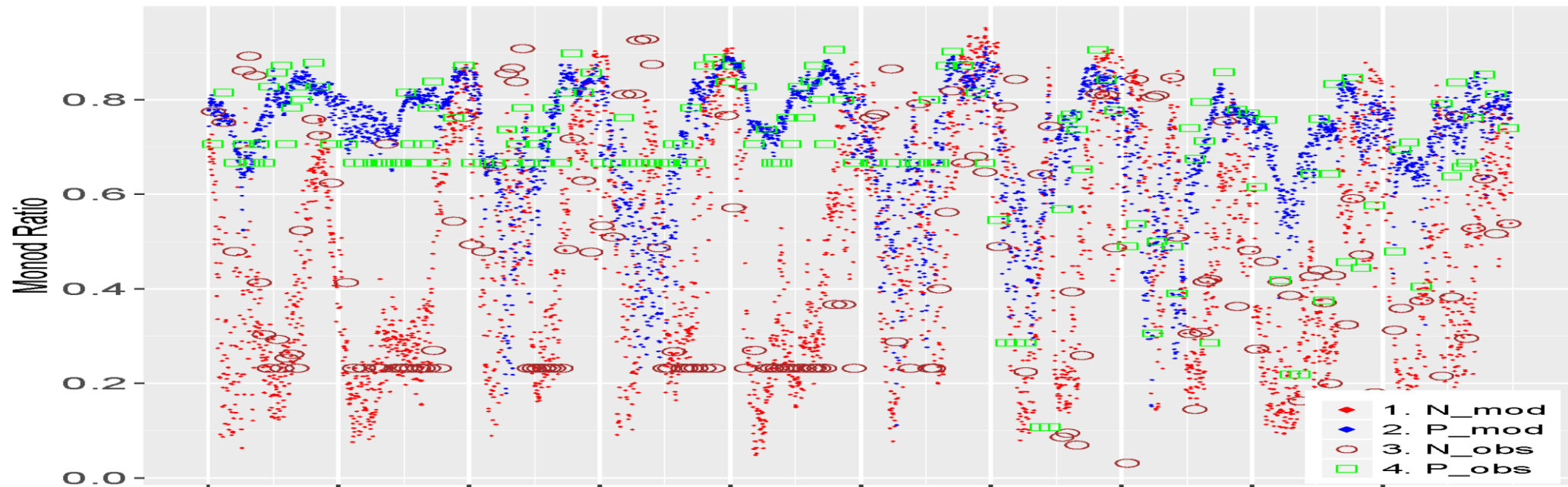
P532



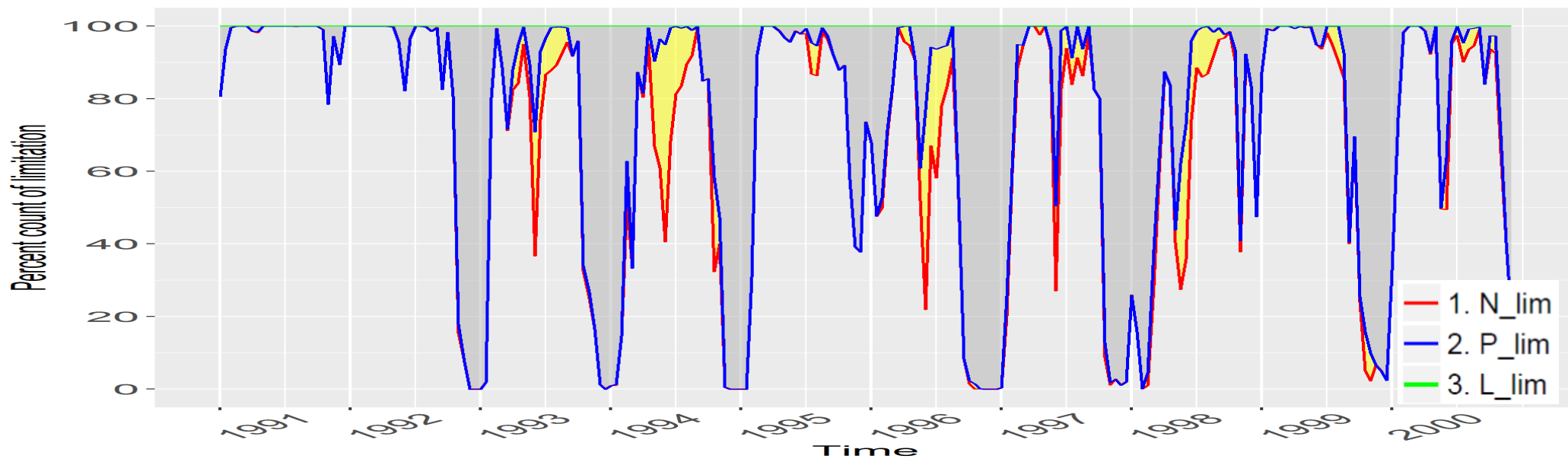
Beta2



**Data-model
comparison
of N-P
limitation at
CB7.4**

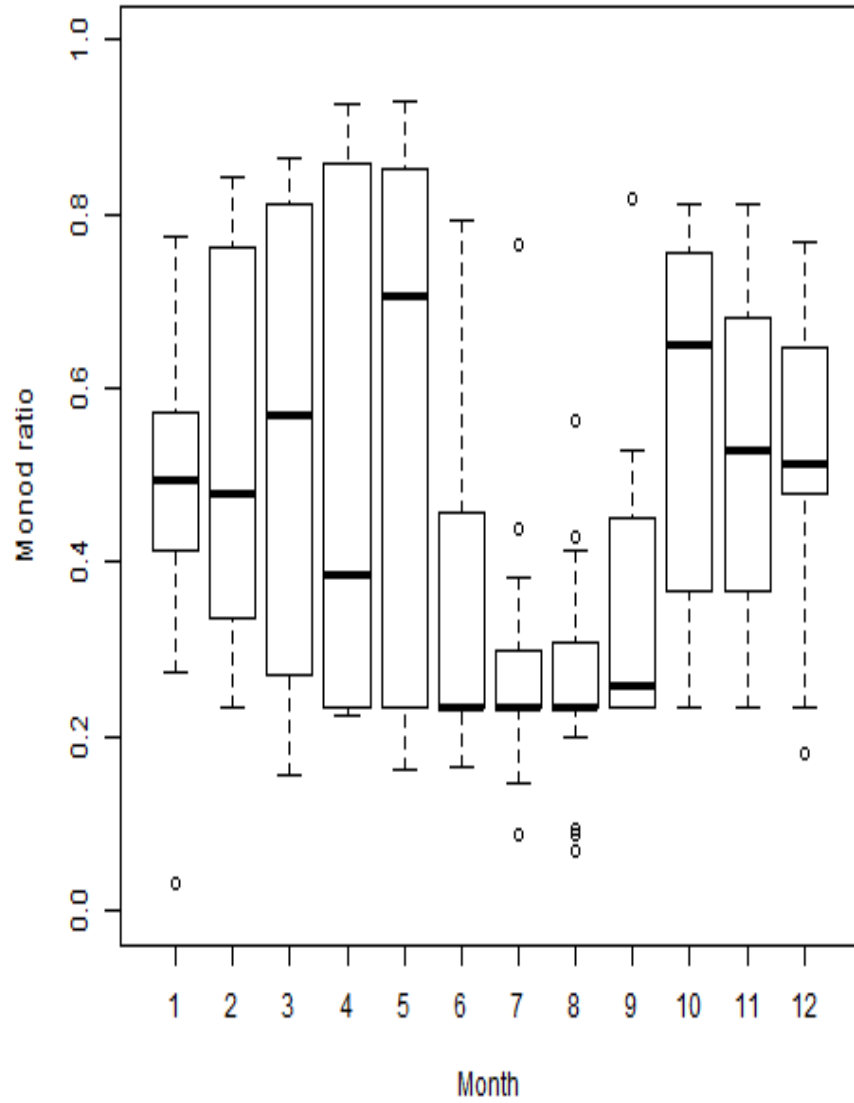


**P532 model
prediction
of relative
N-P-Light
limitation at
CB8PH**

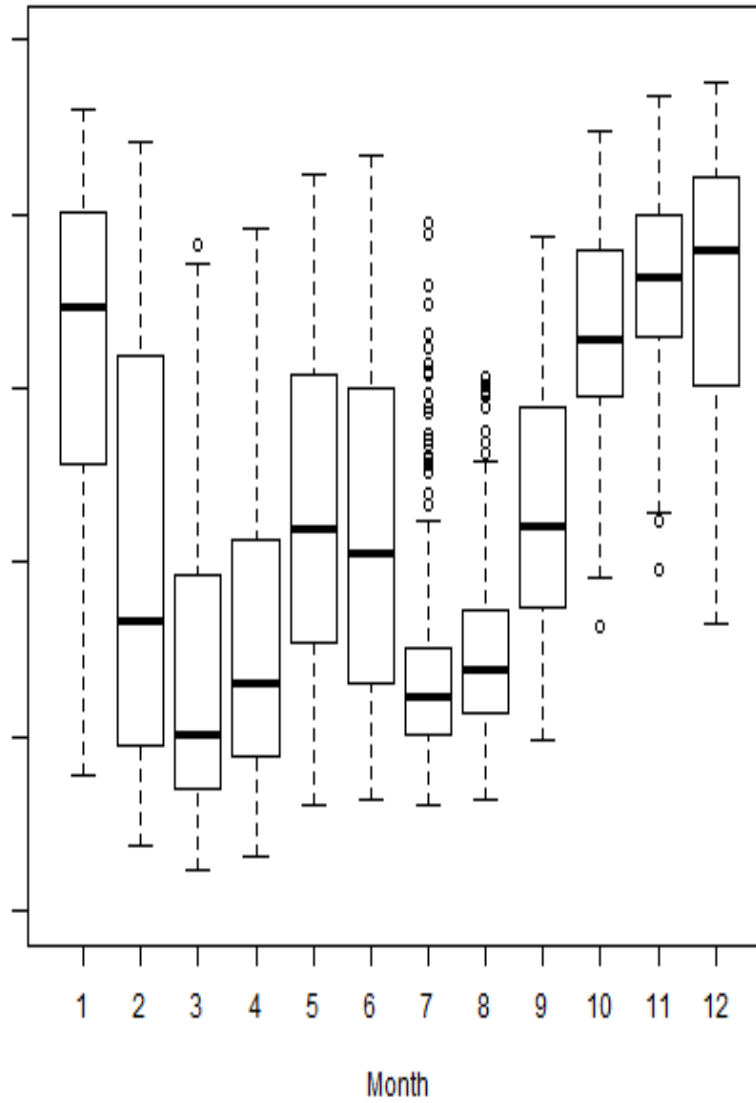


P532 and Beta2 comparison of N-limitation at CB7.4

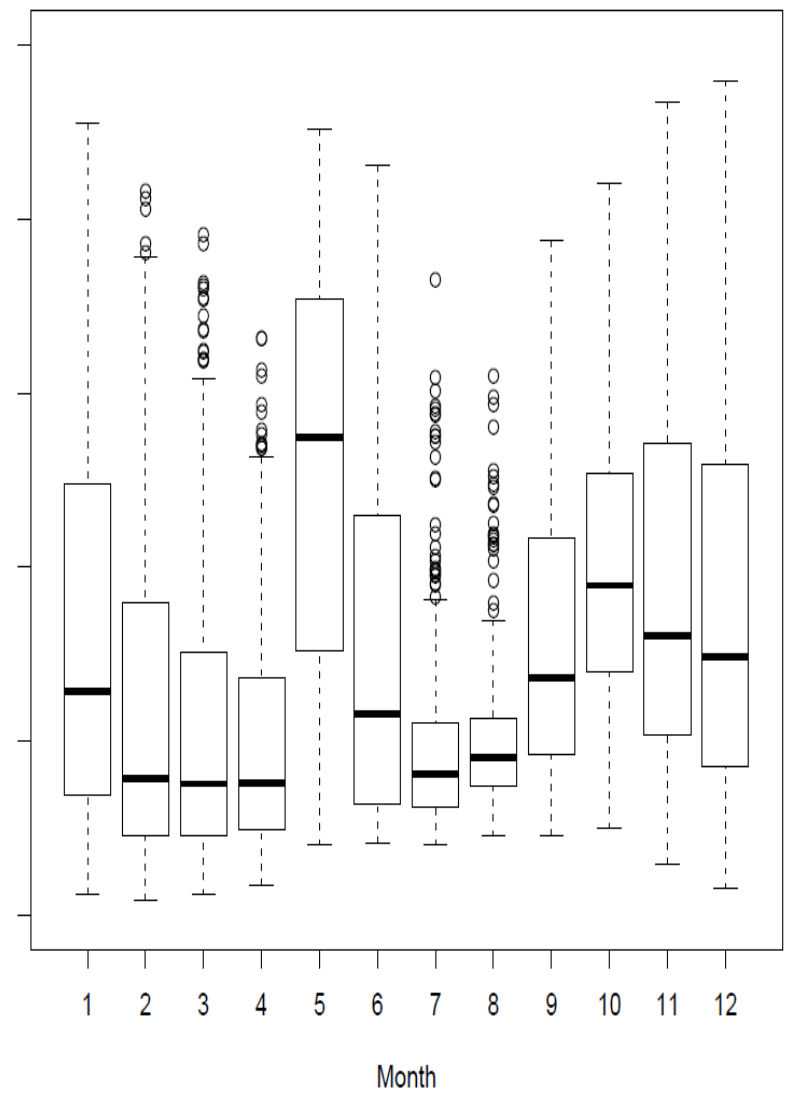
Observed



P532

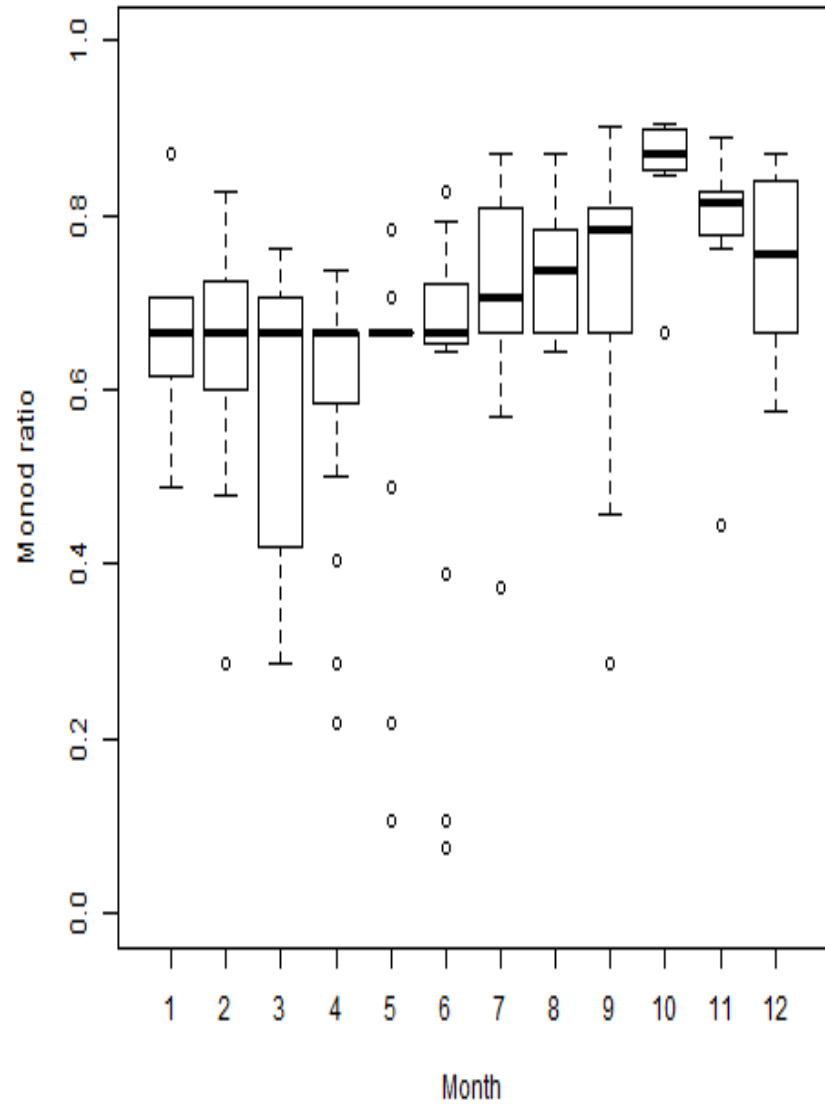


Beta2

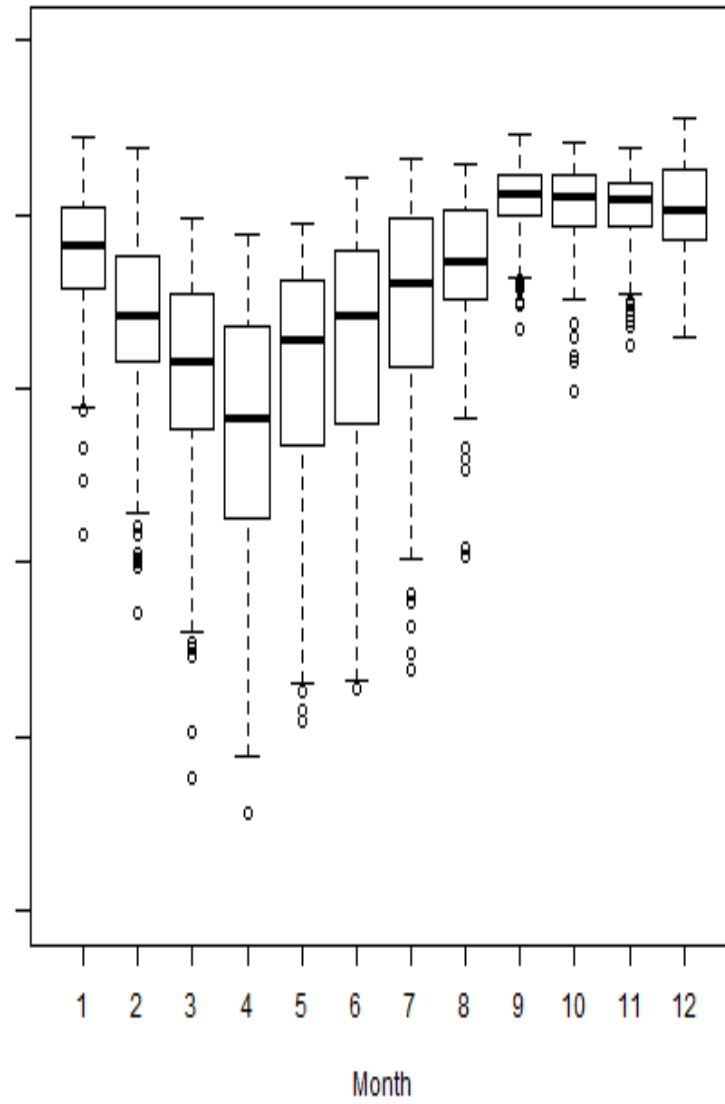


P532 and Beta2 comparison of P-limitation at CB7.4

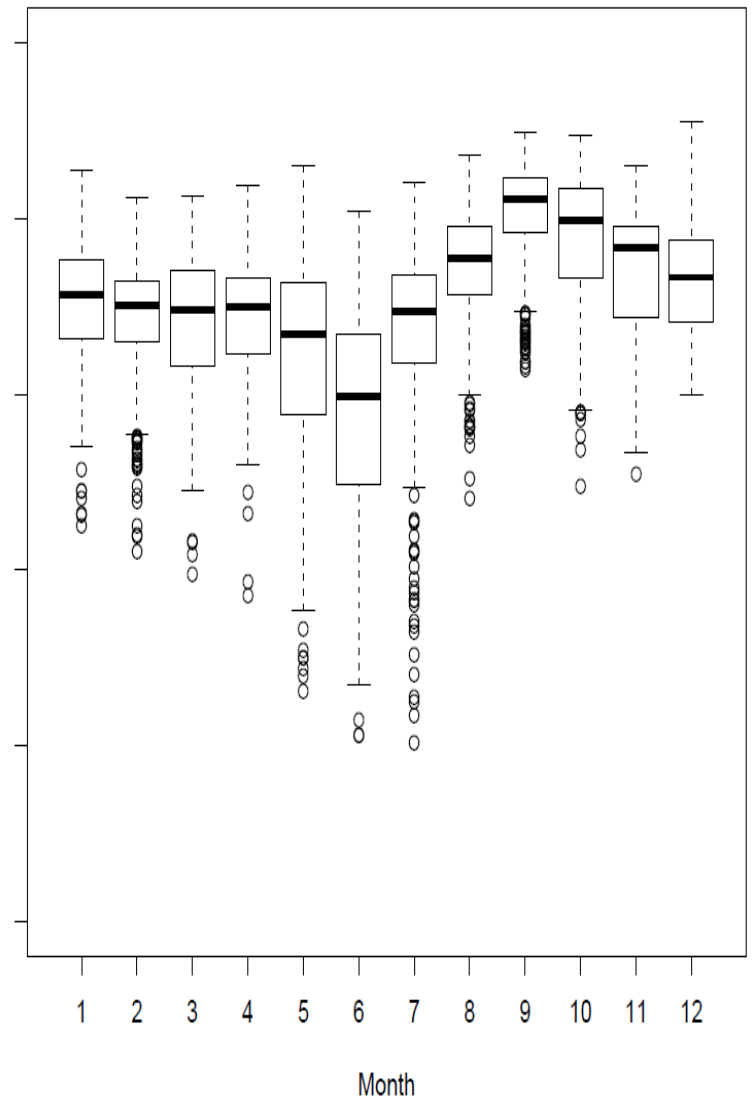
Observed



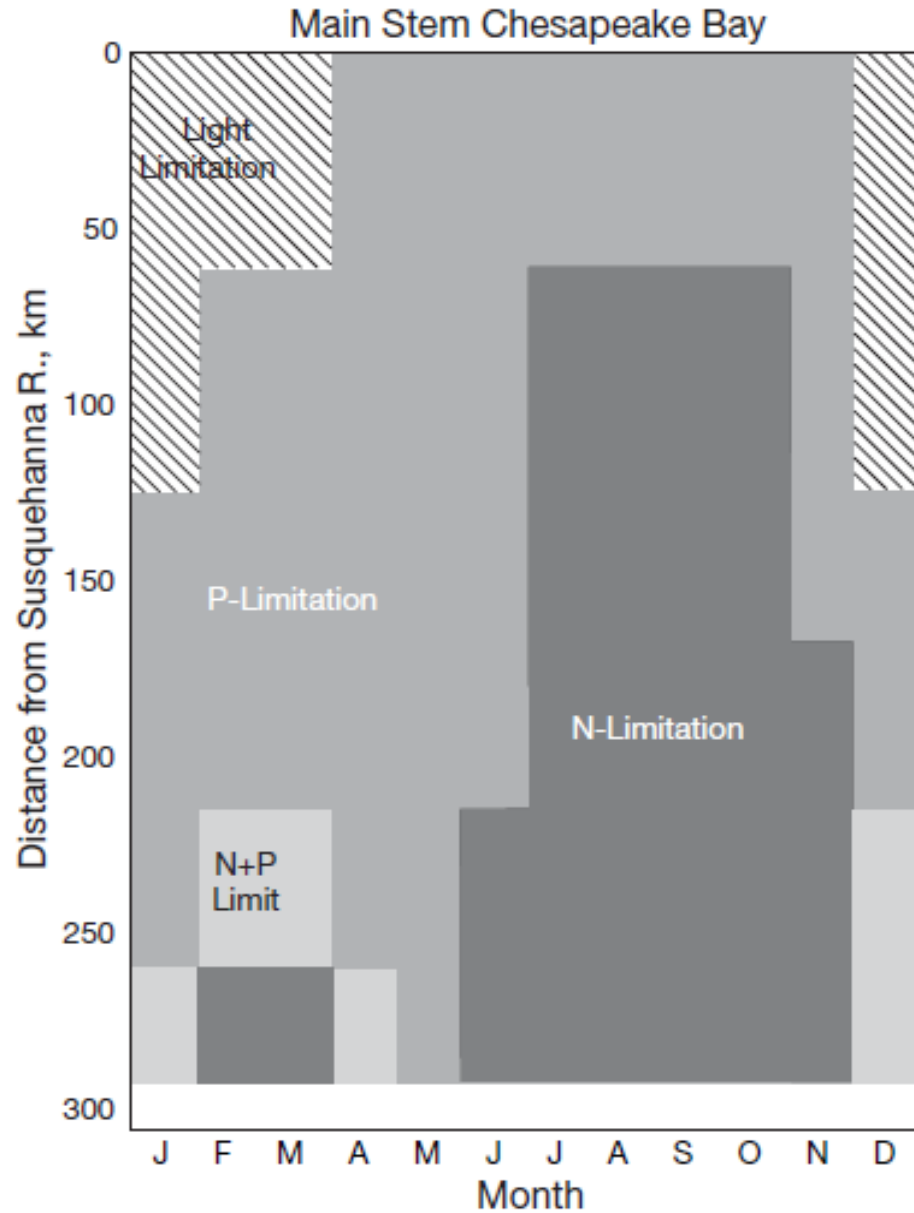
P532



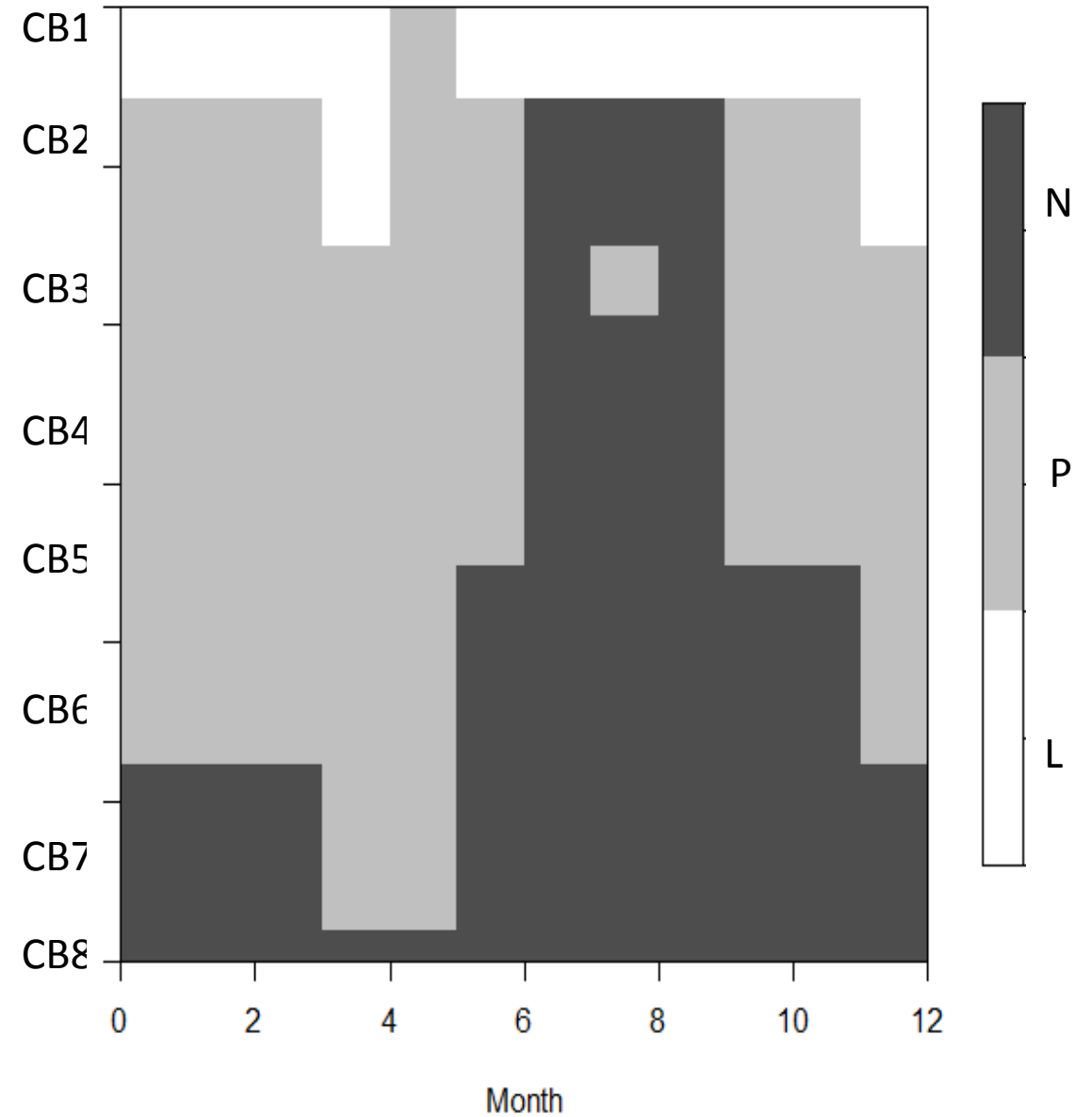
Beta2



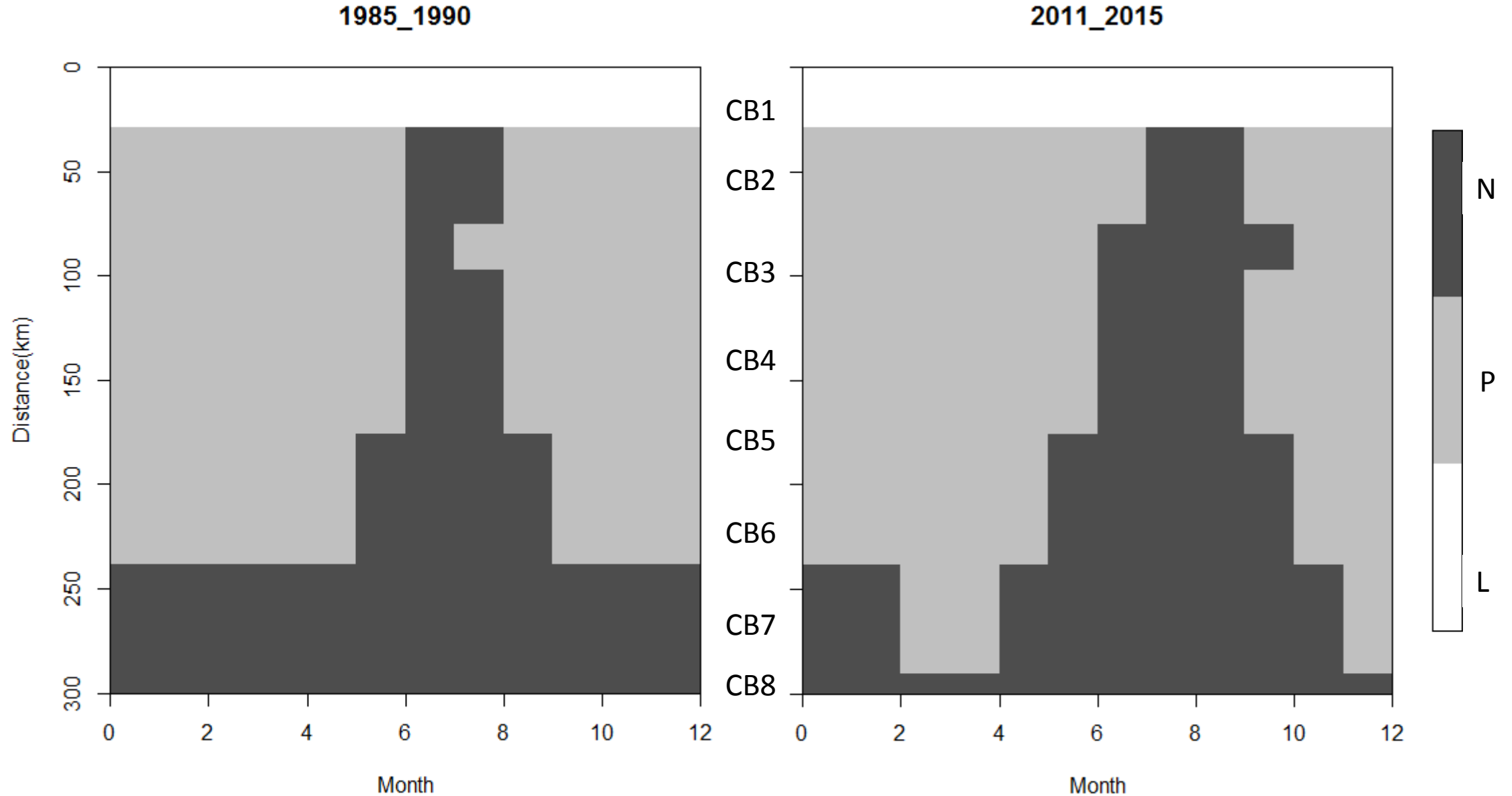
Bioassay



Concentration data

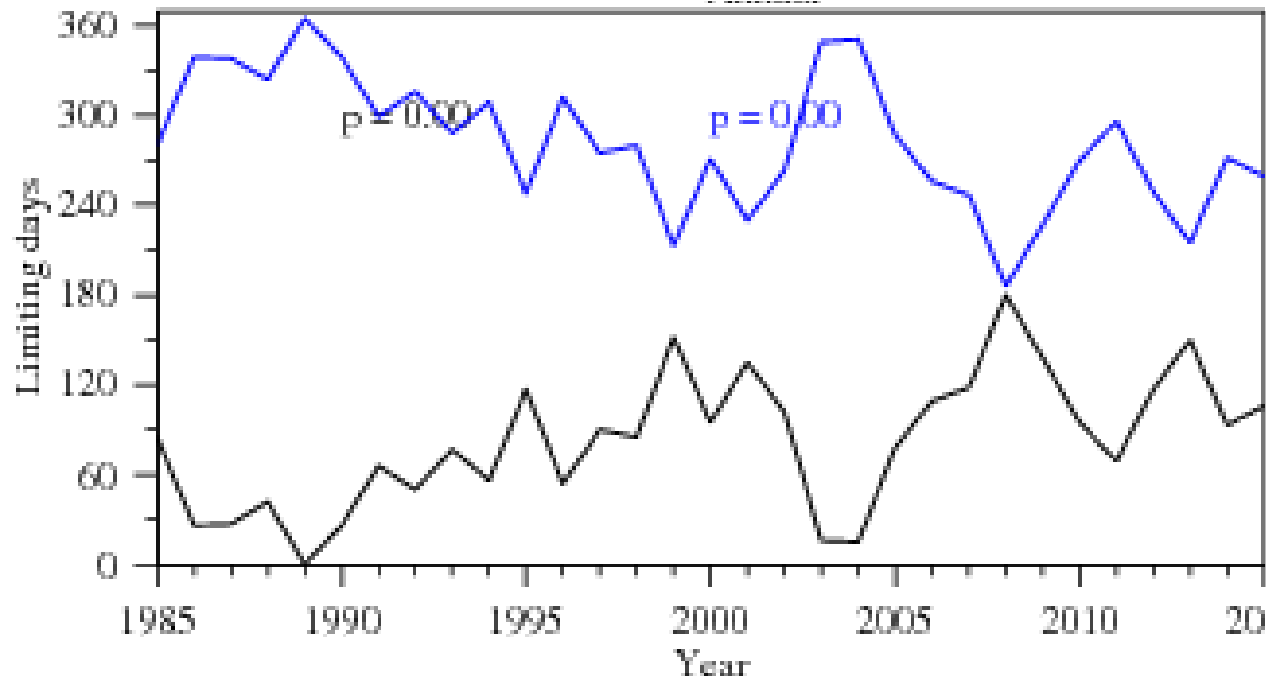


Comparison earlier and later 5-years periods

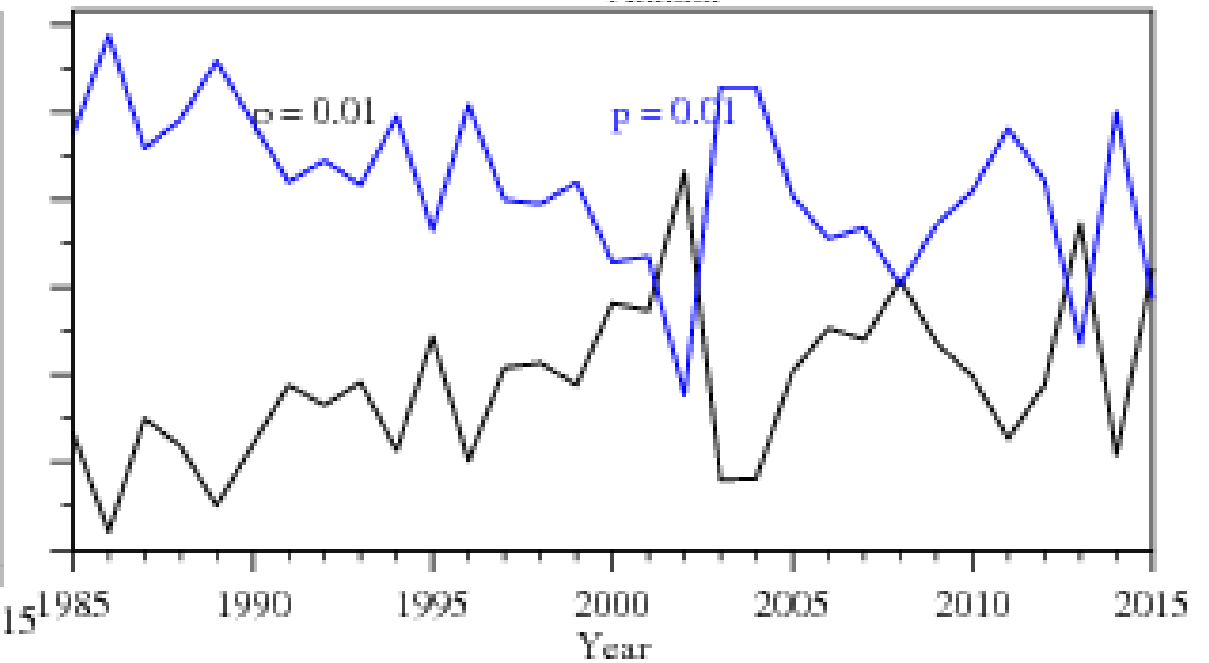


Nitrogen (black line) and phosphorus (blue) limiting days per year

CB4.2



CB5.2



Messages

- **Michaelis-Menten function provided coherent estimation of nutrient limitation as compared to bioassay.**
- **Clear spatial and seasonal shift in nutrient limitation.**
- **Increasing trend in N-limitation and decreasing trend in P-limitation.**
- **In general the model reproduced relatively well observation, but tend to underestimate N-limitation and overestimate P-limitation in the upper Bay.**