



Supplement of

Net primary productivity in the Gulf of California: spatio-temporal patterns and drivers in a warming climate (2003–2024)

Eduardo González-Rodríguez et al.

Correspondence to: Rafael Cervantes-Duarte (rcervan@ipn.mx) and Juan David Acevedo-Acosta (acevedoacosta.juandavid@gmail.com)

The copyright of individual parts of the supplement might differ from the article licence.

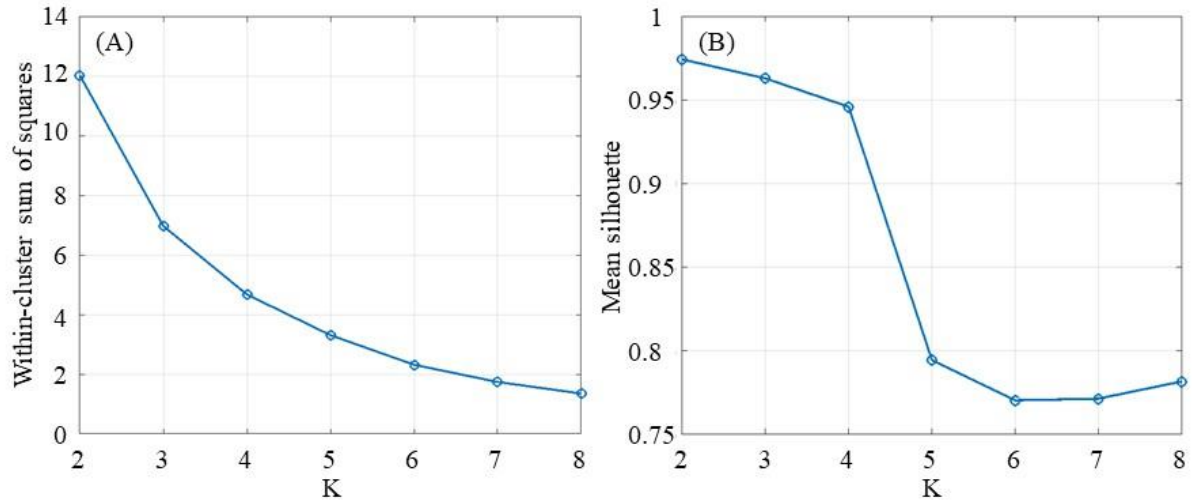


Figure S1. Evaluation of the optimal number of clusters for classifying net primary productivity in the Gulf of California using (A) the elbow method and (B) silhouette analysis. Both diagnostics favoured solutions comprising a small number of clusters, whereas increasing K , particularly to $K \geq 5$, provided only marginal improvement and resulted in poorer cluster separation.

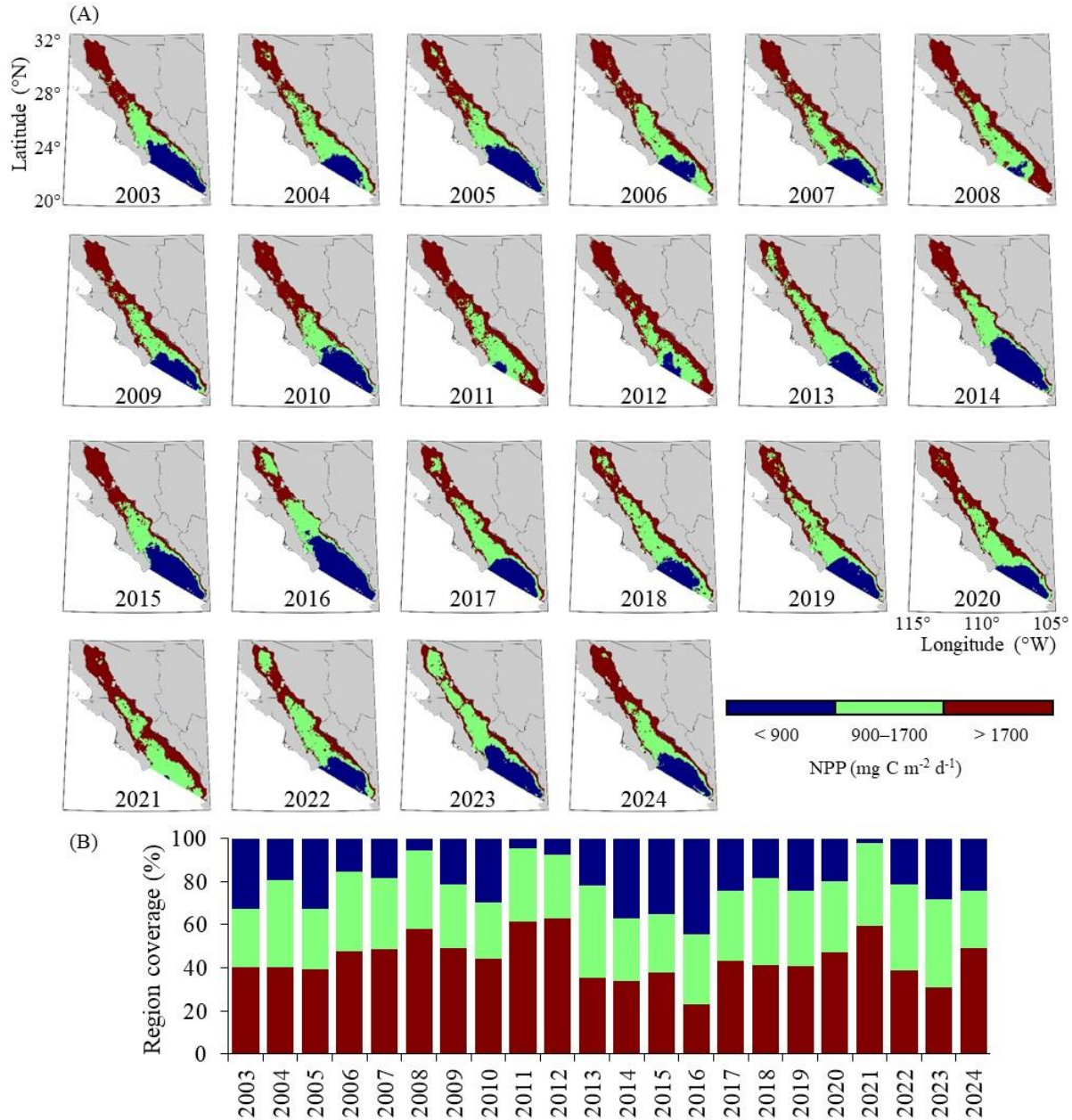


Figure S2. (A) Spatial distribution of cold-season coverage (December–May) across productivity zones for each year from 2003 to 2024. (B) Annual time series of the percentage of the study region covered by each productivity zone. The productivity zones are defined as the low-productivity zone (LPZ, < 900 mg C m⁻² d⁻¹), mid-productivity zone (MPZ, 900–1700 mg C m⁻² d⁻¹), and high-productivity zone (HPZ, > 1700 mg C m⁻² d⁻¹).

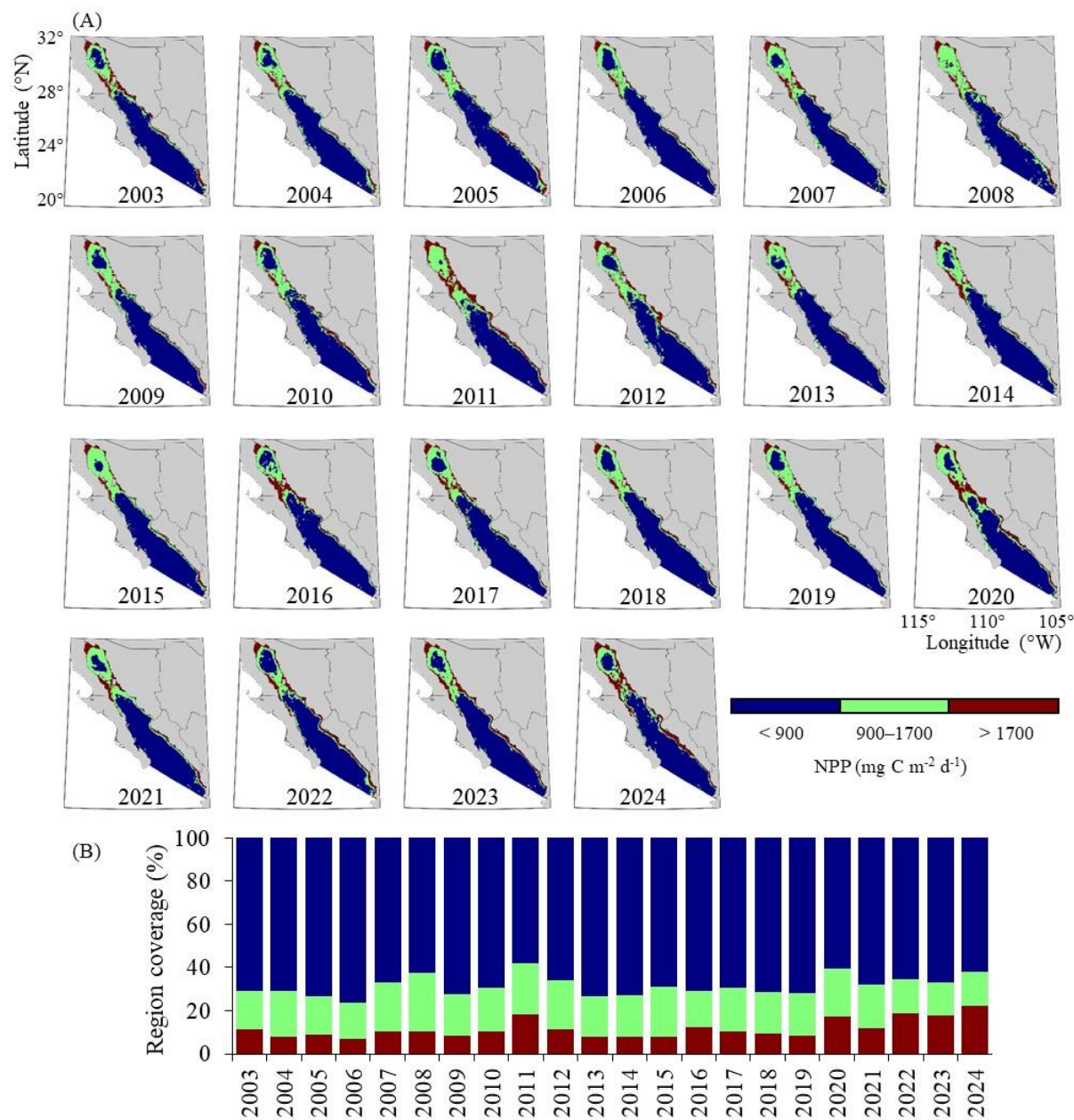


Figure S3. (A) Spatial distribution of warm-season coverage (June–November) across productivity zones for each year from 2003 to 2024. (B) Annual time series of the percentage of the study region covered by each productivity zone. The productivity zones are defined as the low-productivity zone (LPZ, $< 900 \text{ mg C m}^{-2} \text{ d}^{-1}$), mid-productivity zone (MPZ, $900\text{--}1700 \text{ mg C m}^{-2} \text{ d}^{-1}$), and high-productivity zone (HPZ, $> 1700 \text{ mg C m}^{-2} \text{ d}^{-1}$).

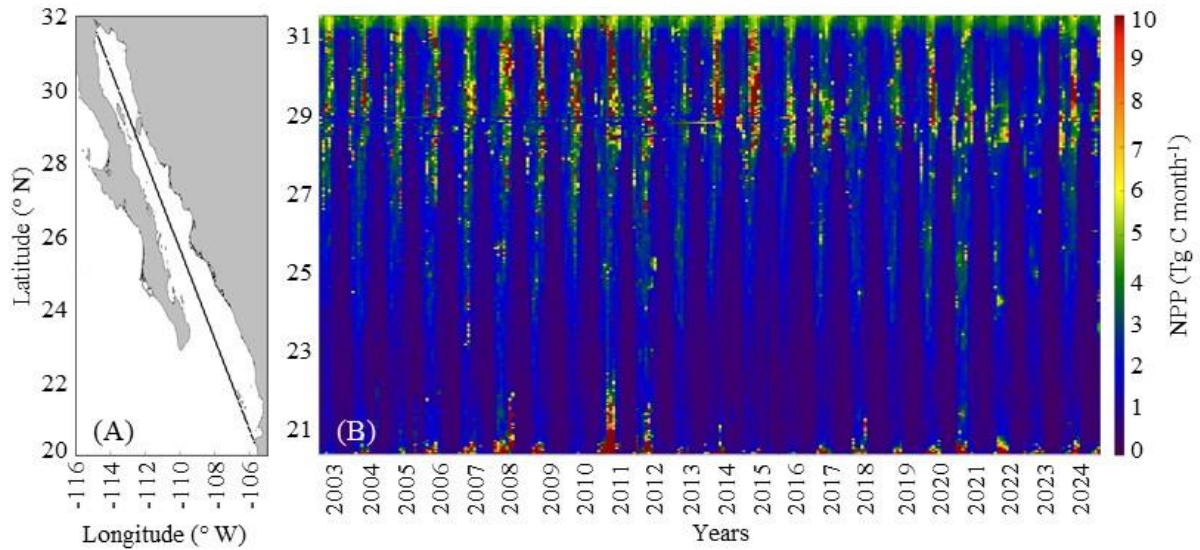


Figure S4. Monthly variation in the latitudinal distribution of net primary productivity (NPP; Tg C month⁻¹) in the central Gulf of California. (A) The location of the latitudinal transect, and (B) the corresponding Hovmöller diagram of monthly variation of NPP along the transect.

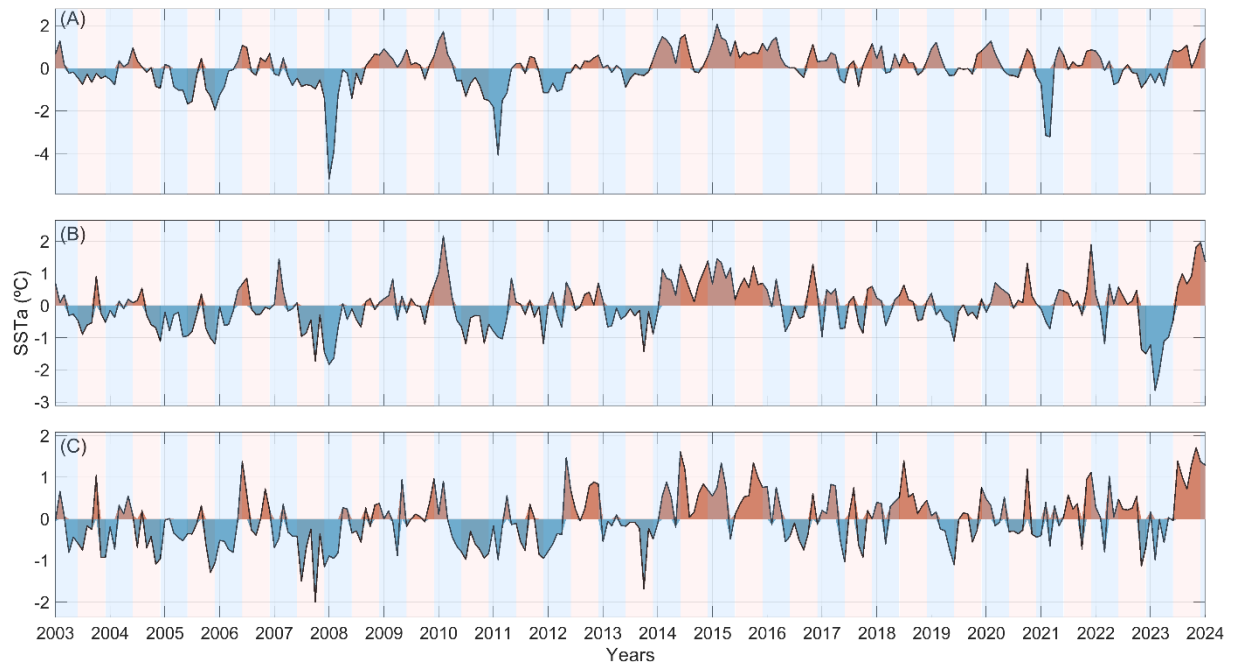


Figure S5. Monthly sea surface temperature anomalies (SSTa) from 2003 to 2024 for the three net primary productivity (NPP) zones of the Gulf of California: (A) low-productivity zone (LPZ), (B) mid-productivity zone (MPZ), and (C) high-productivity zone (HPZ). Positive and negative anomalies indicate warmer- and cooler-than-average conditions, respectively. Alternating shaded bands denote cool and warm seasonal periods.



Figure S6. Euphotic-zone depth anomalies (EZDa) from 2003 to 2024 for the (A) low-productivity zone (LPZ), (B) mid-productivity zone (MPZ), and (C) high-productivity zone (HPZ) of the Gulf of California. Positive and negative anomalies indicate deepening and shoaling of the euphotic zone, respectively. Alternating shaded bands denote cool and warm seasonal periods.

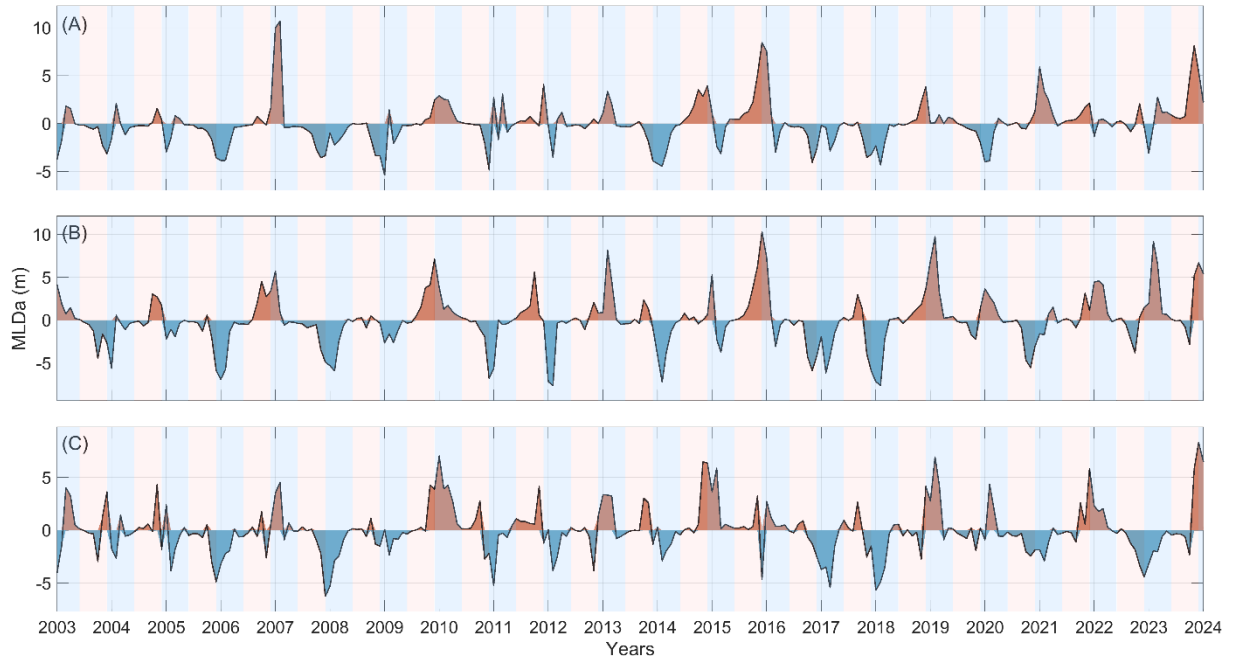


Figure S7. Mixed layer depth anomalies (MLDa) from 2003 to 2024 for the (A) low-productivity zone (LPZ), (B) mid-productivity zone (MPZ), and (C) high-productivity zone (HPZ) of the Gulf of California. Positive and negative anomalies indicate a deepening and shoaling of the mixed layer, respectively. Alternating shaded bands distinguish cool and warm periods.

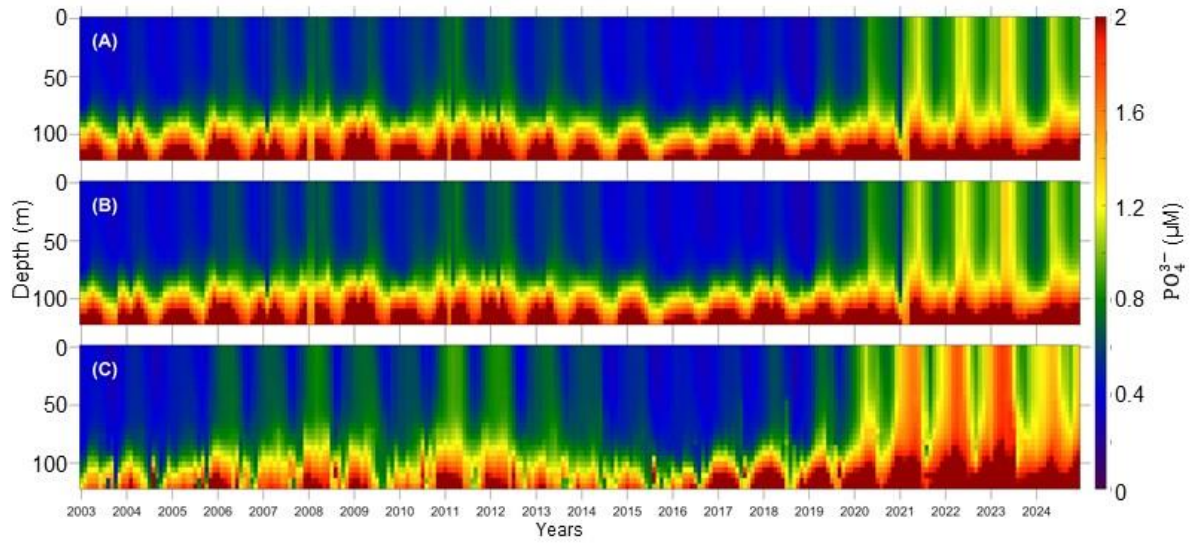


Figure S8. Temporal and vertical distribution of phosphate (PO_4^{3-}) concentrations within the upper 120 m of the water column throughout the study period (2003–2024) in the (A) low-productivity zone (LPZ), (B) mid-productivity zone (MPZ), and (C) high-productivity zone (HPZ) of the Gulf of California.

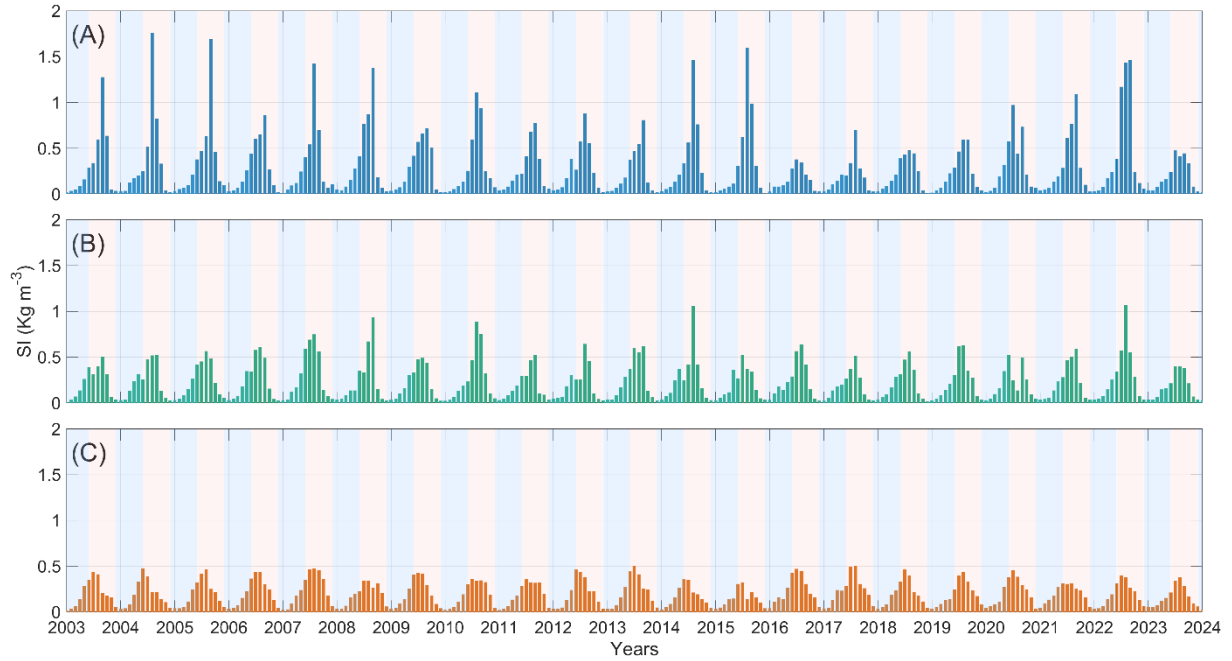
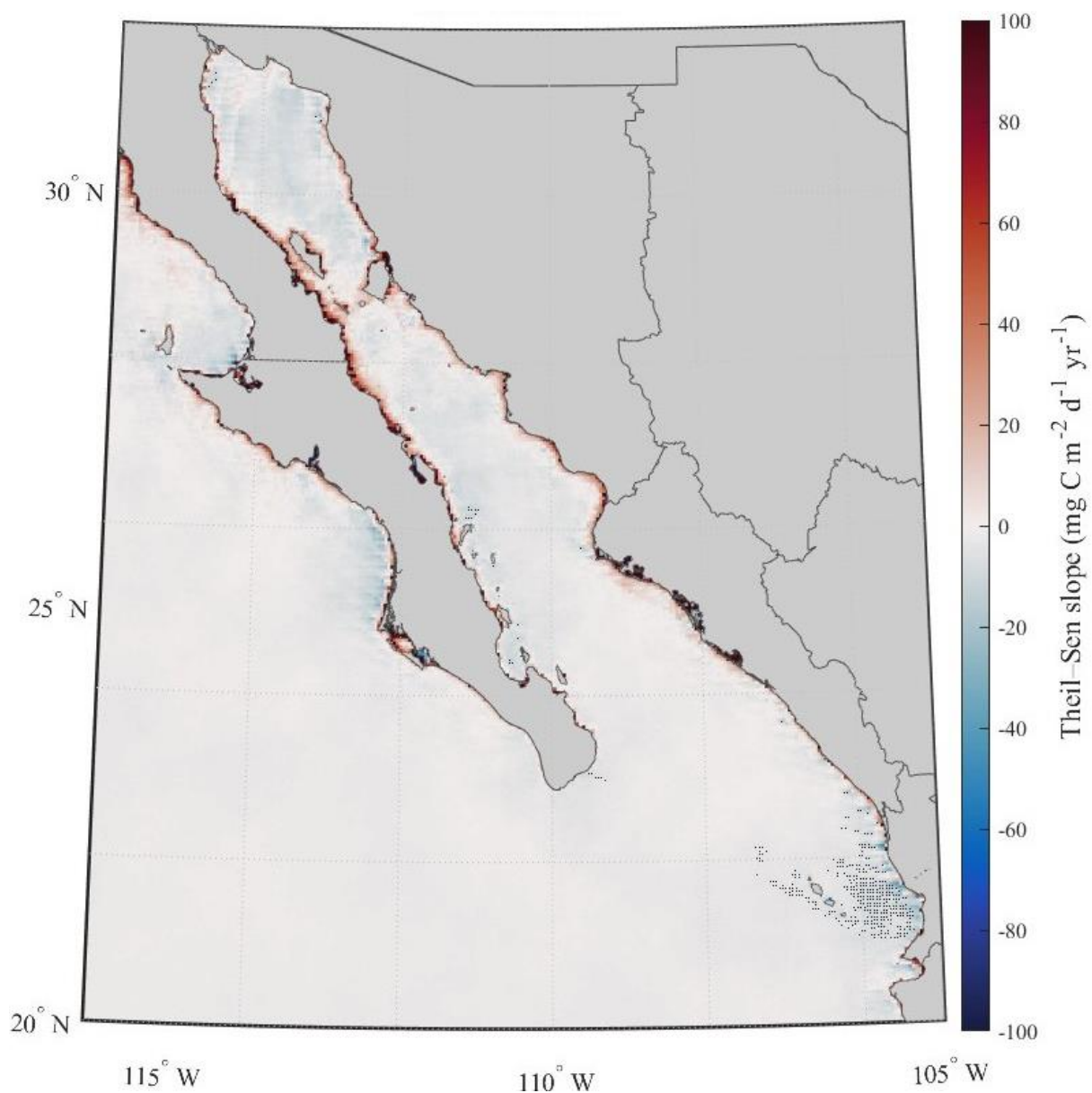


Figure S9. Stratification index (SI; kg m^{-3}) from 2003 to 2024 in the three NPP zones: (A) low-productivity zone (LPZ), (B) mid-productivity zone (MPZ), and (C) high-productivity zone (HPZ) of the Gulf of California. Alternating shaded bands denote cool and warm seasonal periods.

75



76

77 **Figure S10.** Spatial trends in net primary productivity (NPP; $\text{mg C m}^{-2} \text{d}^{-1} \text{year}^{-1}$) across the
 78 Gulf of California from 2003 to 2024. Blue indicates negative trends, whereas red indicates
 79 positive trends. Black dots denote pixels with statistically significant trends ($p < 0.05$).

80

Table S1. Spearman’s rank correlations (r_s) between climate indices (PDO, NPGO, and MEI.v2) and the spatial extent of the low-productivity zone (LPZ), mid-productivity zone (MPZ), and high-productivity zone (HPZ) in the Gulf of California (2003–2024). Significance levels were adjusted for temporal autocorrelation using the effective-sample-size method of Pyper and Peterman (1998). N_{eff} denotes the effective sample size after accounting for temporal autocorrelation; p_{orig} denotes the original significance level calculated under the assumption of independent observations; and p_{corr} denotes the significance level corrected for temporal autocorrelation. Statistically significant correlations ($\alpha=0.05$, based on p_{corr}) are shown in bold.

Climate index	Zone	r_s	N_{eff}	p_{orig}	p_{corr}
PDO	LPZ	0.058	106.98	0.344	0.550
	MPZ	0.055	139.78	0.373	0.518
	HPZ	-0.118	91.33	0.055	0.263
NPGO	LPZ	0.065	189.32	0.293	0.374
	MPZ	-0.059	140.09	0.337	0.486
	HPZ	-0.097	141.99	0.118	0.253
MEI.v2	LPZ	0.116	264	0.061	0.061
	MPZ	-0.043	264	0.486	0.486
	HPZ	-0.136	264	0.027	0.027

References

Pyper, B. J. and Peterman, R. M.: Comparison of methods to account for autocorrelation in correlation analyses of fish data. Can. J. Fish. Aquat. Sci., 55, 2127–2140, <https://doi.org/10.1139/f98-104>, 1998.