

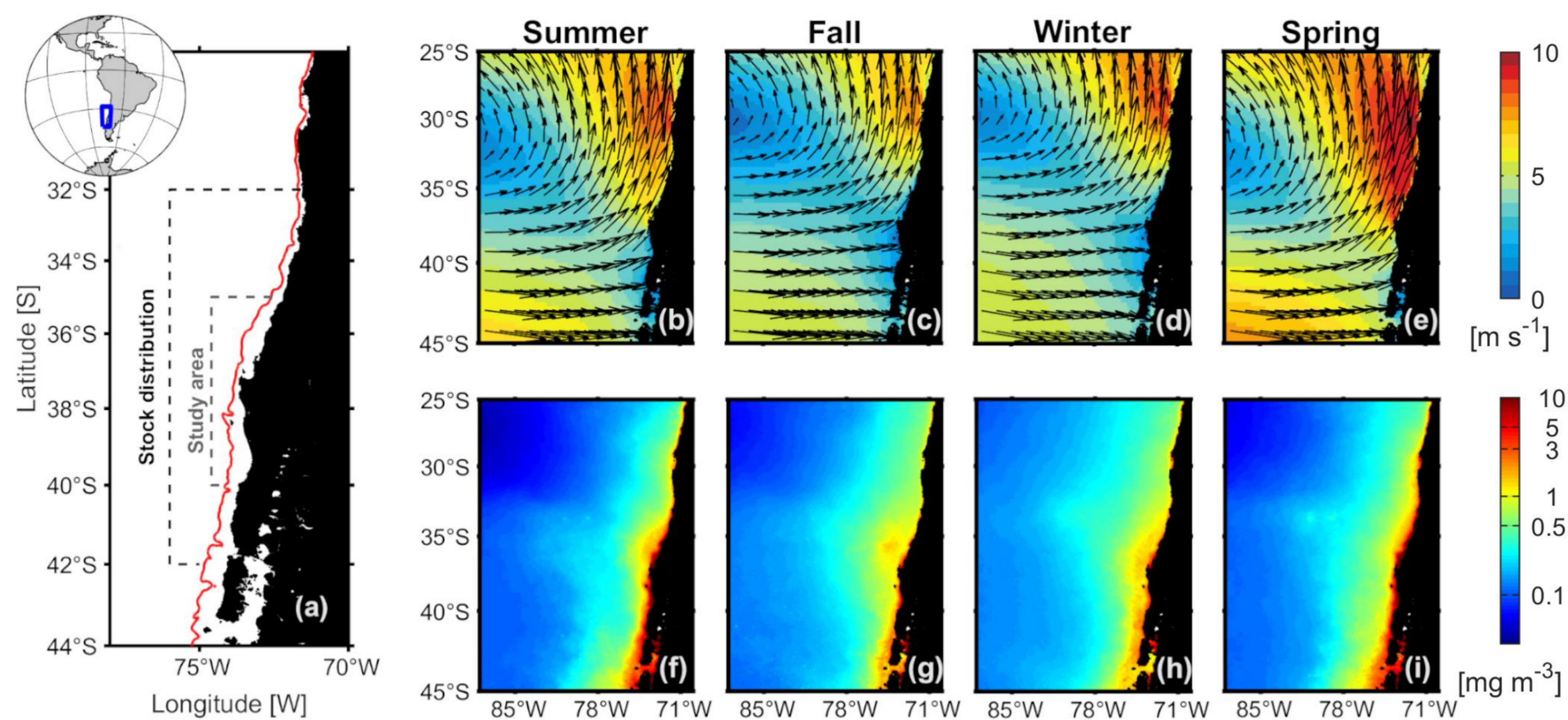
EFFECT OF WIND VARIABILITY ON THE RECRUITMENT OF ANCHOVY *ENGRAULIS RINGENS* IN THE SOUTHERN HUMBOLDT UPWELLING ECOSYSTEM



Marcos Arteaga¹, Sebastián, I. Vásquez^{1,3}, Sergio Neira² and Luis Cubillos²

¹Instituto de Investigación Pesquera (INPESCA) Talcahuano, Chile (marteaga@inpesca.cl) ²Programa de Doctorado en Ciencias con mención en Manejo de Recursos Acuáticos Renovables, Universidad de Concepción, Concepción, Chile. ³Programa de Doctorado en Oceanografía, Universidad de Concepción, Concepción, Chile.

INTRODUCTION



Anchoveta distribution (left) and seasonal climatology of wind (up) and chlorophyll-a (down) between 1990 and 2020.

- **Recruitment and environment:** Fish recruitment is a key driver of population dynamics particularly in small pelagic species.
- **Wind and upwelling dynamics:** In eastern boundary upwelling systems, wind controls productivity and transport, with extreme intensities increasing offshore advection that can reduce recruitment.
- **Anchovy in south-central Chile:** Anchovy (*Engraulis ringens*) is an ecologically and economically important species
- **Study objective:** This study uses generalized additive models to evaluate the non-linear effects of wind, chlorophyll-a, and spawning biomass on anchovy recruitment, including the role of extended windy events and recruitment regimes.

METHODOLOGY

- **Study area:** South-central Chile (35–40°S), main spawning and recruitment zone of *Engraulis ringens*.
- **Data:** Coastal winds, satellite chlorophyll-a and spawning biomass from stock assessment.
- **Predictors:** Spring wind intensity, windy days, extended windy events, chlorophyll-a, and spawning biomass (1-yr lag).
- **Analysis:** Anchovy recruitment modeled with Generalized Additive Models (GAMs) to assess non-linear effects and regime shifts.



Volume (33); Issue5; Sept (2024)
<https://doi.org/10.1111/fog.12677>



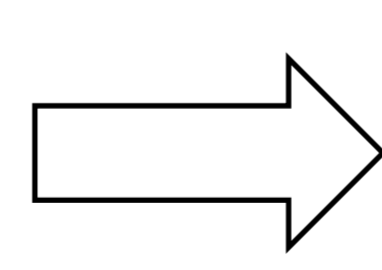
RESULTS

Results of generalized additive models relating anchovy recruitment (dependent variable) to wind, spawning stock biomass, and chlorophyll-a (independent variables) in the central-south zone of Chile

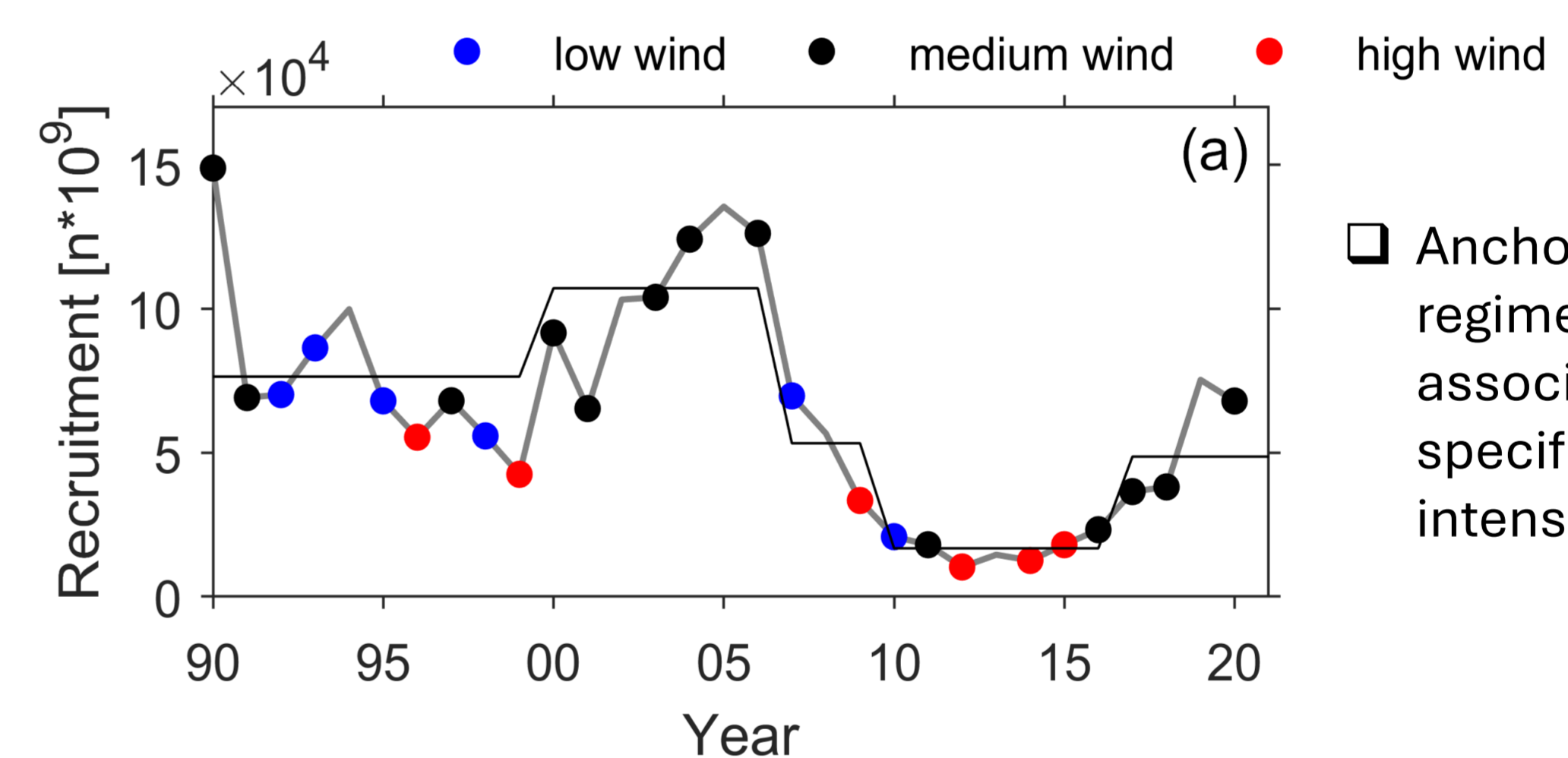
No.	Models	p value of the parameters: values < .05 are show in bold type							GCV	DEV	AIC
		p (1)	p (2)	p (3)	p (4)	p (5)	p (6)	p (7)			
Wind and spawning biomass											
M 1	Rec: $ssb_1 + wind_v_2$	2.3E-05	.0156	-	-	-	-	-	.41222	77.7	59.2
M 2	Rec: $ssb_1 + wind_w_3$	2.7E-06	-	.0729	-	-	-	-	.46869	72.3	63.9
M 3	Rec: $ssb_1 + wind_u_4$	4.5E-05	-	-	.0815	-	-	-	.48077	80.0	61.2
M 4	Rec: $ssb_1 + wind_threshold_5$	1.7E-05	-	-	-	0.0300	-	-	.44204	74.2	62.0
M 5	Rec: $ssb_1 + windy_events_6$	2.2E-05	-	-	-	-	.0956	-	.47773	71.0	64.7
Wind, Chlorophyll-a and spawning biomass											
M 6	Rec: $ssb_1 + Cloa_7$	9.2E-05	-	-	-	-	.9030	.54914	64.2	69.54	
M 7	Rec: $ssb_1 + wind_v_2 + Cloa_7$	3.6E-05	.0164	-	-	-	.5312	0.44478	77.2	60.98	
M 8	Rec: $ssb_1 + wind_threshold_5 + Cloa_7$	3.0E-05	-	-	-	.0324	.6836	.48117	73.7	64.05	
M 9	Rec: $ssb_1 + wind_w_3 + Cloa_7$	4.0E-05	-	.0582	-	-	.4761	.50336	71.6	65.72	
M 10	Rec: $ssb_1 + wind_u_4 + Cloa_7$	8.4E-05	-	-	.0975	-	.7896	.53025	79.7	63.19	
M 11	Rec: $ssb_1 + windy_events_6 + Cloa_7$	3.4E-06	-	-	-	-	.0889	.6051	.51592	70.9	66.49
Individual relationships											
M 12	Rec: $Cloa_7$	-	-	-	-	-	.6180	1.0444	.9	91.19	
M 13	Rec: ssb_1	5.6E-06	-	-	-	-	-	.50764	64.3	67.6	
M 14	Rec: $wind_v_2$	-	.0811	-	-	-	-	.93227	16.3	87.53	
M 15	Rec: $wind_w_3$	-	-	.1510	-	-	-	.9647	5.7	88.78	
M 16	Rec: $wind_u_4$	-	-	-	.2770	-	-	.99756	10	89.64	
M 17	Rec: $wind_threshold_5$	-	-	-	-	.1390	-	.96067	6.8	88.64	
M 18	Rec: $windy_events_6$	-	-	-	-	-	.3530	1.0222	3	90.52	

Note: The significance value of the predictors from p1 to p7, the cross-validated GCV value, explained deviance DEV, and the Akaike information criterion (AIC) are presented. Spawning stock biomass (ssb1), wind_v2 (alongshore wind), wind_w3 (total wind), wind_u4 (cross-shore wind), wind_threshold5 (number of days above the threshold of ~15.2 m/s), windy_events6 (number of events with three or more days above the threshold of ~15.2 m/s), and Cloa7 correspond to chlorophyll-a.

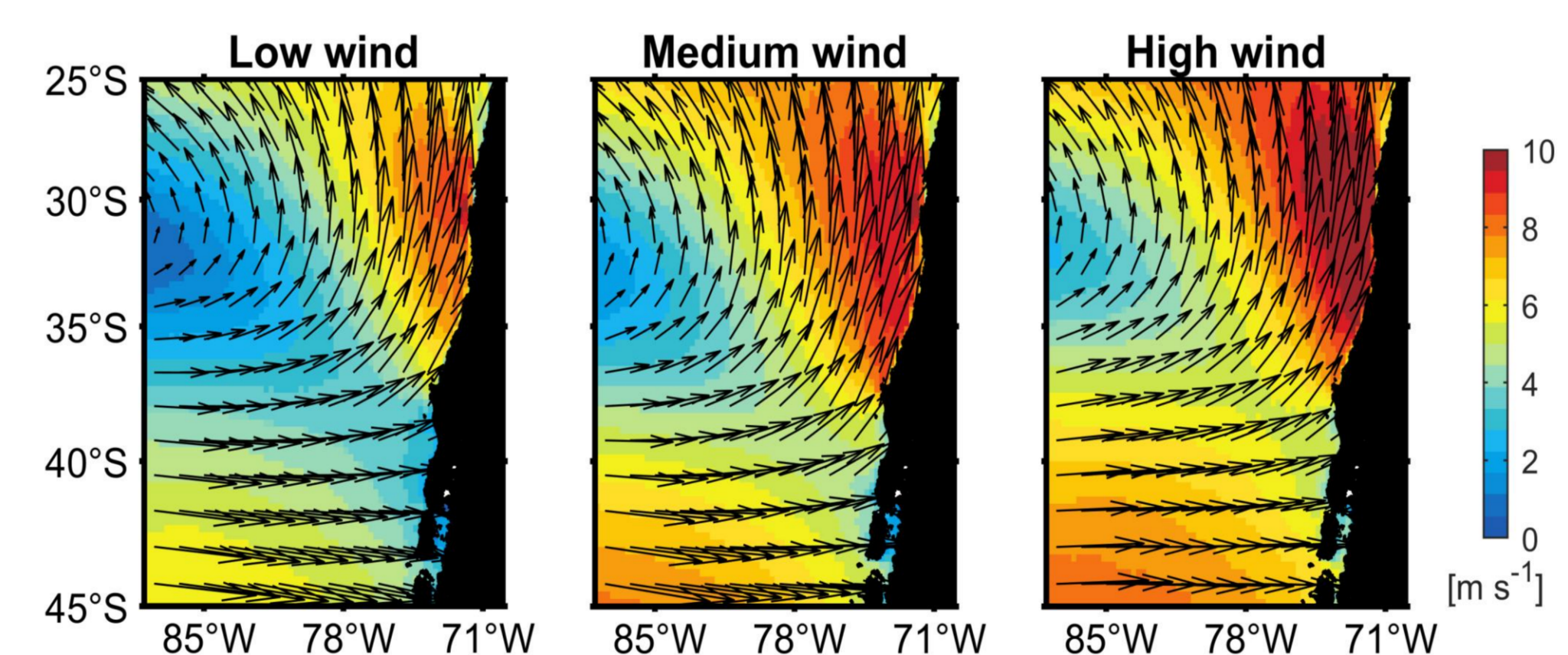
GAMs revealed a parabolic relationship between the velocity of upwelling-favorable winds and anchovy recruitment. Maximized recruitment occurred at wind speeds around 6 ms⁻¹ but decreased with winds above 7 ms⁻¹ and below 5 ms⁻¹



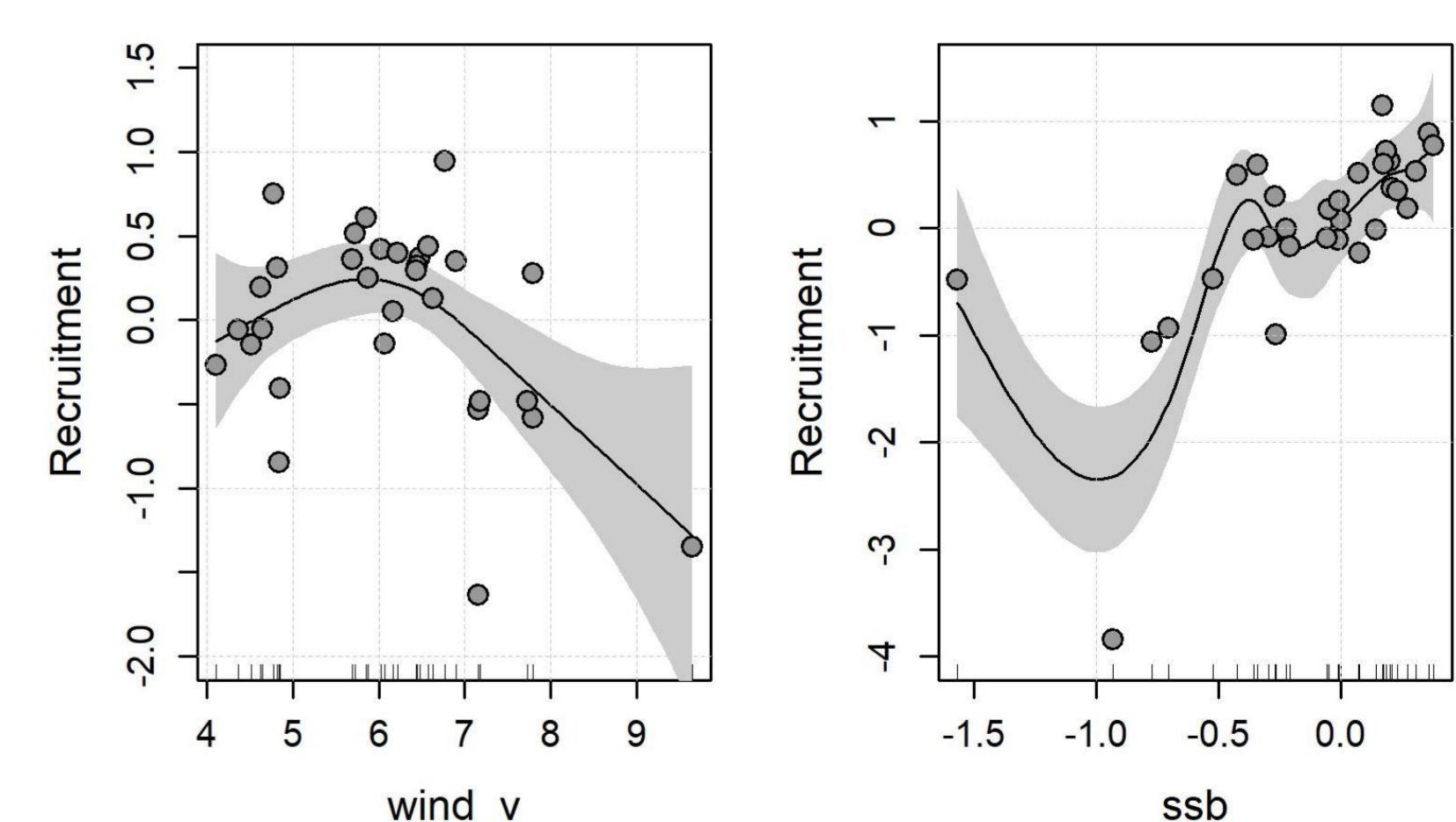
BEST MODEL (M 1)



Anchovy recruitment regimes were associated with specific wind intensities.

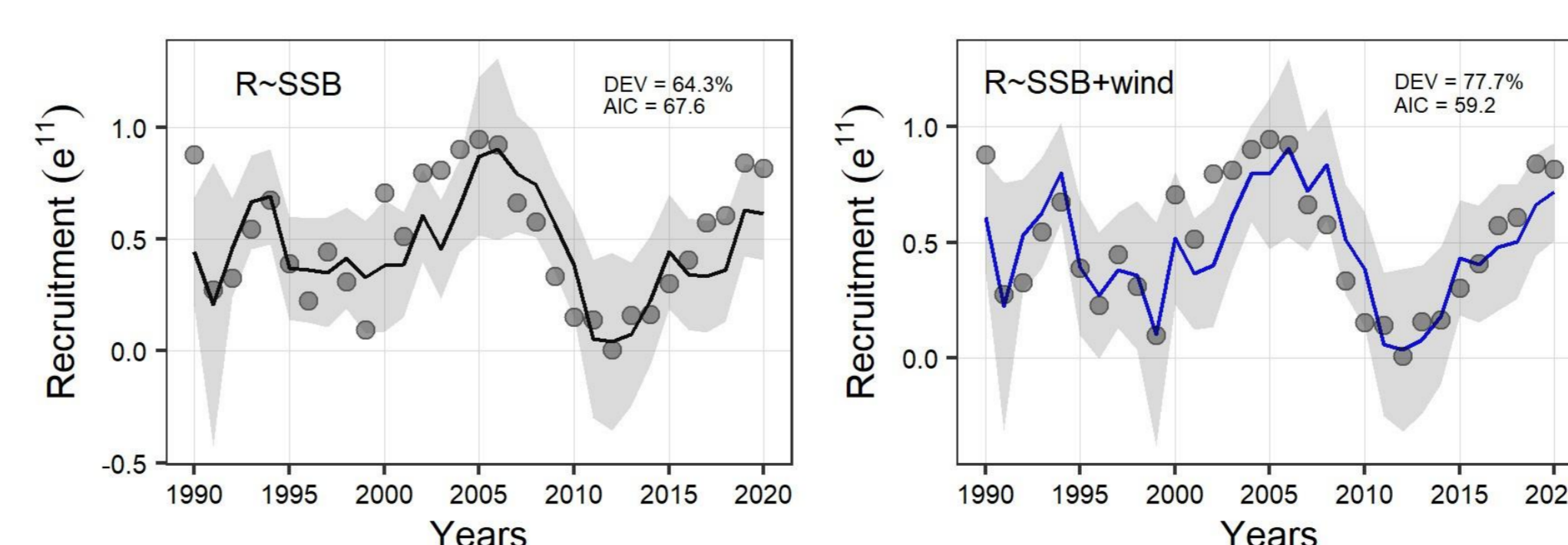


Wind speed (color in m · s⁻¹) and direction (vectors) in south-central Chile during periods of low, medium, and high wind conditions identified in the GAM



CONCLUSION

- This study concludes that alongshore winds act synergistically with spawning biomass to explain anchovy recruitment and that extended windy conditions were related to periods of low abundance
- In anchoveta from central-southern Chile, the coastal retention process seems to be critical for the success of annual cohorts.



- This environmentally-based indicator could be used as an early signal of recruitment strength for stock assessment and fisheries management.

ACKNOWLEDGMENT

M.A. and S.I.V. were partially supported by the Chilean National Research and Development Agency (ANID) with the doctoral grant 21190500 and 21221020 respectively.