Growth rate extremes of a Sciaenid in an ocean-warming hotspot

SUPPLEMENTARY INFORMATION

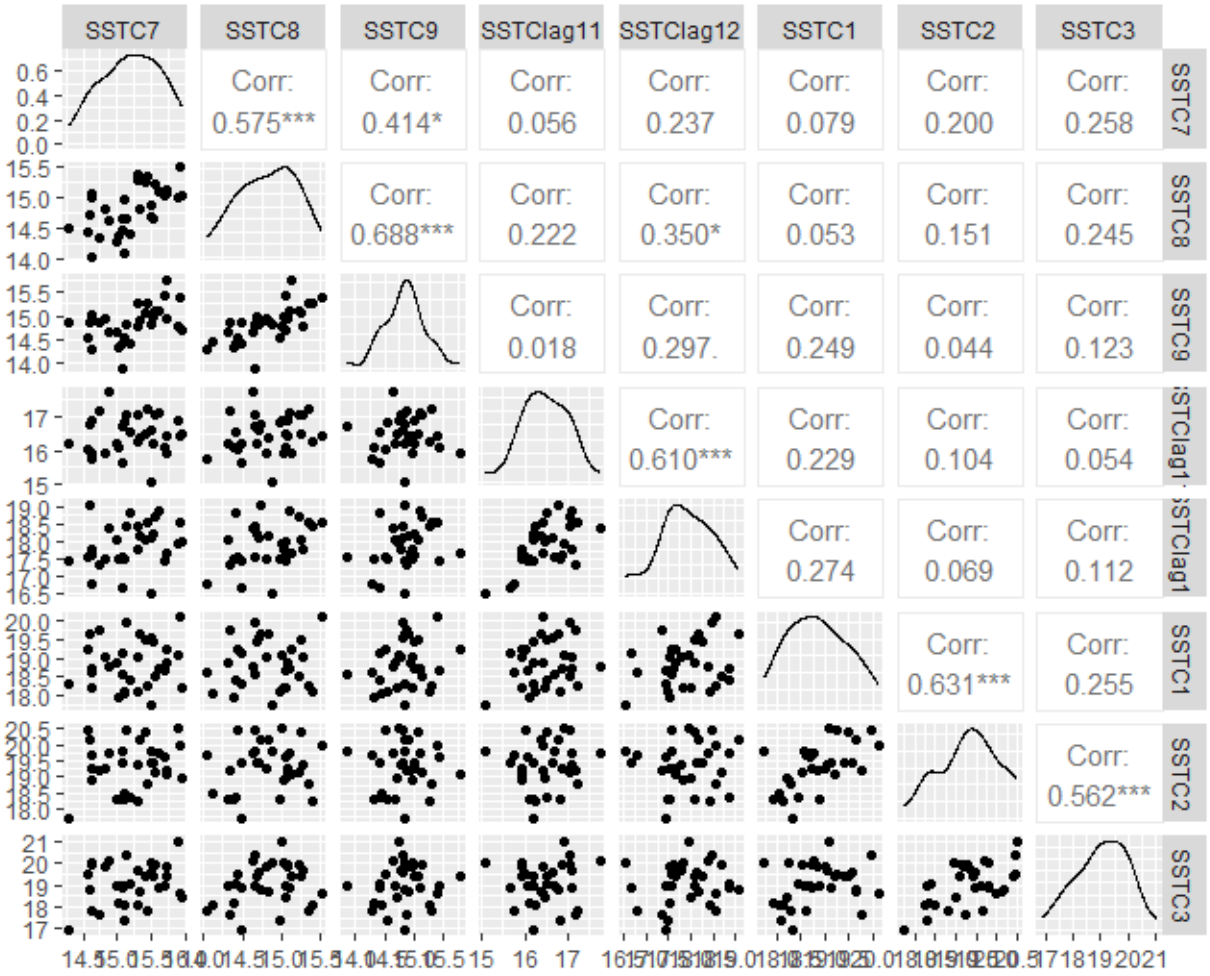

Figure S1. Correlation plots of environmental variables used to test potential extrinsic effects on *Argyrosomus inodorus* growth. The bottom left half shows scatter plots of one variable against the other. The top right shows the correlation coefficient between two variables; and * indicates significant correlation, *** indicates very highly significant correlation. Variables: AAO = Antarctic Oscillation Index, MEI = SSTC = SST averaged for central Namibia (20-24°S, 12-14°E), UI_K = Kunene upwelling index, UI_CC= Cape Columbine Upwelling index, UI_WB = Walvis Bay Upwelling index. The number denotes the month. (17-20°S, 10-12°E) central Namibia (20-24°S, 12-14°E),

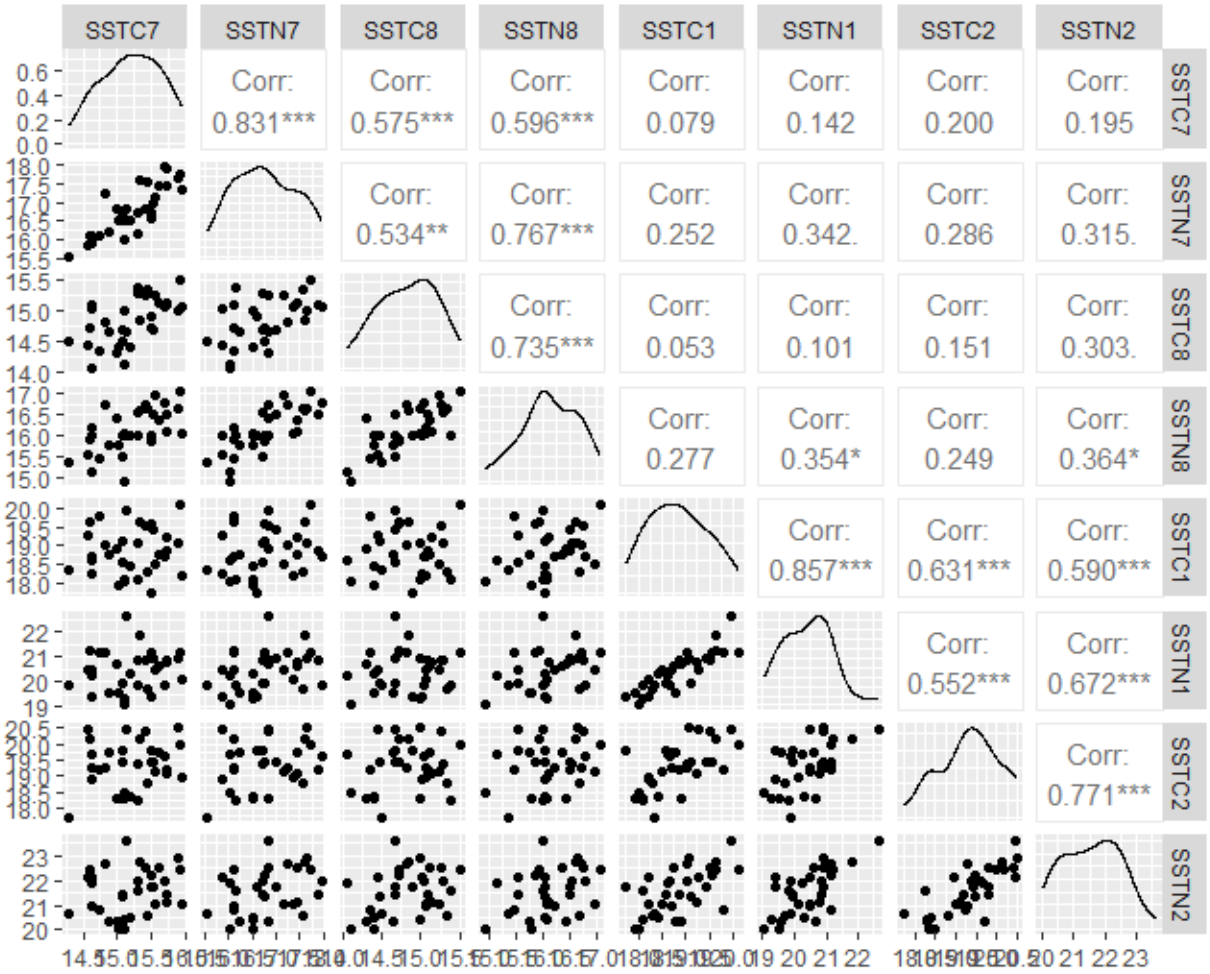

Figure S1. Correlation plots of environmental variables used to test potential extrinsic effects on *Argyrosomus inodorus* growth. The bottom left half shows scatter plots of one variable against the other. The top right shows the correlation coefficient between two variables; and * indicates significant correlation, *** indicates very highly significant correlation. Variables: SSTC = SST averaged for central Namibia (20-24°S, 12-14°E) and the number denotes the month.

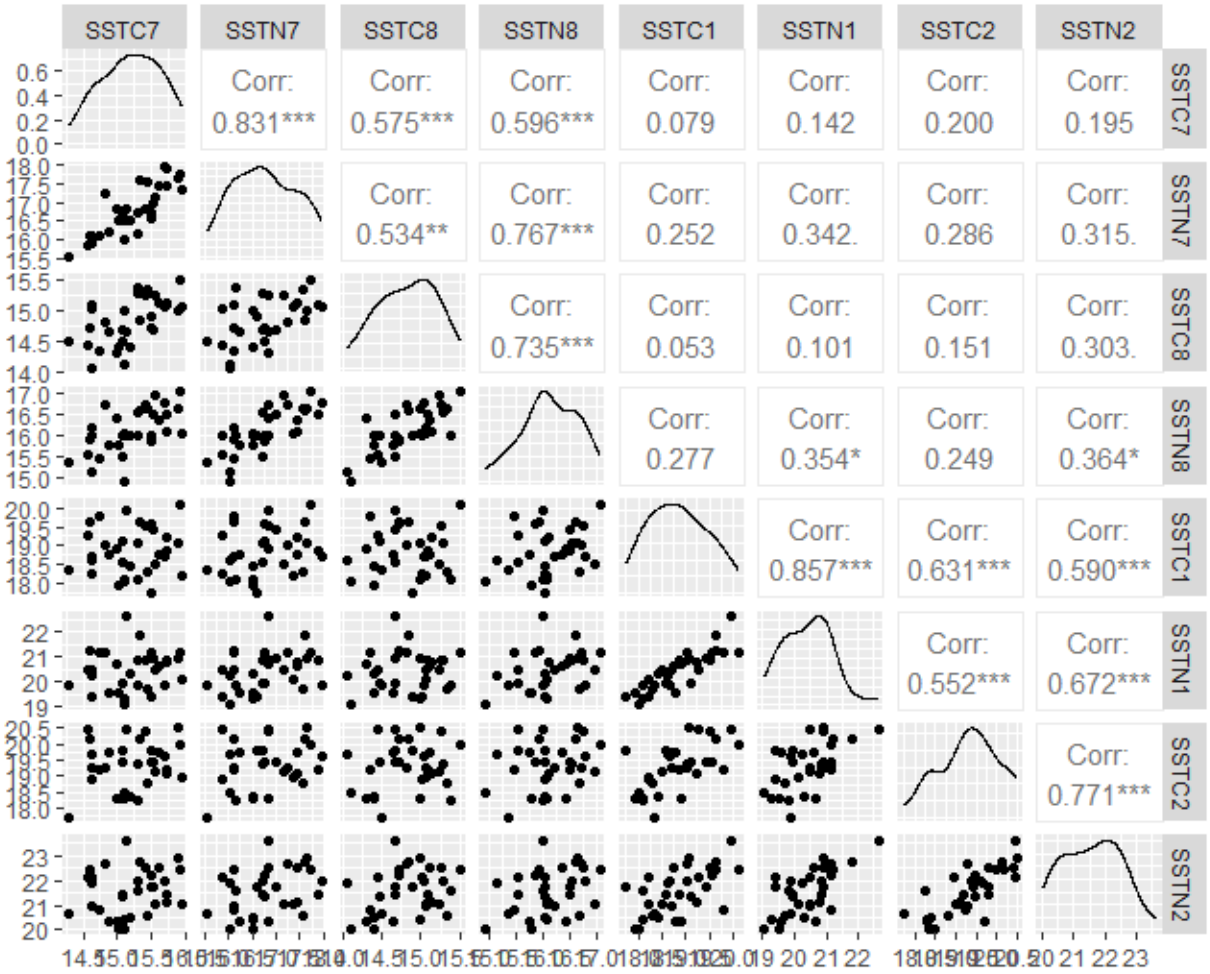

Figure S2. Correlation plots of environmental variables used to test potential extrinsic effects on *Argyrosomus inodorus* growth. The bottom left half shows scatter plots of one variable against the other. The top right shows the correlation coefficient between two variables; and * indicates significant correlation, ** indicates highly significant correlation, *** indicates very highly significant correlation. Variables: SSTC = SST averaged for central Namibia (20-24°S, 12-14°E), SSTN = SST averaged for northern Namibia (17-20°S, 10-12°E). The number denotes the month.

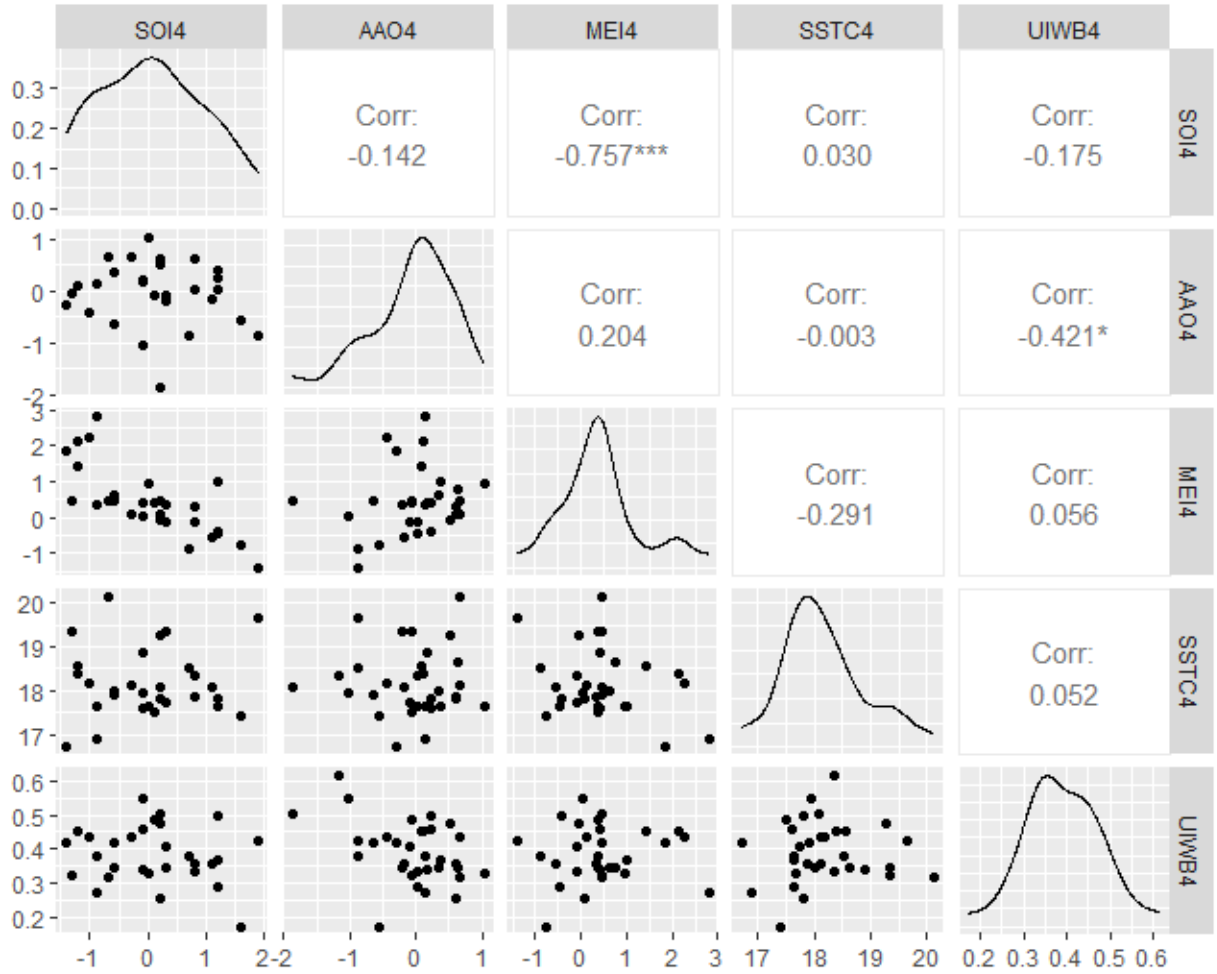

Figure S3. Correlation plots of environmental variables used to test potential extrinsic effects on *Argyrosomus inodorus* growth. The bottom left half shows scatter plots of one variable against the other. The top right shows the correlation coefficient between two variables; and * indicates significant correlations, *** indicates very highly significant correlations. Variables: SOI = Southern Oscillation index, AAO = Antarctic Oscillation Index, MEI = Multivariate El Nino index, SSTC = SST averaged for central Namibia (20-24°S, 12-14°E), UIWB = Walvis Bay Coastal Upwelling index. The number denotes the month, in this case April for all.

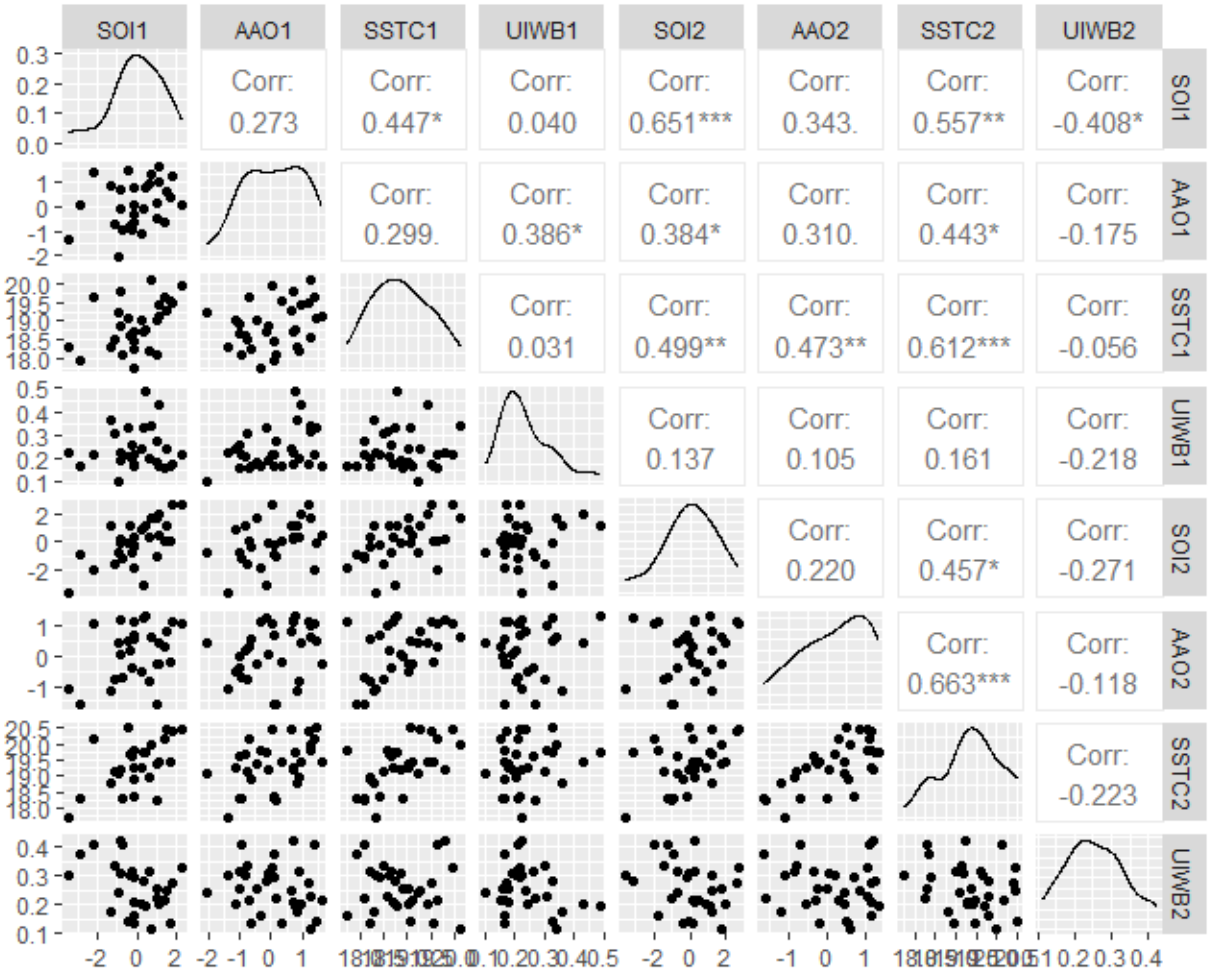

Figure S4. Correlation plots of environmental indices. The bottom right shows scatter plots of one variable against the other. The top right shown the correlation coefficient; and * indicates significant correlations, ** indicates highly significant correlation, *** indicates very highly significant correlation. Variables: SOI = Southern Oscillation index, AAO = Antarctic Oscillation Index, SSTC = SST averaged for central Namibia (20-24°S, 12-14°E), UIWB = Walvis Bay Coastal Upwelling index. The number denotes the month.

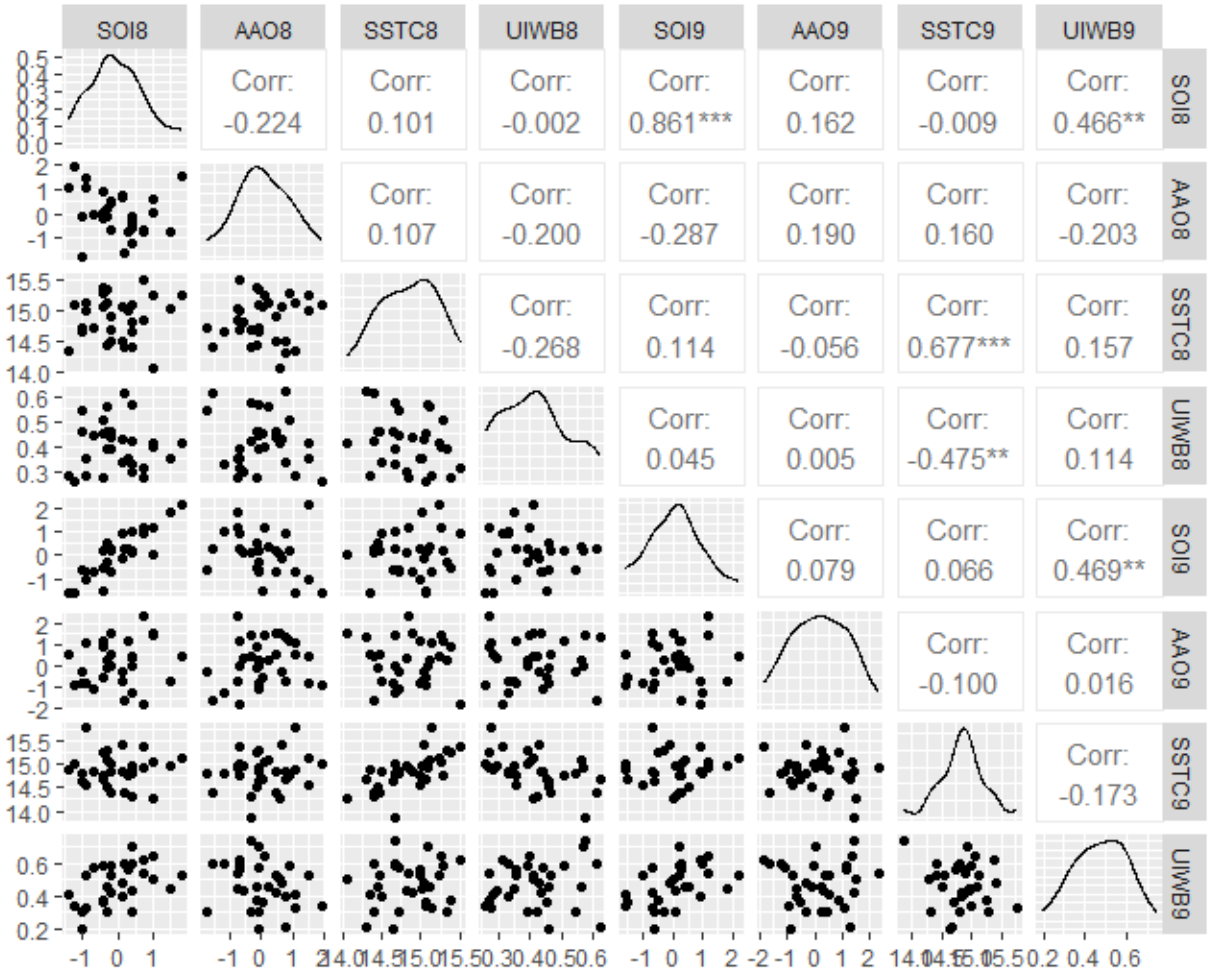

Figure S5. Correlation plots of environmental indices. The bottom right shows scatter plots of one variable against the other. The top right shown the correlation coefficient; and ** indicates highly significant correlation, *** indicates very highly significant correlation. Variables: SOI = Southern Oscillation index, AAO = Antarctic Oscillation Index, SSTC = SST averaged for central Namibia (20-24°S, 12-14°E), UIWB = Walvis Bay Coastal Upwelling index. The number denotes the month.

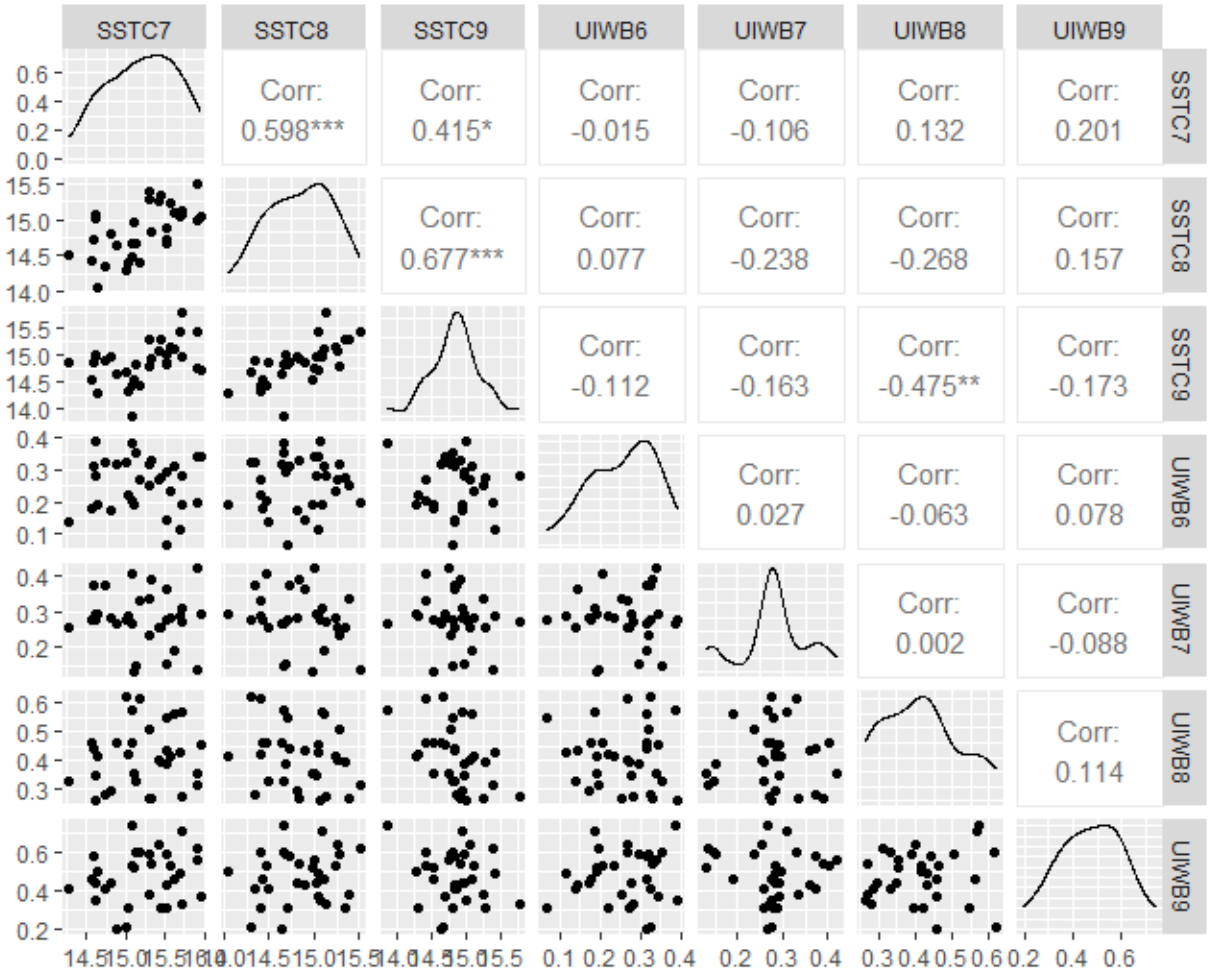

Figure S6. Correlation plots of environmental indices. The bottom right shows scatter plots of one variable against the other. The top right shown the correlation coefficient; and * indicates significant correlation, ** indicates highly significant correlation, *** indicates very highly significant correlation. Variables: SSTC = SST averaged for central Namibia (20-24°S, 12-14°E), UIWB = Walvis Bay Coastal Upwelling index. The number denotes the month.

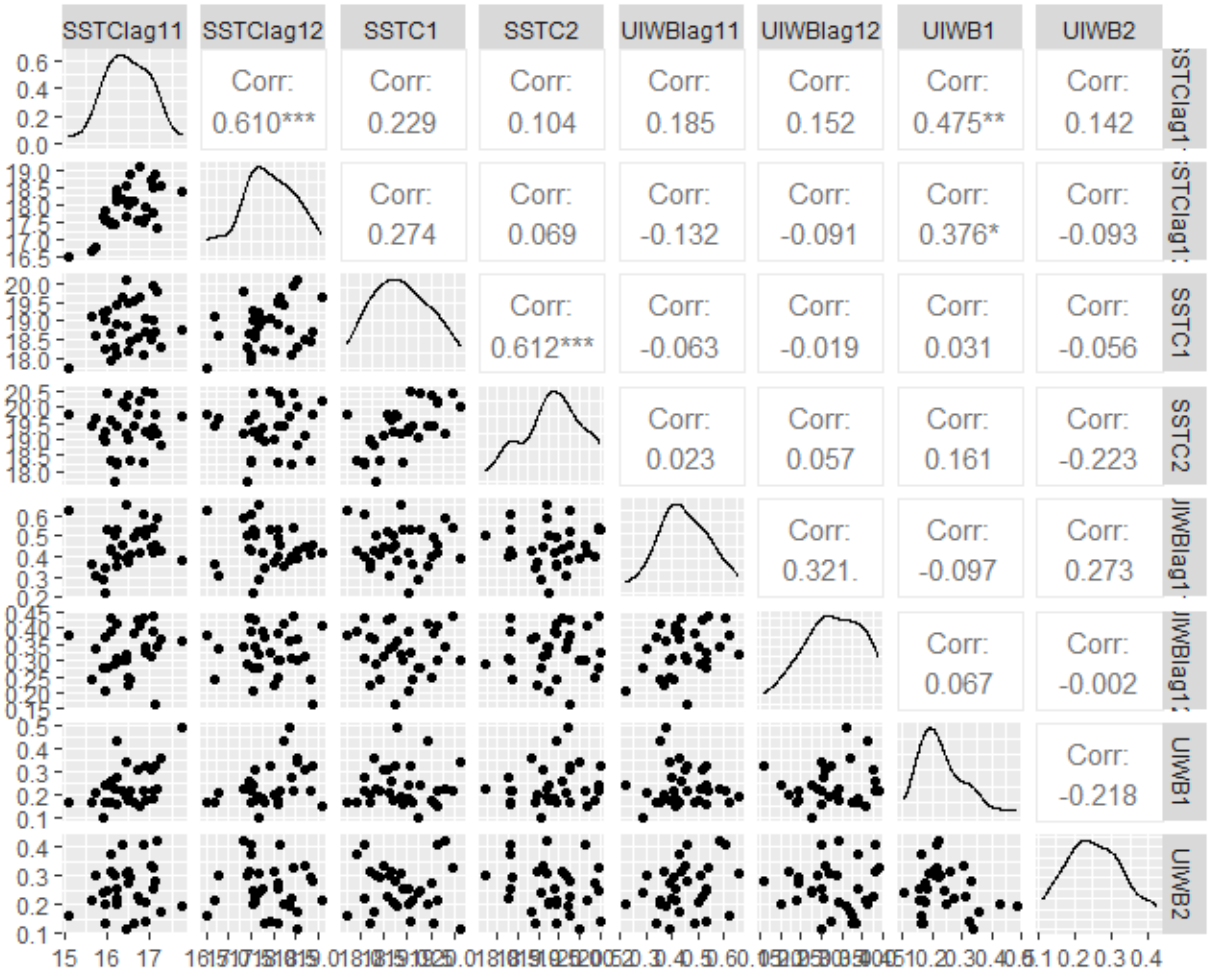

Figure S7. Correlation plots of environmental indices. The bottom right shows scatter plots of one variable against the other. The top right shown the correlation coefficient; and * indicates significant correlation, ** indicates highly significant correlation, *** indicates very highly significant correlation. Variables: SSTC = SST averaged for central Namibia (20-24°S, 12-14°E), UIWB = Walvis Bay Coastal Upwelling index. The number denotes the month.

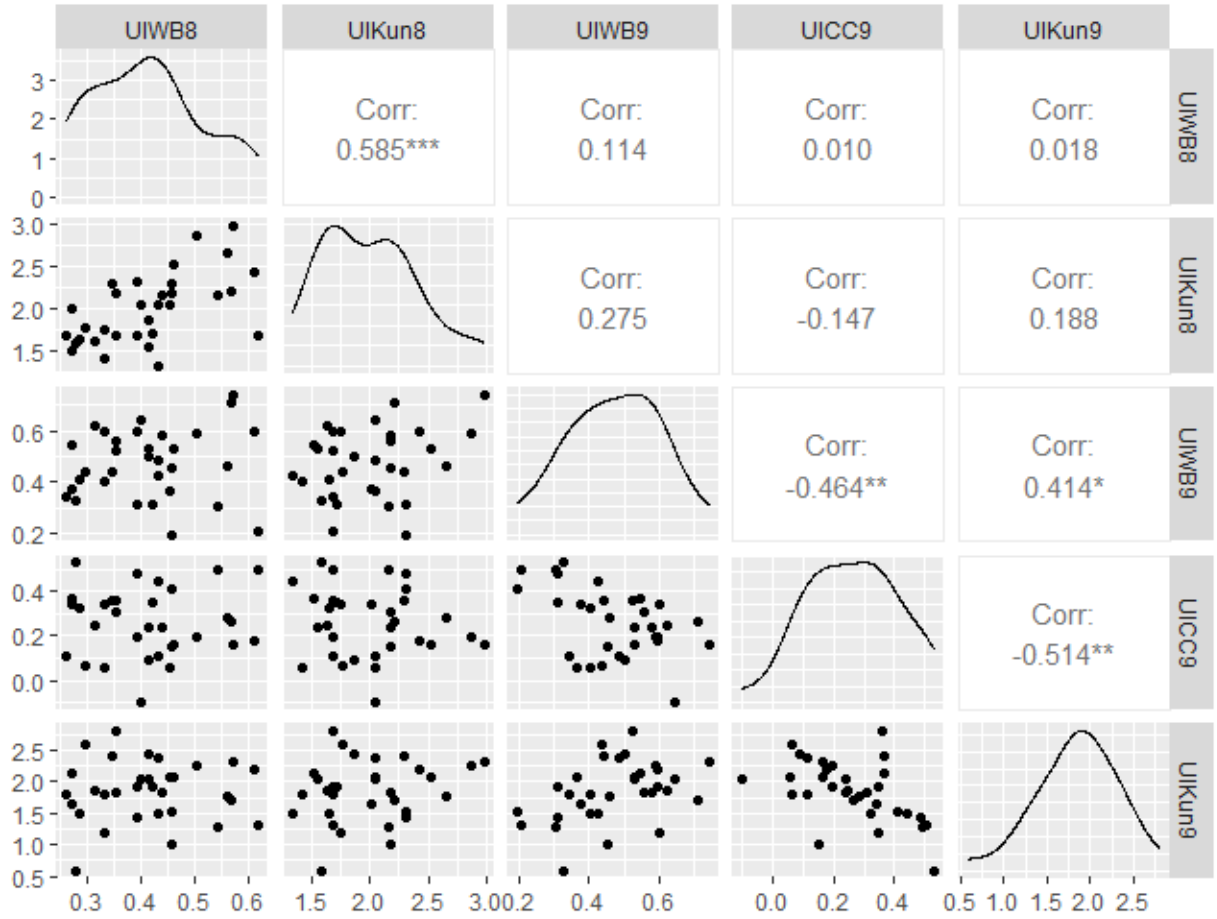

Figure S8. Correlation plots of environmental indices. The bottom right shows scatter plots of one variable against the other. The top right shown the correlation coefficient; and * indicates significant correlation, ** indicates highly significant correlation, *** indicates very highly significant correlation. Variables: UIKun = Kunene coastal upwelling index, UIWB = Walvis Bay coastal upwelling index. The number denotes the month.

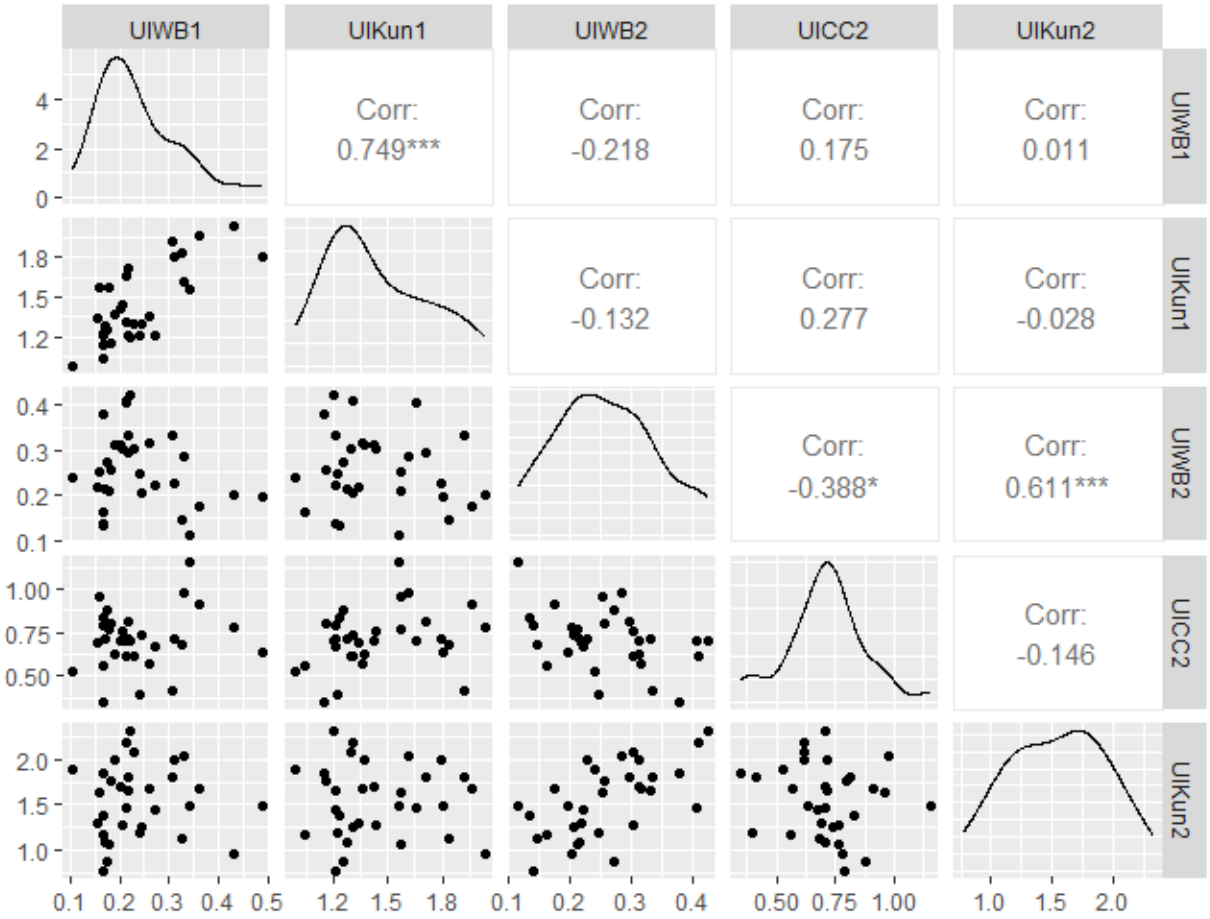

Figure S9. Correlation plots of environmental indices. The bottom right shows scatter plots of one variable against the other. The top right shown the correlation coefficient; and * indicates significant correlation, *** indicates very highly significant correlation. Variables: UIKun = Kunene coastal upwelling index, UIWB = Walvis Bay coastal upwelling index. The number denotes the month.

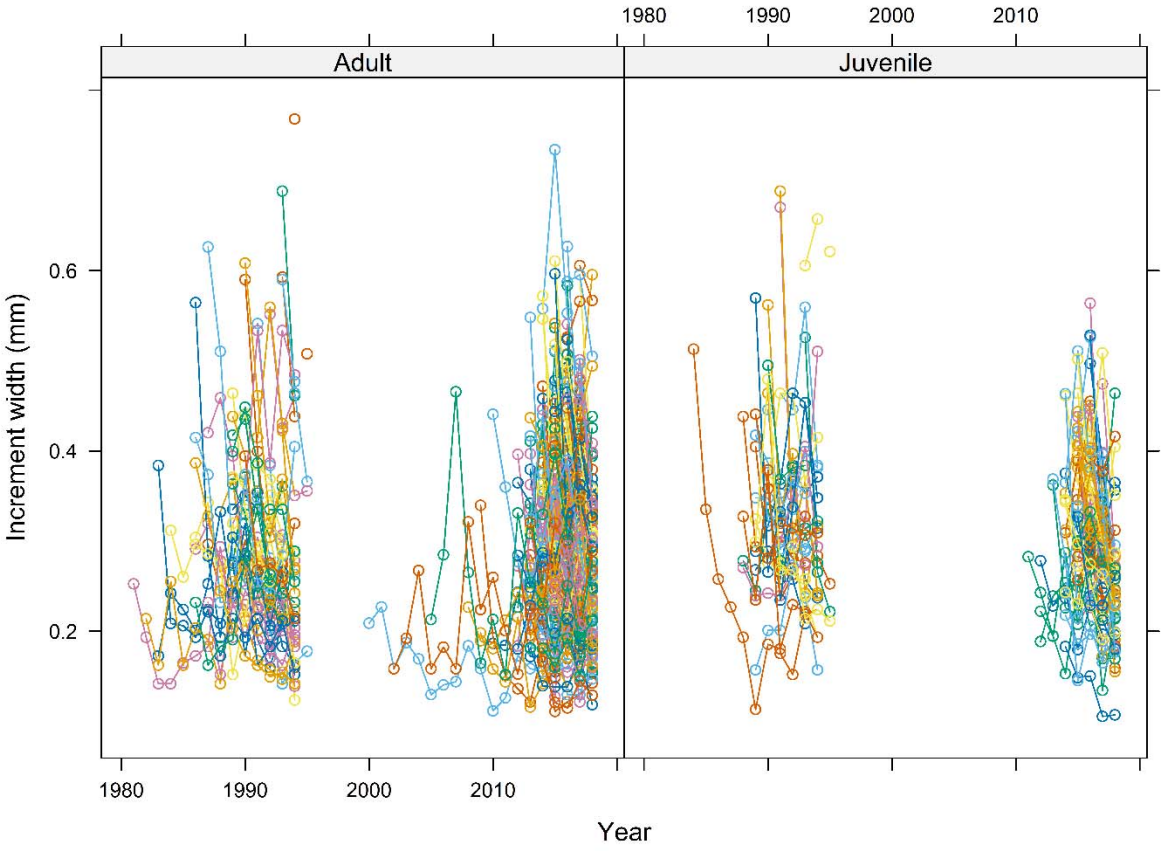

Figure S10. Absolute increment width (mm) against year of formation for all individual otoliths of *Argyrosomus inodorus* caught off Namibia from 1994-1996 and 2018-2019. Left panel: Adult fish; i.e. mature fish: those either classified as gonad stages 2+ or above the length at 50 % maturity of 35 cm total length (Kirchner et al., 2001b). Right panel: Juvenile fish.

Table S1. Results of the intrinsic effects (mixed effects) model optimization based on the full dataset of 1981 to 2018 (1981-1995, 2000-2018) *Argyrosomus inodorus* otolith chronologies (n = 1532, groups FishID = 326, Years = 34). The models were sorted by AICc for the fixed effects selection (using maximum likelihood) and the final selected model is highlighted in bold. AAC = Age-at-capture; Random age slopes for FishID, Year and Cohort are denoted by "log(age)|" and "1|" denotes only a random intercept was calculated*; K = degrees of freedom; AICc = Akaike's information criterion, adjusted for small sample sizes**;** LL: Log-likelihood.

Fixed effects	**Random effects**	**K**	**AICc**	**Delta AICc**	**LL**	**Conditional R^2**
Selection of random effects using restricted maximum likelihood (REML)						
log(age)*Sex + log(AAC) + Area		12	228.58			
log(age)*Sex + log(AAC) + Area	**log(age)|FishID**	**15**	**-45.27**		**37.79**	**0.679**
log(age)*Sex + log(AAC) + Area	1|FishID	13	22.36		1.94	0.622
log(age)*Sex + log(AAC) + Area	log(age)|FishID + 1|Year	16	**-67.96**	0	50.16	**0.688**
log(age)*Sex + log(AAC) + Area	log(age)|FishID + log(age)|Year	18	-63.87	4.09	50.16	0.687
log(age)*Sex + log(AAC) + Area	log(age)|FishID + 1|Cohort	16	-46.89	21.07	39.63	0.686
log(age)*Sex + log(AAC) + Area	log(age)|FishID + log(age)|Cohort	18	-46.22	21.74	41.34	0.681
Selection of fixed effects using maximum likelihood (ML) (n = 1532, groups FishID = 326, Years = 34)						
log(age) + Sex + log(AAC)	**log(age)|FishID + 1|Year**	**11**	**-129.46**	**0**	**75.82**	**0.681**
log(age) + Sex + log(AAC) + Area	log(age)|FishID + 1|Year	13	-127.28	2.18	76.76	0.683
log(age) + log(AAC)	log(age)|FishID + 1|Year	8	-126.94	2.51	71.52	0.682
log(age)*Sex + log(AAC)	log(age)|FishID + 1|Year	14	-124.66	4.79	76.47	0.682
log(age) + log(AAC) + Area	log(age)|FishID + 1|Year	10	-123.75	5.71	71.95	0.682
log(age)*Sex + log(AAC) + Area	log(age)|FishID + 1|Year	16	-122.44	7.02	77.4	0.684
log(age) + Sex + Area	log(age)|FishID + 1|Year	12	-62.76	66.7	43.48	0.680
log(age) + Area	log(age)|FishID + 1|Year	9	-61.24	68.22	39.68	0.675
log(age)*Sex + Area	log(age)|FishID + 1|Year	15	-58.85	70.61	44.58	0.681
log(age)	log(age)|FishID + 1|Year	7	-56.85	72.61	35.46	0.659
log(age) + Sex	log(age)|FishID + 1|Year	10	-56.17	73.29	38.16	0.663
log(age)*Sex	log(age)|FishID + 1|Year	13	-52.32	77.14	39.28	0.665

*Year and Cohort random effects could not be added together because of the overall sample size restriction.

Table S2. Optimal model parameter estimates and test statistics describing fixed and random sources of growth variation in Argyrosomus inodorus using restricted maximum likelihood (REML) caught along the Namibian coast during the historical (1994-1996) and contemporary (2018-2019) period without environmental parameters. In terms of Sex, female was the base, J = juvenile, M = male, U = unsexed (1981-1995, 2000-2018), n = 1532 growth increments, groups FishID = 326, Years = 34. The non-significant variable (Sex) were subsequently removed and further analysis were

Fixed effects

Covariate	Estimate	SE	t-value	p-value
Intercept	-1.270	0.01902	-66.802	<0.0001
Log(Age)	-0.187	0.01608	-11.633	<0.0001
Log(AAC)	-0.347	0.03791	-9.159	<0.0001
SexJ	-0.0721	0.07413	-0.973	0.3314
SexM	-0.0367	0.02220	-1.652	0.0995
SexU	0.0686	0.03830	1.790	0.0745

Random effects

Covariate	Variance component	SD	Correlation
1|FishID (intercept)	0.0253	0.1592	
Log(Age)|FishID (slope)	0.0174	0.1318	-0.13
1|Year	0.0018	0.0423	
Residual	0.0344	0.1854	

Table S3. Results of the mixed effects model optimization based on the reduced dataset of 1983 to 2018 (1983-1995, 2000-2018) *Argyrosomus inodorus* otolith chronologies (n = 1529, groups: FishID = 326) including environmental data for 32 years to model the potential extrinsic effects on growth of the particular growth year. The models were sorted by AICc, and the final selected model is highlighted in bold. AAC = Age-at-capture; Random age slopes for FishID denoted by "log(age)|"; K = degrees of freedom; AICc = Akaike's information criterion, adjusted for small sample sizes**;** LL: Log-likelihood. Extrinsic effects: AAO = Antarctic Oscillation Index, SSTC = SST averaged for central Namibia (20-24°S, 12-14°E), UI_K = Kunene upwelling index, UI_WB = Walvis Bay Upwelling index. The number denotes the month. *Denotes the model fit was singular.

Fixed effects Extrinsic	**Fixed effects Intrinsic**	**Random effects**	**K**	**AICc**	**Delta AICc**	**LL**	**Conditional R^2**
AAO4 + SSTC9 + SSTClag11	log(age) + log(AAC)	log(age)|FishID	10	-145.26	0	82.70	0.683
SSTC9 + SSTClag11	**log(age) + log(AAC)**	**log(age)|FishID**	**9**	**-144.40**	**0.86**	**81.26**	**0.683**
AAO4 + UI_K8 + SSTClag11	log(age) + log(AAC)	log(age)|FishID	10	-142.46	1.94	81.30	0.683
AAO4 + SSTC9 + SSTClag11	log(age) + log(AAC)	log(age)|FishID + 1|Year	11	-143.23	2.03	82.70	*
AAO4 + UI_K8 + UI_K1	log(age) + log(AAC)	log(age)|FishID	10	-142.18	2.22	81.16	0.681
UI_K8 + SSTClag11	log(age) + log(AAC)	log(age)|FishID	9	-142.04	2.36	80.08	0.684
AAO4 + SSTC9 + UI_K1	log(age) + log(AAC)	log(age)|FishID	10	-140.74	3.66	80.44	0.679
UI_K8 + UI_K1	log(age) + log(AAC)	log(age)|FishID	9	-137.15	7.25	77.63	0.680
SST9 + UI_K1	log(age) + log(AAC)	log(age)|FishID	9	-135.58	8.82	76.85	0.679
UI_K8	log(age) + log(AAC)	log(age)|FishID	8	-132.90	12.36	74.50	0.681
SSTC9	log(age) + log(AAC)	log(age)|FishID	8	-131.43	13.82	73.76	0.679
UI_K1	log(age) + log(AAC)	log(age)|FishID	8	-130.94	14.32	73.52	0.678
UI_WB1	log(age) + log(AAC)	log(age)|FishID	8	-129.37	15.89	72.73	0.679
SSTClag11	log(age) + log(AAC)	log(age)|FishID	8	-126.37	18.88	71.23	0.683
None	log(age) + log(AAC)	log(age)|FishID + 1|Year	8	-125.42	18.98	70.76	0.684
UI_WB8	log(age) + log(AAC)	log(age)|FishID	8	-112.71	32.55	64.40	0.675
UI_CC7	log(age) + log(AAC)	log(age)|FishID	8	-112.05	33.21	64.07	0.676
UI_WB3	log(age) + log(AAC)	log(age)|FishID	8	-107.59	37.67	61.84	0.678

Table S4. Results of the mixed effects model optimization based on the reduced dataset of 2000 to 2017 *Argyrosomus inodorus* otolith chronologies (n = 1529, groups: FishID = 326) including environmental data for 17 years to model the potential extrinsic effects on growth of the particular growth year. The models were sorted by AICc, and the final selected model is highlighted in bold. AAC = Age-at-capture; Random age slopes for FishID denoted by "log(age)|"; K = degrees of freedom; AICc = Akaike's information criterion, adjusted for small sample sizes**;** LL: Log-likelihood. Extrinsic effects: AAO = Antarctic Oscillation Index, SSTC = SST averaged for central Namibia (20-24°S, 12-14°E), UI_K = Kunene upwelling index, UI_WB = Walvis Bay Upwelling index. The number denotes the month. *Denotes the model fit was singular.

Extrinsic Fixed effects	Intrinsic Fixed effects	Random effects	K	AICc	Delta AICc	LL	Conditional R^2
SSTC9 + SSTClag11	**log(age) + log(AAC)**	**log(age)|FishID**	**9**	**-26.91**	**0**	**22.56**	**0.679**
AAO4	log(age) + log(AAC)	log(age)|FishID	8	-26.55	0.36	21.36	0.677
log(CPUE) + SSTC9 + SSTClag11	log(age) + log(AAC)	log(age)|FishID	10	-25.66	1.25	22.96	0.680
AAO4 + SSTC9 + SSTClag11	log(age) + log(AAC)	log(age)|FishID	10	-25.32	1.59	22.79	0.679
UI_CC7	log(age) + log(AAC)	log(age)|FishID	8	-24.03	2.88	20.1	0.678
AAO4 + SSTC9 + UI_K1	log(age) + log(AAC)	log(age)|FishID	10	-23.95	2.96	22.11	0.677
SSTC9	log(age) + log(AAC)	log(age)|FishID	8	-23.87	3.04	20.02	0.676
UI_WB8	log(age) + log(AAC)	log(age)|FishID	8	-23.75	3.16	19.96	0.677
AAO4 + UI_K8 + UI_K1	log(age) + log(AAC)	log(age)|FishID	10	-23.44	3.47	21.85	0.678
AAO4 + SSTC9 + SSTClag11	log(age) + log(AAC)	log(age)|FishID + 1|Year	11	-23.26	3.65	22.79	*
log(CPUE) + SSTC9	log(age) + log(AAC)	log(age)|FishID	9	-23.19	3.72	20.7	0.676
AAO4 + UI_K8 + SSTClag11	log(age) + log(AAC)	log(age)|FishID	10	-22.81	4.10	21.54	0.677
log(CPUE)	log(age) + log(AAC)	log(age)|FishID	8	-22.68	4.23	19.43	0.675
UI_K8 + SSTClag11	log(age) + log(AAC)	log(age)|FishID	9	-22.45	4.46	20.33	0.677
SSTClag11	log(age) + log(AAC)	log(age)|FishID	8	-22.32	4.59	19.25	0.677
SST9 + UI_K1	log(age) + log(AAC)	log(age)|FishID	9	-21.84	5.07	20.03	0.676
UI_K1	log(age) + log(AAC)	log(age)|FishID	8	-21.78	5.13	18.97	0.676
None	log(age) + log(AAC)	log(age)|FishID + 1|Year	8	-21.73	5.18	18.95	0.677