Impact of climate change on long-term zooplankton biomass in the Gulf of Guinea upwelling region

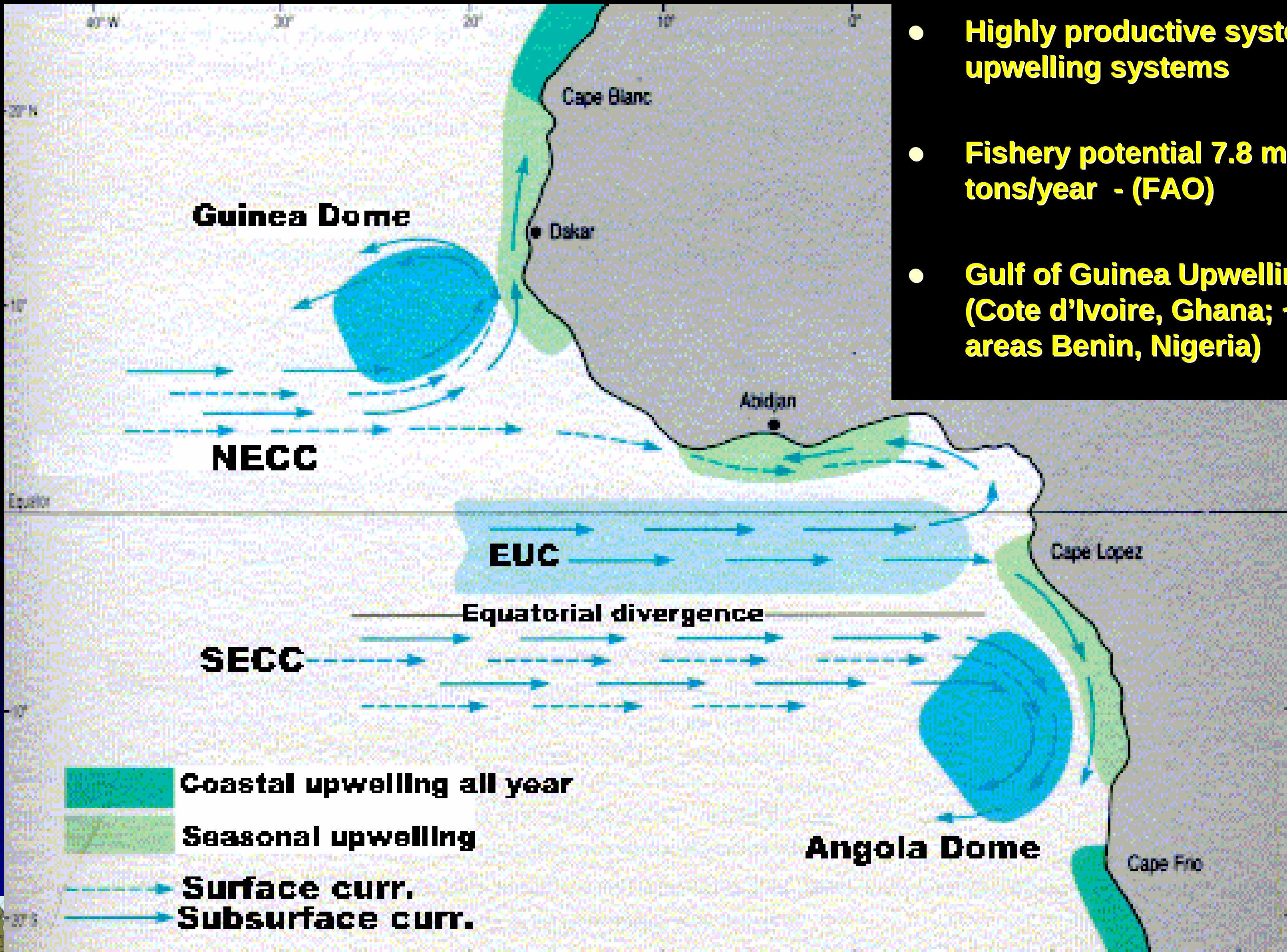
Format

- Background
- Methodology and Results
- Discussion
- Conclusion & speculation(s)

GCLME Productivity Centre

University of Ghana

Central Eastern Atlantic

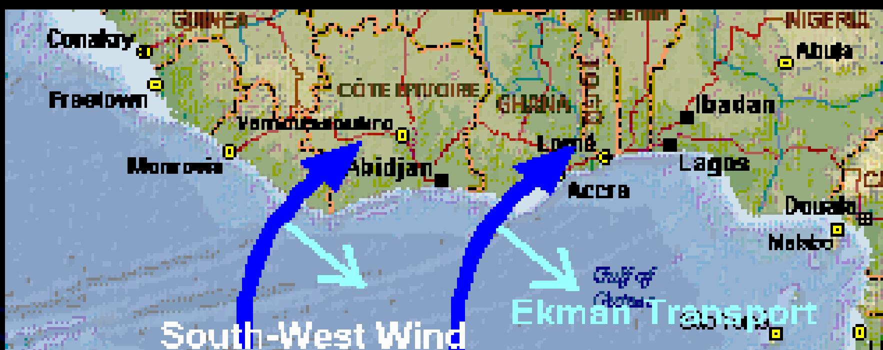


- Highly productive system due to upwelling systems
- Fishery potential 7.8 million tons/year - (FAO)
- Gulf of Guinea Upwelling system (Cote d'Ivoire, Ghana; ~ new areas Benin, Nigeria)

Gulf of Guinea Upwelling

- **Upwelling phenomenon differs from typical Ekman driven type of eastern-boundary system**
- **Four hypothesis proposed (Roy, 1995) ; each contributing to overall**

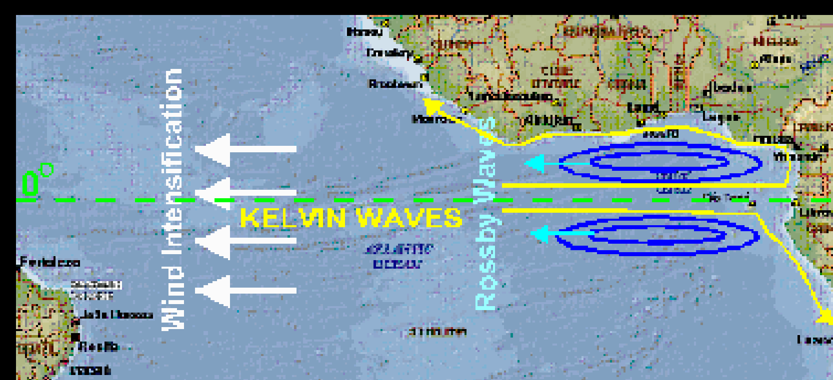
Ekman transport



Cape effect

Induced current

Remote effect



Historical Plankton Surveys

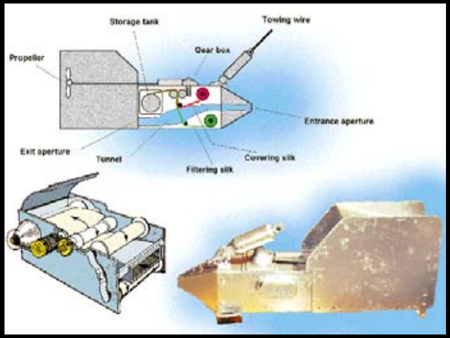
- **European cruises: 19thC – mid 20thC**
  - Mainly on species identification & classification [e.g. Buccaneer (1886), Valvivia (1898), Meteor (1925), Dana (1930), Atlantide (1945-46), Calypso (1956).
- **Regional/National efforts: 1950s – Present**
  - Species dynamics; productivity, biology, etc.
  - Ghana, Cote d'Ivoire, Nigeria
- **The zooplankton of the Gulf of Guinea (Bainbridge, 1972); Zooplankton in the upwelling zones of the African Atlantic littoral (Thiriot, 1977); Neritic zooplankton of the seasonal upwelling areas in the Gulf of Guinea (Binet, 1983); First CPR analysis (Wiafe, 2002)**
- **Long term monitoring**
  - Generally inconsistent
  - Only MFRD, Ghana has 35 years data (1961 – 1995)
  - **BUT information mostly exist in Technical Reports!**

Current Plankton activities – GoG/GCLME Projects

- **Ghana, Nigeria, Cote d'Ivoire, Togo, Benin, Cameroon in collaboration with SAHFOS, U.K.**
  - **1995 – 1998**
- **16 countries (Guinea Bissau to Angola)**
  - **2004 – 2009**
- **Marine Productivity Centre, Ghana**
- **Productivity Module (LME concept)**
  - **Indicators:**
    - **Primary productivity (gc/m^2/y)**
    - **Chlorophyll a**
    - **SST; water column temperature**
    - **Photosynthetically active radiation (PAR)**
    - **Plankton diversity & biomass**

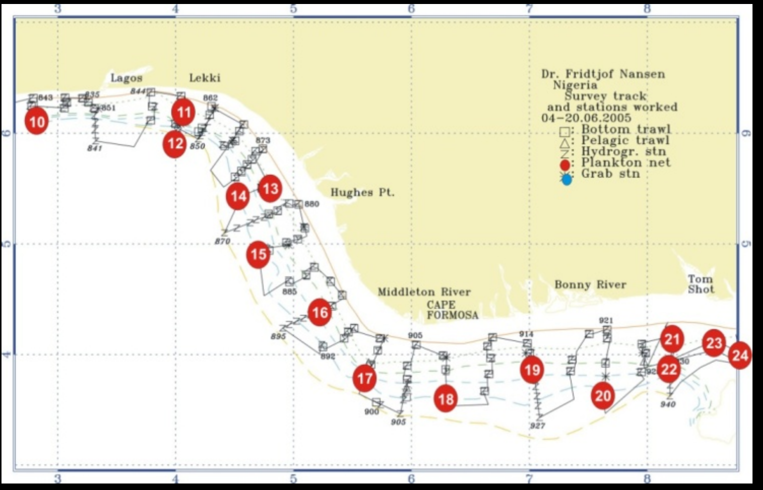

Ro-Ro *M.V. Kumasi*
3 west bound tows: GH, GG and GJ Routes

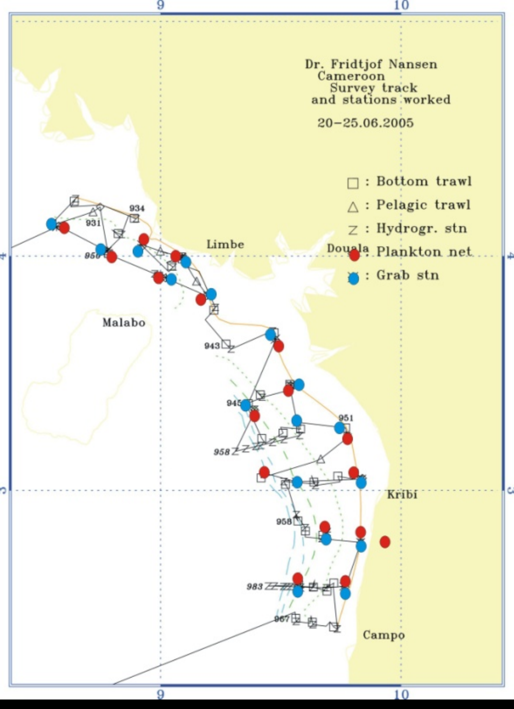

Ro-Ro *M.V. NDS Prominence*
2 west bound tows: GI Route

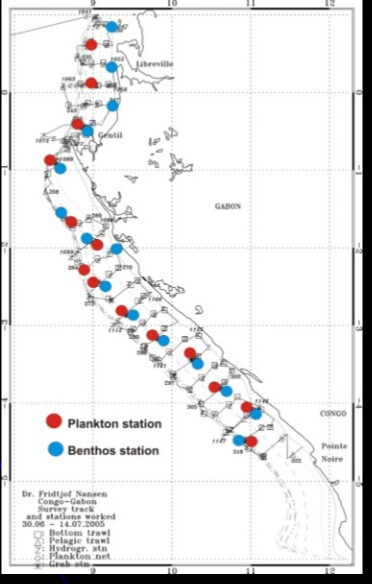


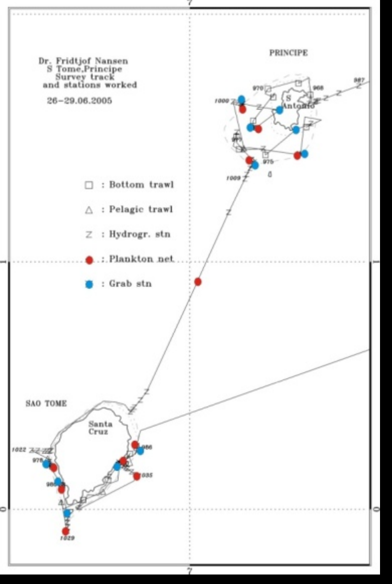
RV Fridtjof Nansen cruises in GCLME (2000 – 2009)

- Nansen to carry out annual fisheries cruises in GCLME
- Integration of plankton and benthic fauna sampling
- Gear: ICITA, net (330 microns; Hydrobios multinet; CPR)
- CPR monitoring will complement surveys





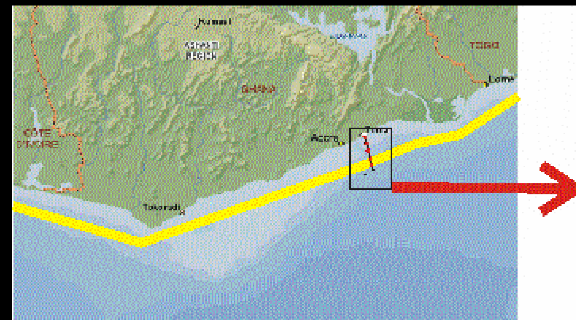


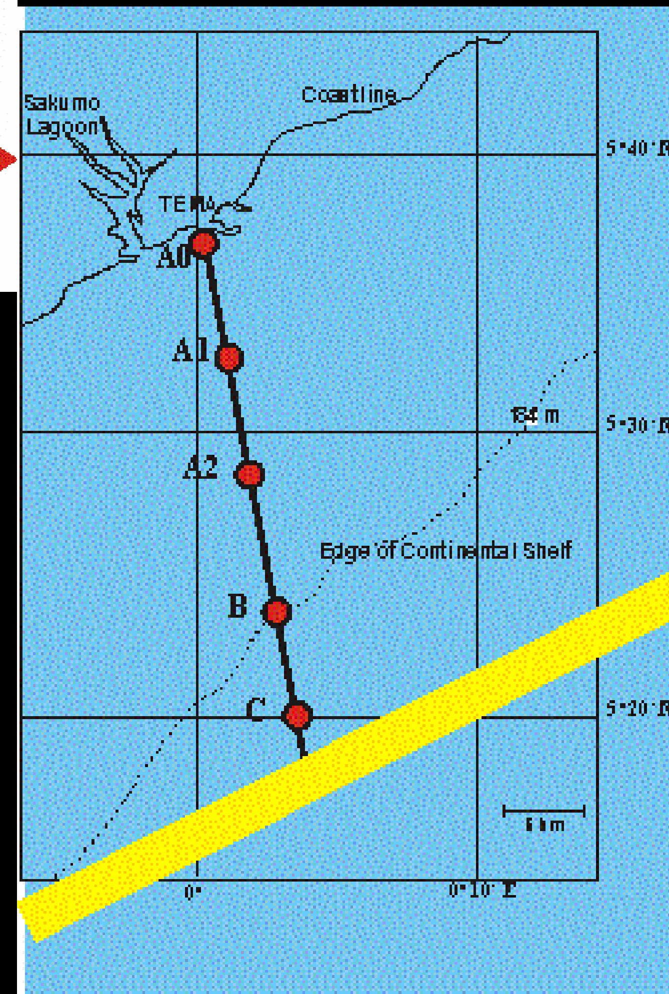


Impact of climate change on zooplankton distribution

- **Aim:**
  - Describe long term biomass of zooplankton in the Gulf of Guinea upwelling region (1969 – 1992)
  - Provide time-series model of abundance
  - Identify patterns and how they relate to environmental variables
  - Possible implications &/or consequences

Methodology & Data sources



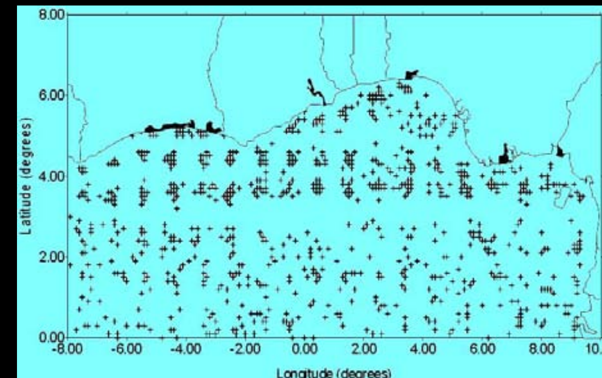


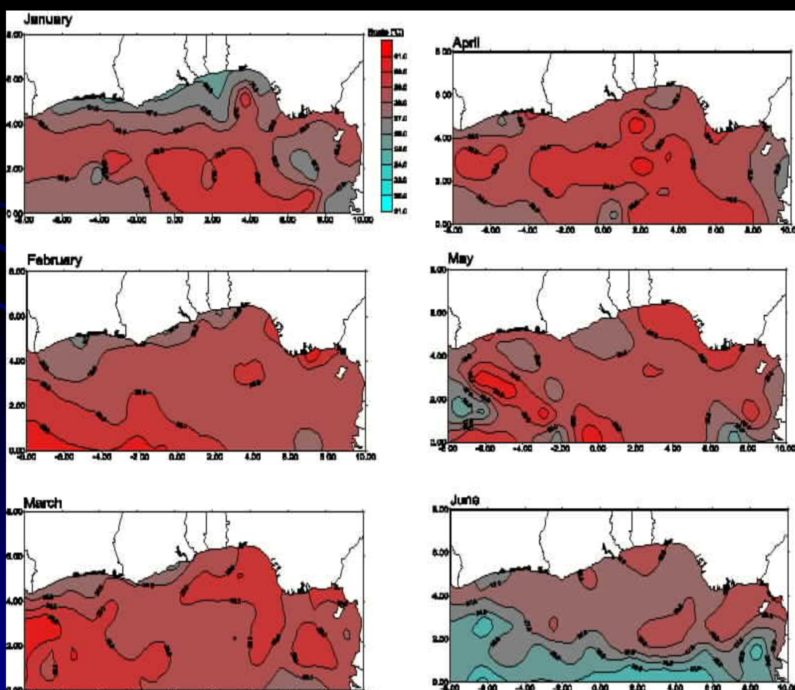
- **Zooplankton & Fish larvae (ml/1000m^3) from MFRD, Ghana & GCLME Project**
- **Use of ICITA net of 330 microns mesh; one metre ring diameter & 2.4 m length; step oblique (in 5 steps) from 50 m depth**
- **SST, SOI, SLP, Wind field (I-COADS, CDC of NOAA)**

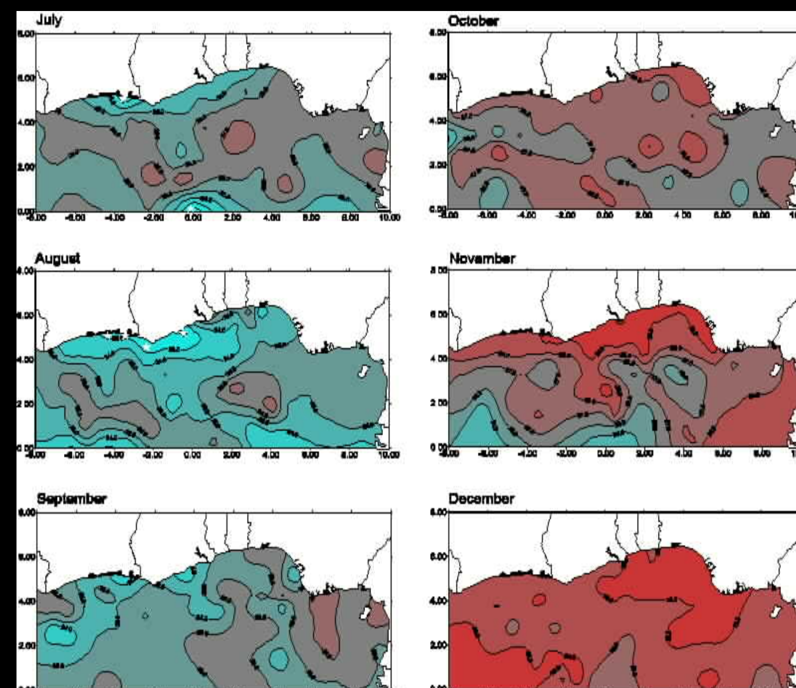
SOI or NAO? (Binet, 1996)

Gulf of Guinea SST distribution

- **Pearson, $r_{(I\text{-}COADS:SURVEY)} = 0.9;\ \alpha<0.01$)**
- **4 oceanographic seasons**
  - **Minor upwelling (Jan – Mar)**
  - **Hydrographic stability (Apr – Jun)**
  - **Major upwelling (July – Sep)**
  - **Hydrographic stability (Oct – Dec)**

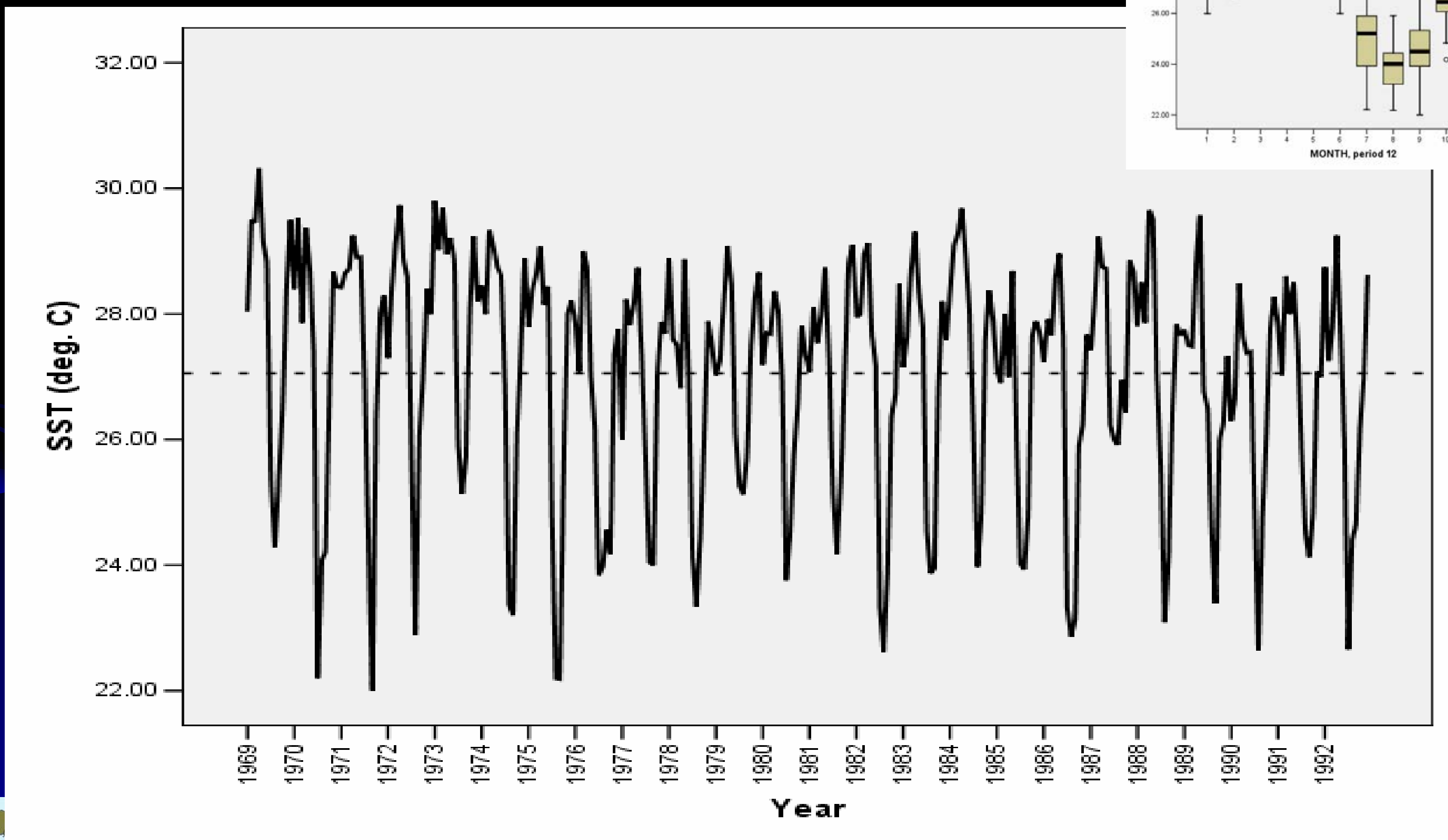


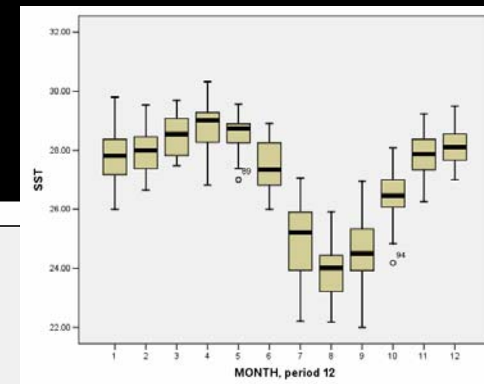




Integrated SST (1969 – 1992)

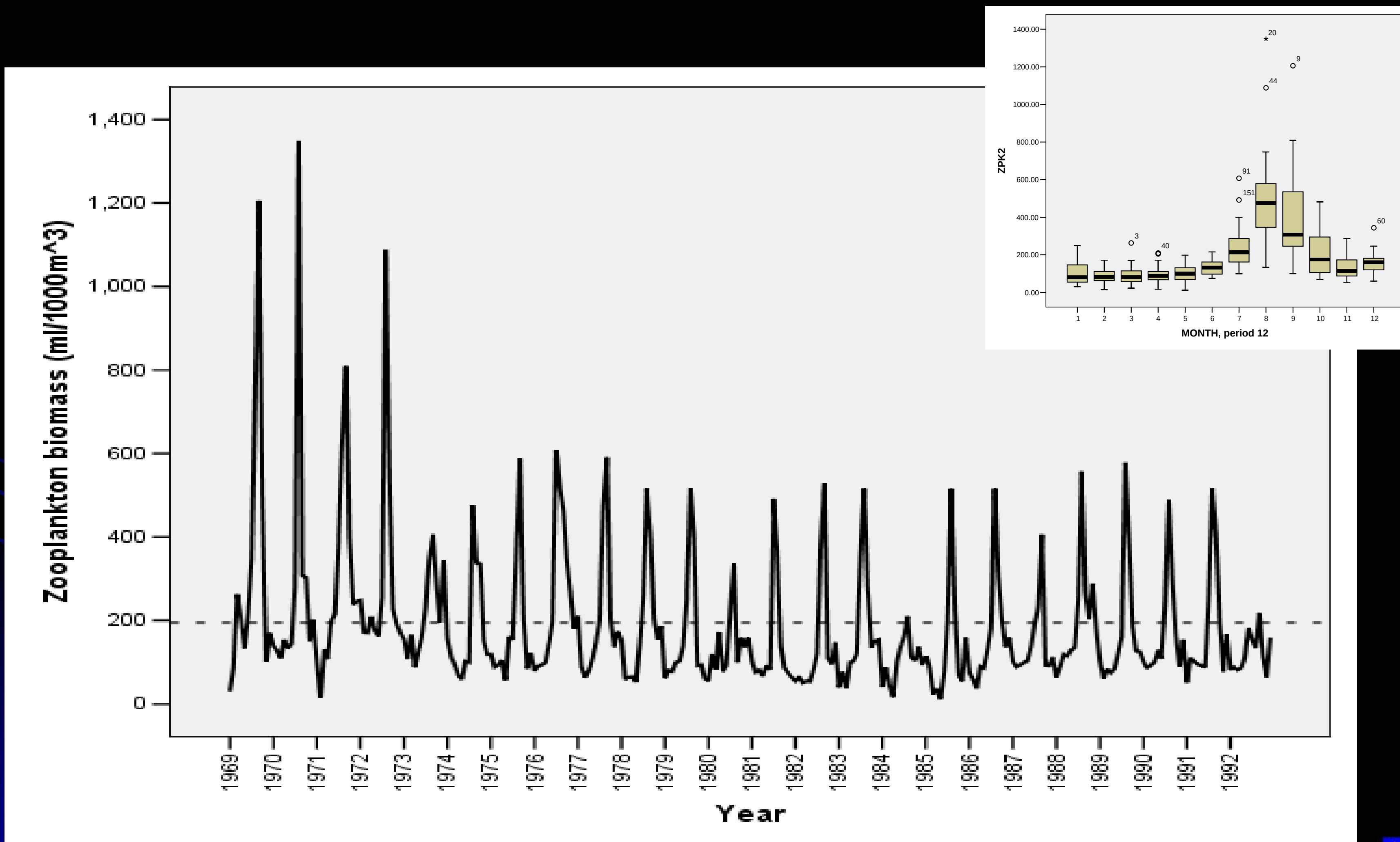
- **Troughs correspond to major upwelling**



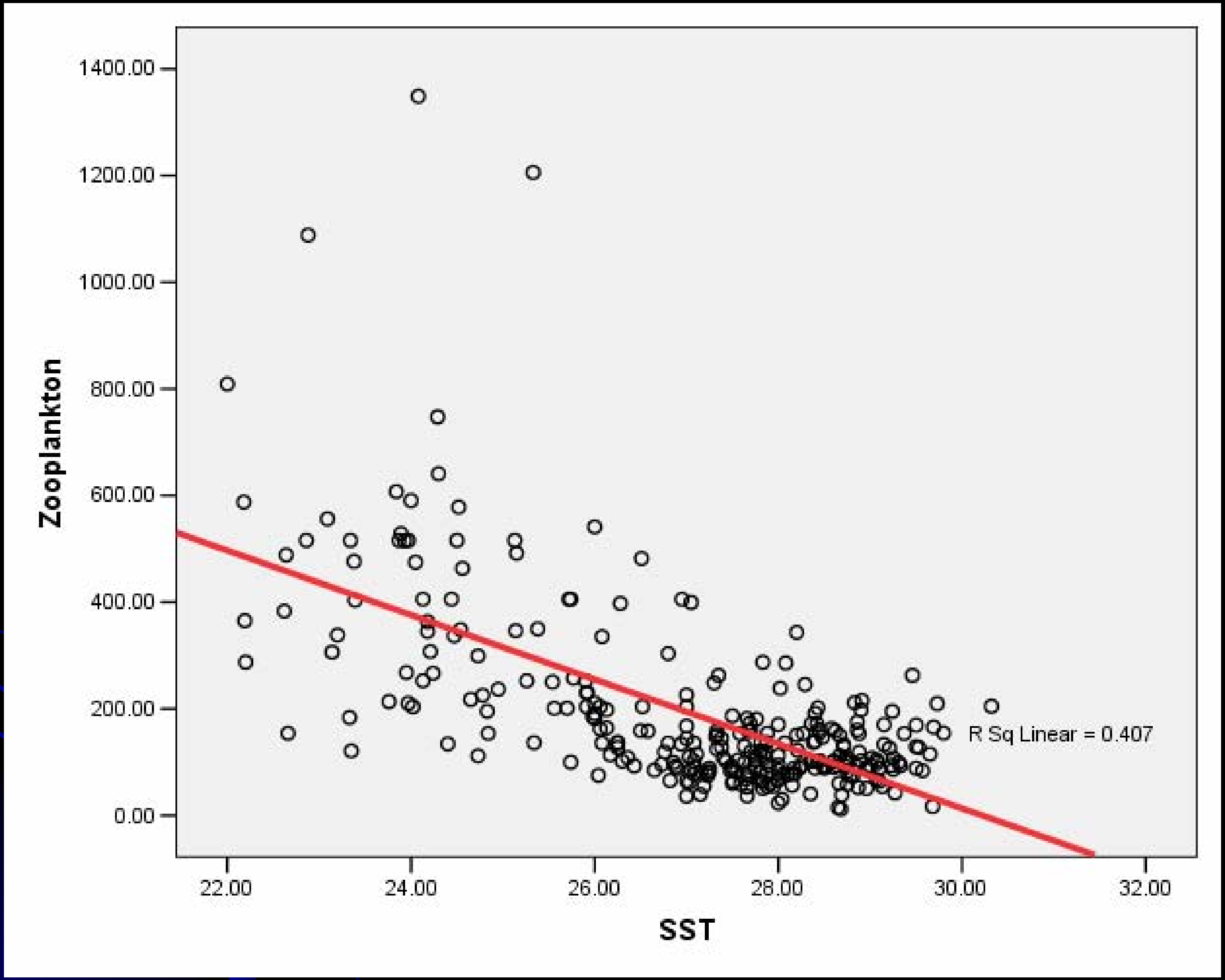


Zooplankton biovolume (ml/1000 m^3)

- **Peaks corresponds to major upwelling**

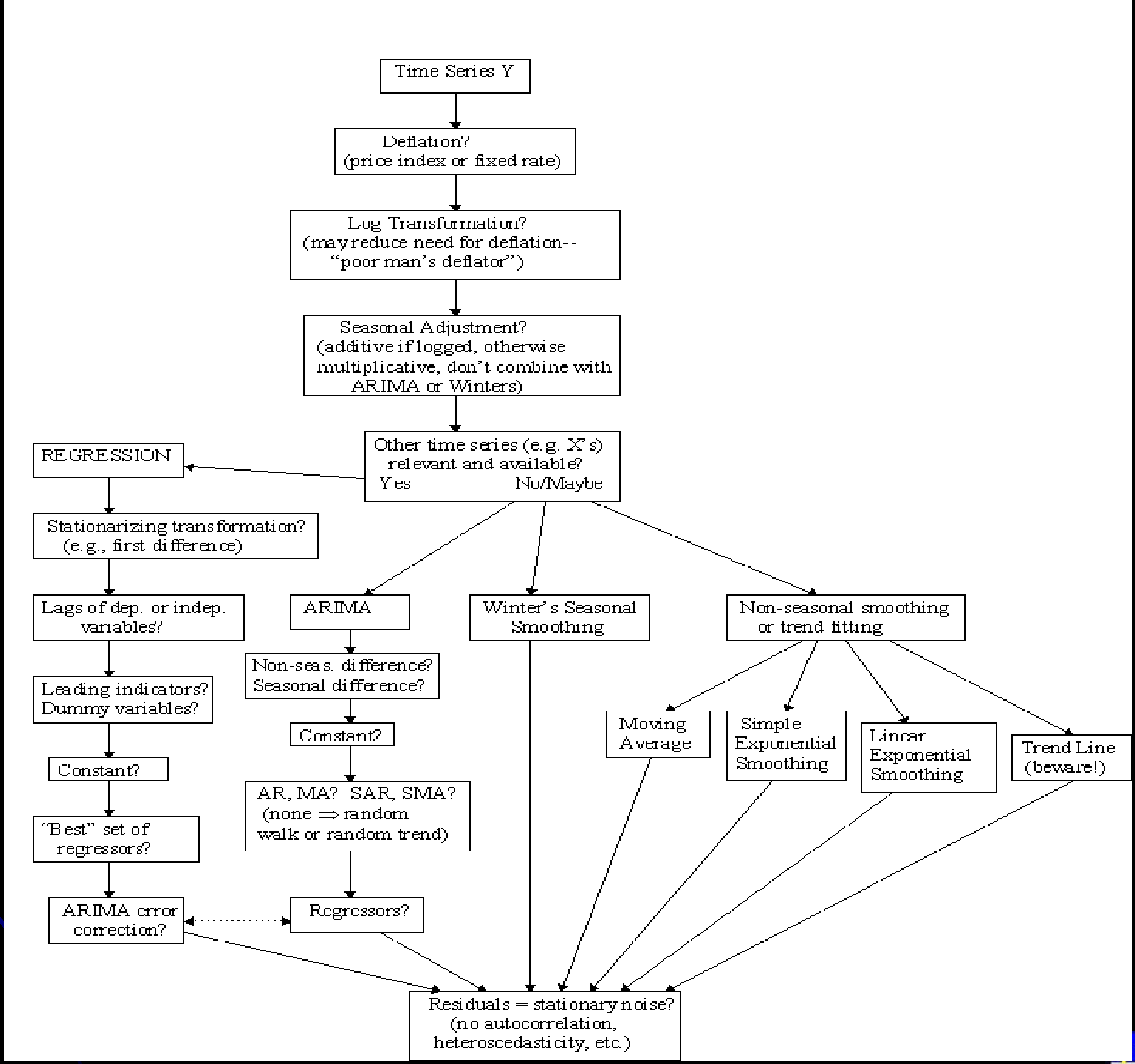


Zooplankton vrs SST



ARIMA Modeling

- **STEPS**
  - **Identification**
  - **Estimation**
  - **Diagnosis**
  - **Forecasting**
    - (Box & Jenkins,1976)



$ARIMA(0,0,0)(2,1,0)_{12}$

- **Correlogram indicated non-stationarity and annual seasonality requiring seasonal differencing.**

- **Seasonally differencing of one stabilized series level (mean ~ 0)**
- **Seasonal spikes in ACF/PACF plots suggested AR $(2)_{12}$**

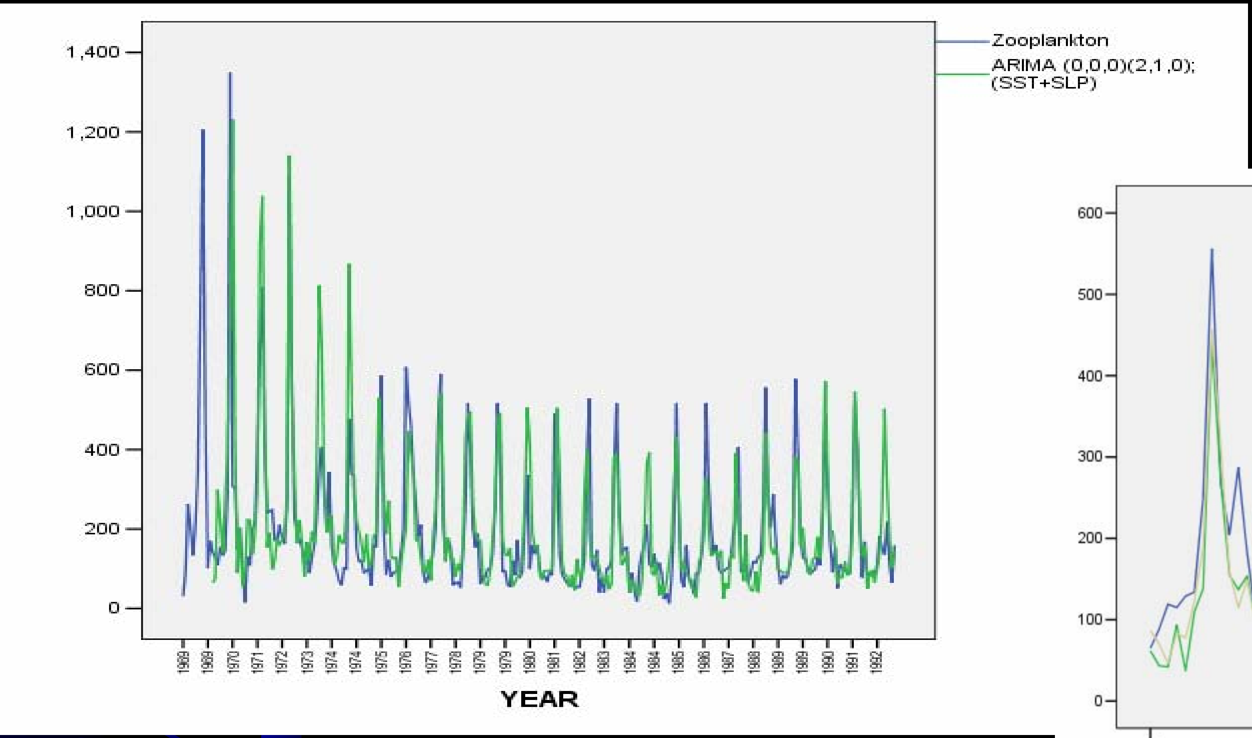
- **Melard's algorithm used for parameter estimation (α<0.001)**
- **Box-Ljung values in the vicinity of lag of ¼ of total seriesl held true.**
- **Significant predictors in model were SST and Sea level pressure**

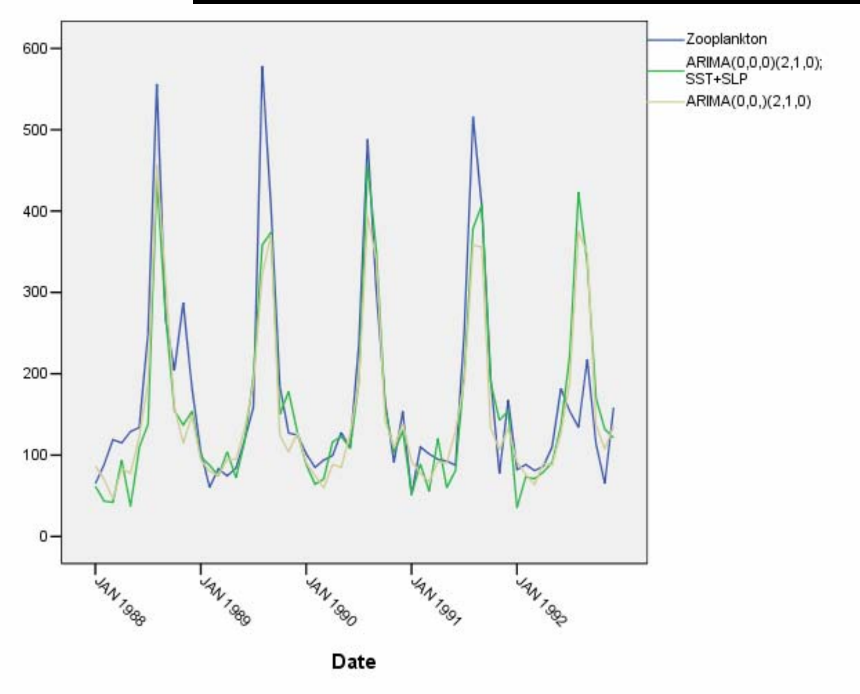
Parameter Estimates

		Estimates	Std Error	t	Approx Sig
Seasonal Lags	Seasonal AR1	-.798	.062	-12.959	.000
	Seasonal AR2	-.143	.060	-2.369	.019
Regression Coefficients	SST	-11.886	6.203	-1.916	.046
	Pressure	17.590	5.297	3.321	.001

A Kalman filtering algorithm was used for estimation.

Model prediction





- **ARIMA model with predictors did not fit better than the actual data without predictors.**

Model	R^2 ($\alpha<0.05$)
SST	41.2
SST + SLP	47.5
SST+SLP+FL	48.5
SST+SLP+FL+S	49.3

Seasonal trends

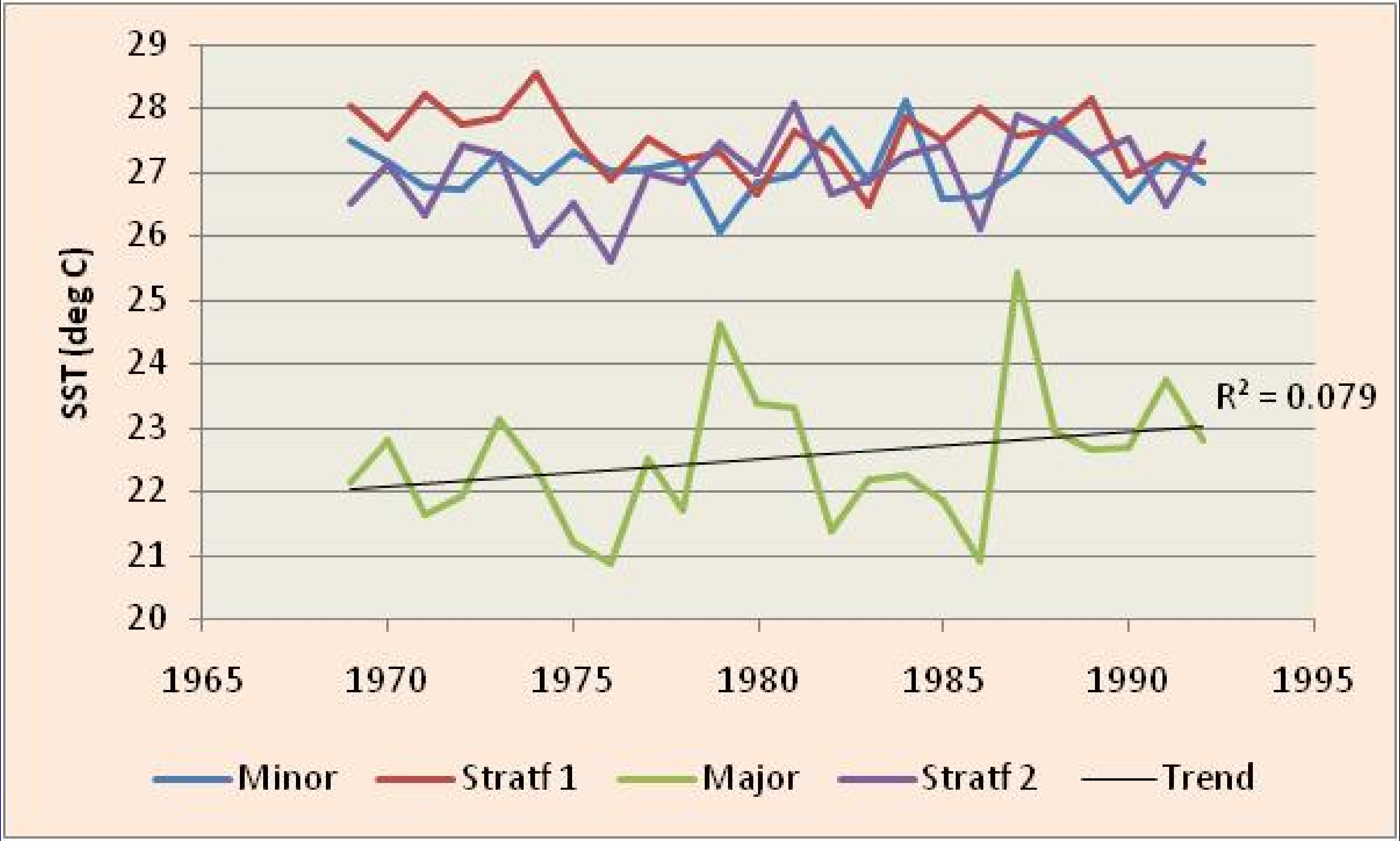
- **Data decomposed into the four oceanographic regimes**
- **Mann Kendall trend analysis performed with regard to each season**
  - **(based on +ve or –ve path)**
- **General decline in zooplankton biomass**
  - **(also during major upwelling)**
- **Warming of SST**
  - **(also major upwelling)**

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \mathrm{sign}(X_j - X_k)$$

where sign $(X_j - X_k)$ are the sign of all $n(n - 1)/2$ possible differences; $\alpha > 0.05$

Hydrographic season	Zooplankton	*Sardinella* larvae	SLP	SST	SOI
Minor upwelling	-82	87			
Hydrographic stability 1					
Major upwelling	-70			64	
Hydrographic stability 2	**-100**	**69**	**70**	**78**	**-67**
Overall Trend	**-5.14**	**1.99**			**-2.45**

Seasonal distribution (SST, ZP, FL)



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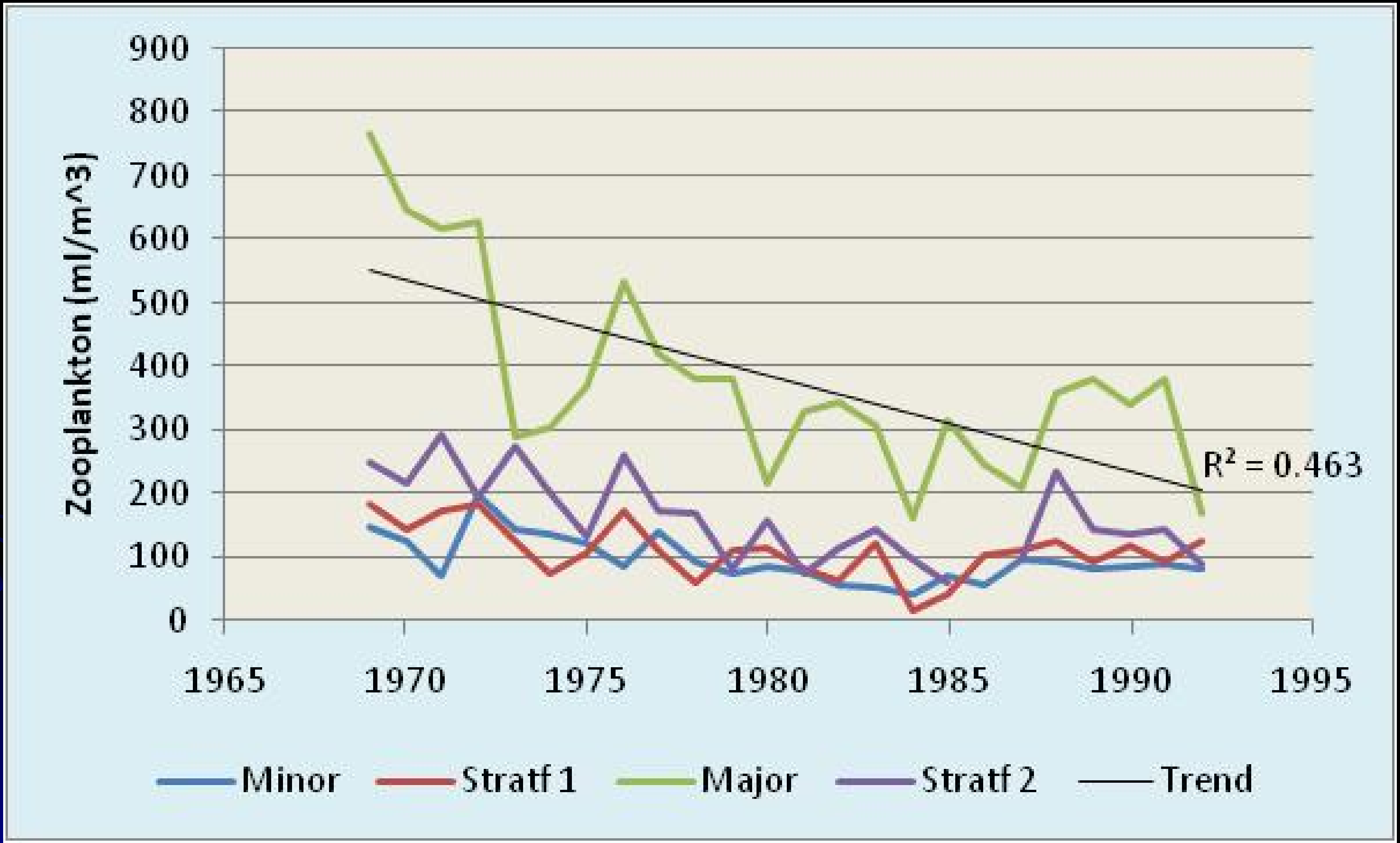
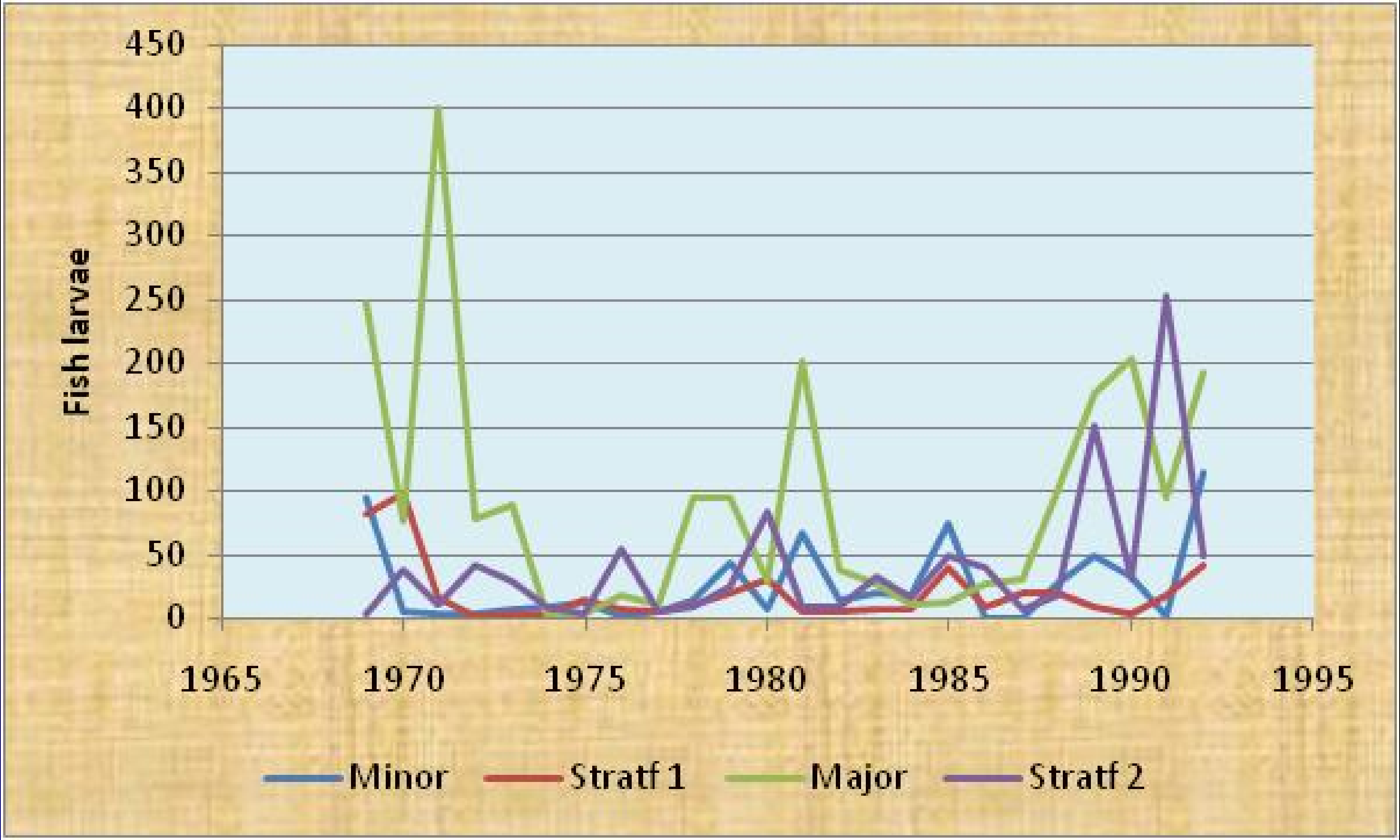


Seasonal distribution (SST, ZP, FL)

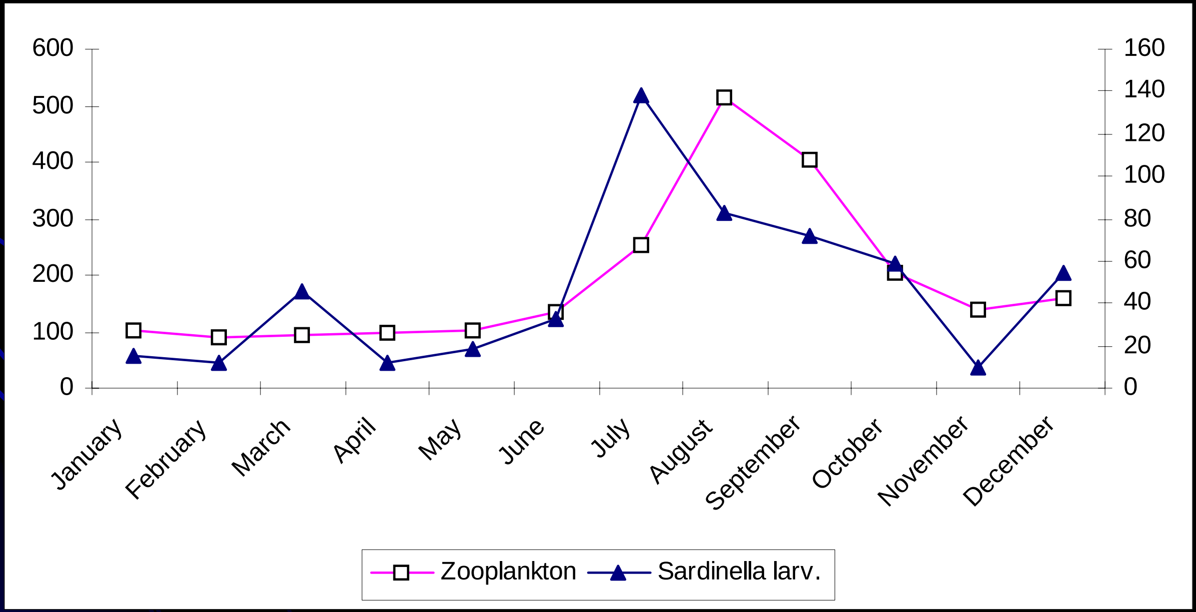


Cummulative model

Major Upwelling production

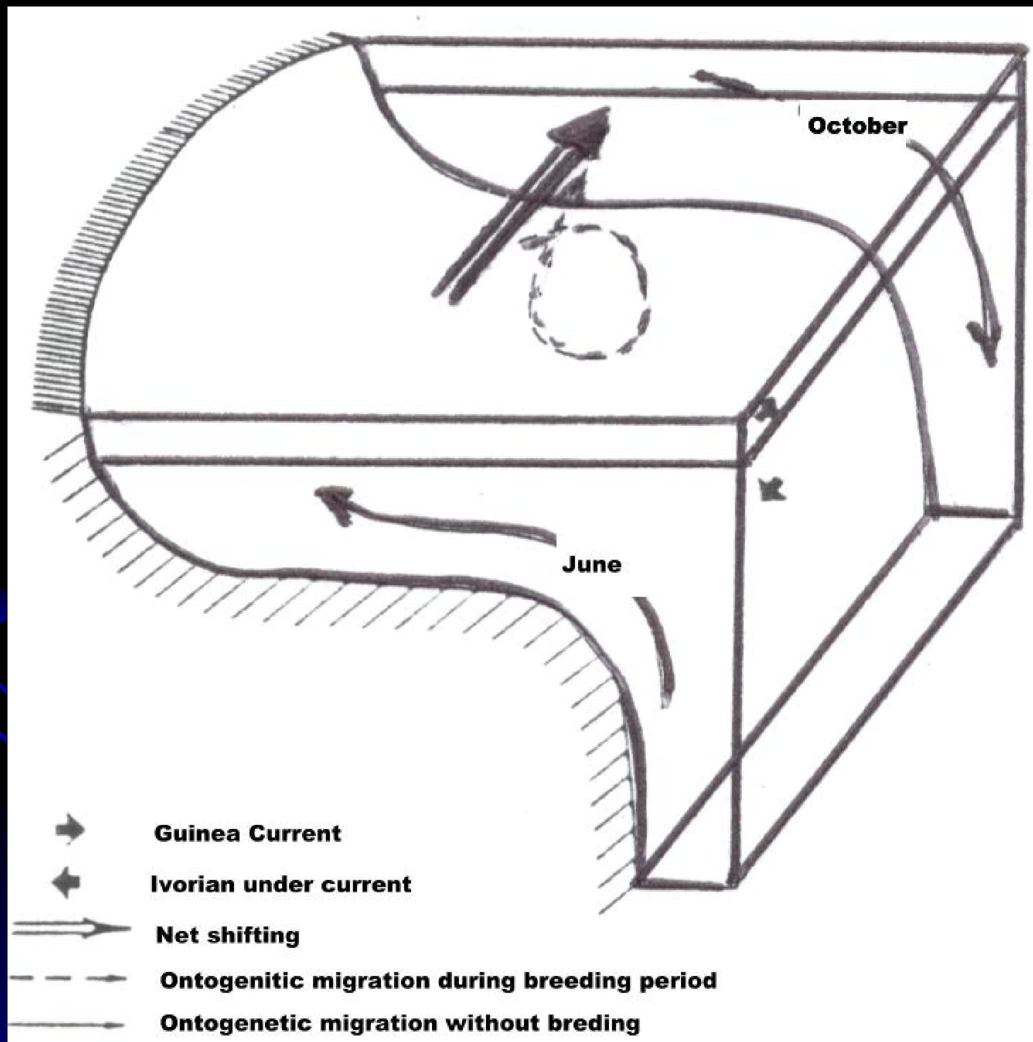
- **Average over 1969 – 1992**

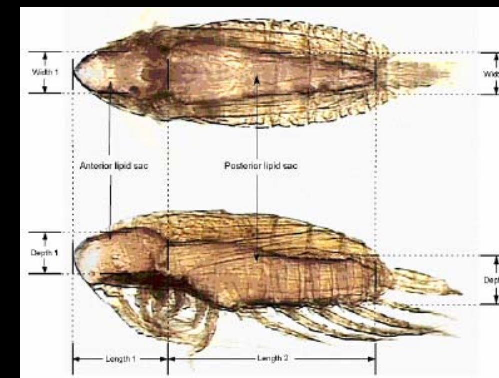
- **ZP = Sardn. larvae + SST + Wind**
  - **(R^2 = 54; p = 0.001)**
- **Bakun's triad (enrichment, concentration and retention)**
  - **processes combining to yield favourable reproductive habitat for small pelagics**



Discussion

- **Seasonal migration of Calanoides carinatus**



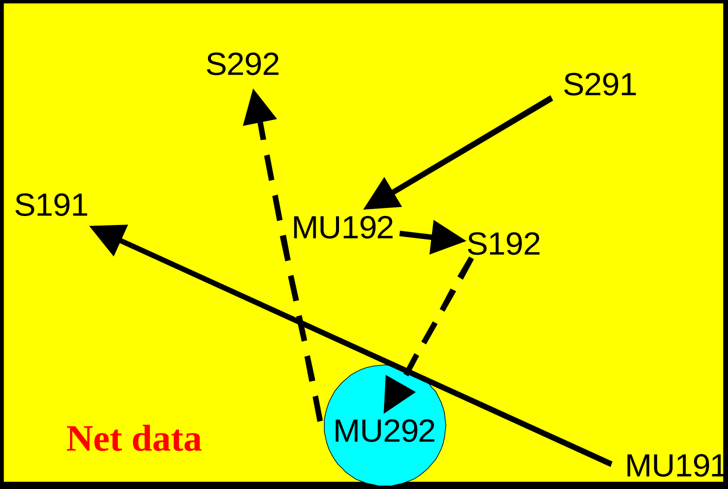


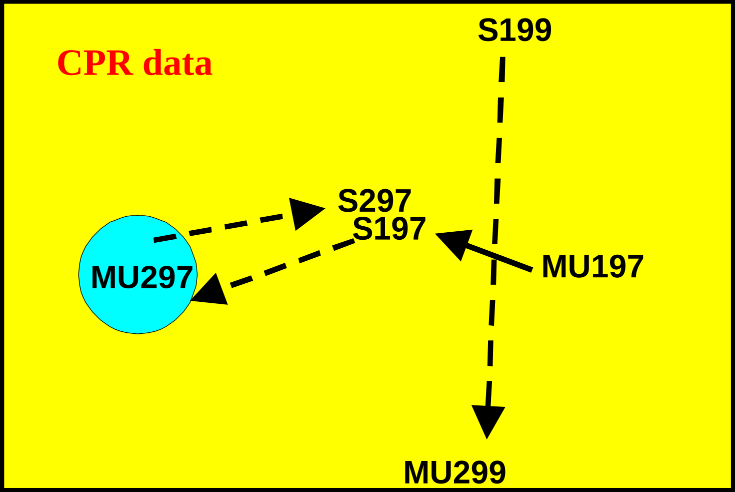
Seasonal Community structure

- **Temporal pattern in community**
- **structure (MDS plot).**
  - **Straight arrows = similarity in CS;**
  - **broken arrows = dissimilarity in CS.**

- **Major upwelling characterized by distinct community**

- **Possible consequence**
  - **Warming waters will influence this intergrity**





Conclusion

- **Description of long term biomass of zooplankton (1969 – 1992)**
  - High abundance during major upwelling; general decline in trend; pronounced for the upwelling season
- **Provide time-series model of abundance**
  - Most appropriate model ARIMA$(0,0,0)(2,1,0)_{12}$; SST, SLP as predictors contributed minimal
- **Effect of environmental factors on distribution**
  - Gradual warming of sea surface temperature, especially during the major upw.; SST accounted for 40% of variability in long term zooplankton distribution for decomposed major upwelling season
- **Possible implications &/or consequences**
  - Possible top-down predation control by Sardinella larvae regulated by hydro-climatic factors; possible loss of integrity in community structure during major upwelling season if current warming persist

THANK U

Acknowledgement

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