A numerical study of Indian West coast fishery of the 'oil sardine' using food energetic model

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ABSTRACT


The annual landings of Indian west coast oil sardines (*Sardinella longiceps)* exhibit large scale variability with prolonged years of surplus or deficit without known reasons. Using *S. longiceps* landing at Kerala coast during 1961-2017, we have elucidated a link between the variability in landing with oceanic climate variables. The colder temperature and timely upwelling leading to nutrient enrichment in the surface waters and thereby availability of food to *S. longiceps* are found during surplus years. The fresh surface salinity and shoaling of MLD during the surplus years could lead to the aggregation of fish at shallow depths, which favours fishing. The present study found that the PDO and AMO have pronounced impacts on the landing than that previously reported with ENSO.

A fish bioenergetics model was indigenously developed by coupled with a lower ecosystem model to study the relationship between the climate variables and growth of fish. An ecosystem model called North Pacific Ecological Modeling for Understanding Regional Oceanography (NEMURO) was adapted and transformed for Indian Ocean conditions. The coupled model reproduced appropriate growth rate and wet-weight of Indian oil sardine and it is comparable with available observation.


INTRODUCTION

Indian oil sardine (*S. longiceps*) is the single largest contributor (8.8%) towards total landings (CMFRI, 2018). Even though, commercial level exploitation was confined mainly to the southwest coast, its distribution along the Indian coast is extending from Gujarat in the west coast to West Bengal in the east coat. It is economically important in addition to human consumption. This species is important as a critical forage for marine thus it provides a key linkage from lower trophic to upper trophic levels (Pikitch et al., 2014).

Globally, the fishery has shown wide fluctuations during the past 100 years. Changes in ecological parameters such as temperature and availability of food directly affect the physiology, growth, metabolic activities, reproduction and larval survival of this species. A fish bioenergetics model was coupled with a lower trophic level ecosystem model, to investigate the relationship between sea surface temperature (SST), prey density and growth of oil sardine.

DATA AND METHODOLOGY

Climate impact on the Indian oil sardine

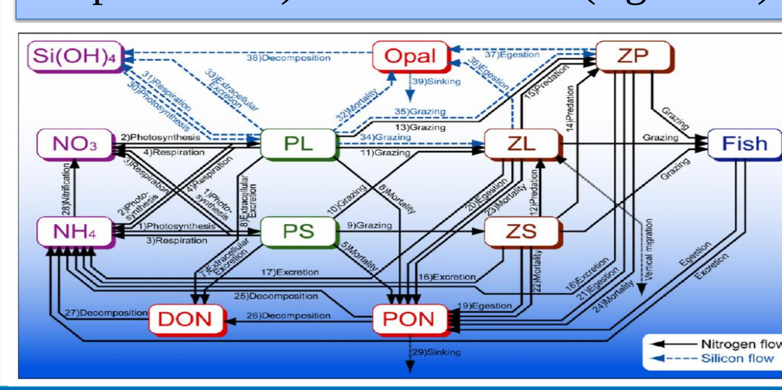
- Landing data of *S. longiceps* for a period from 1961 to 2017 (Kripa et al., 2018)
- Availability of food (http://data.ceda.ac.uk/neodc) On monthly scale for the period of 1998 to 2016, at a spatial resolution of 4 km × 4 km.
- Salinity and Temperature (http://www.metoffice.gov.uk/hadobs/en4), Monthly mean data (EN.4.2.1) with a vertical resolution of 10 m and at 1° × 1° spatial resolution
- Mixed layer depth (http://apdrc.soest.hawaii.edu/data/data.php) at resolution 0.5° × 0.5° spatial grid
- Wind stress curl (as a measure of upwelling, https://apps.ecmwf.int), Monthly means of zonal and meridional winds at 10 m level (u10 and v10) at a resolution of 0.25° × 0.25° grid.

Numerical model for Wet weight

Rate of change of wet weight of Oil sardine is

$$\frac{dW_i}{dt} = [C_i - (R_i + S_i + EG_i + EX_i)]\frac{CAL_z}{CAL_f}W_i - EGG_i W_i,$$

W_i is the wet weight of the fish in grams, C_i is the consumption, EX_i is the excretion or losses of nitrogenous wastes, EG_i is the egestion, R_i is the respiration or losses through metabolism, S_i is the specific dynamic action, EGG_i the fraction of body weight lost on the day of spawning, CAL_z & CAL_f are the energy density (J) of zooplankton (J g zooplankton^{-1}) and of sardine (J g fish^{-1}).

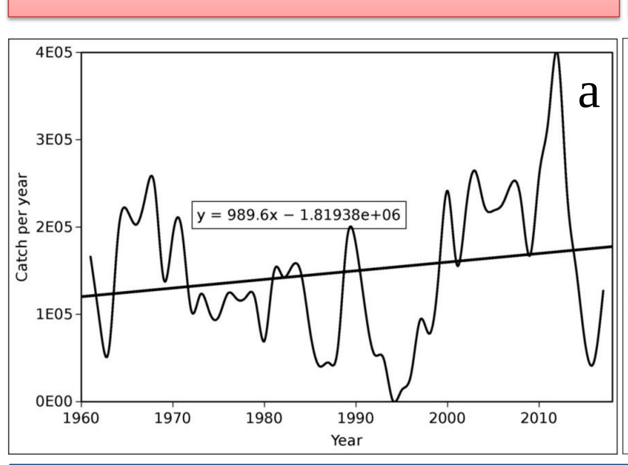


Schematic representation of NEMURO-FISH

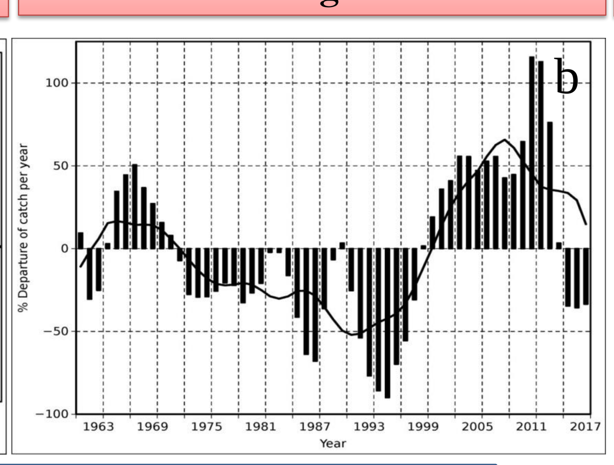
RESULTS AND DISCUSSIONS

Climate impacts on the landings of oil sardine over the Kerala coast

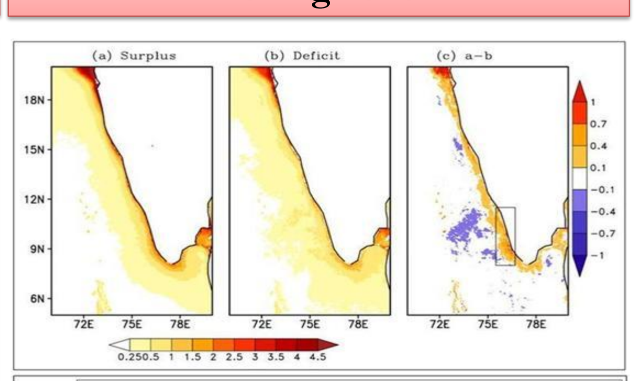
Variability and trend of *S. longiceps* over the southeastern Arabian coast

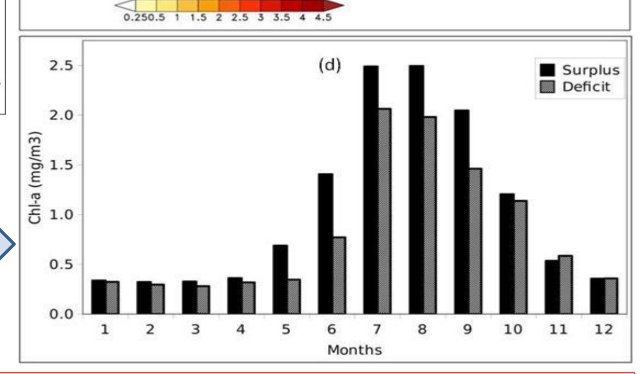


Percentage deviations from detrended long-term mean



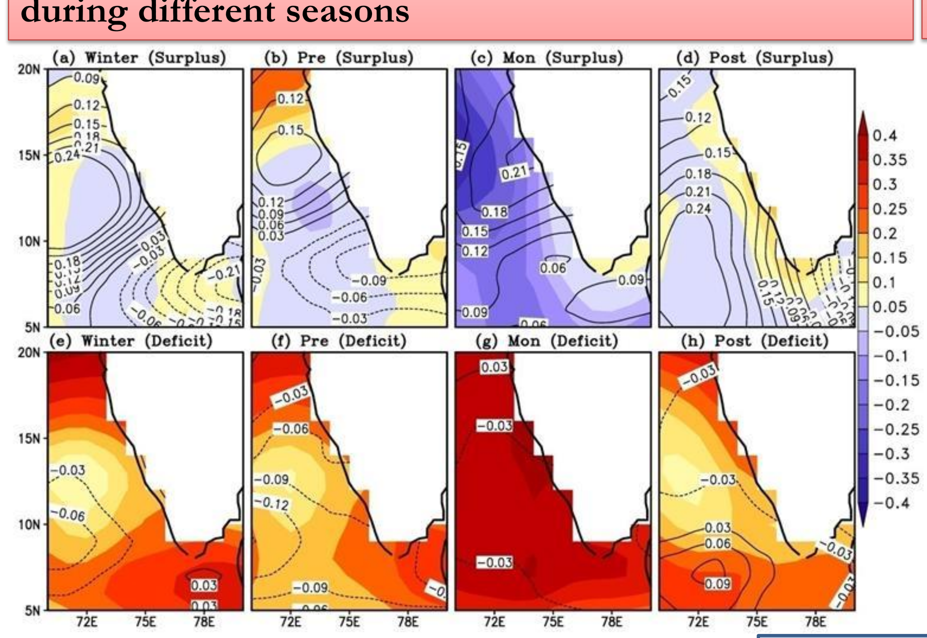
Chlorophyll-*a* concentration in the fishing zone



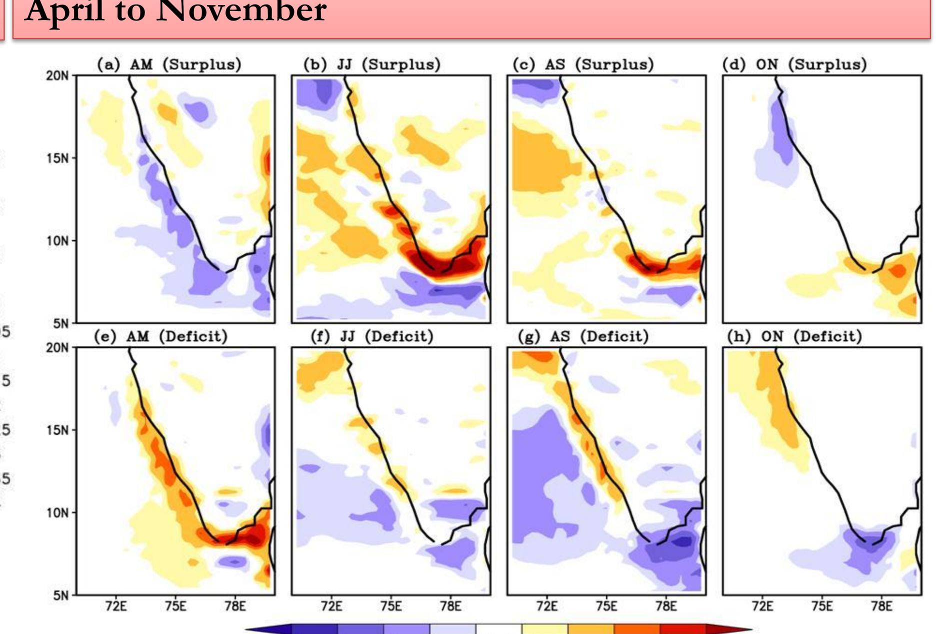


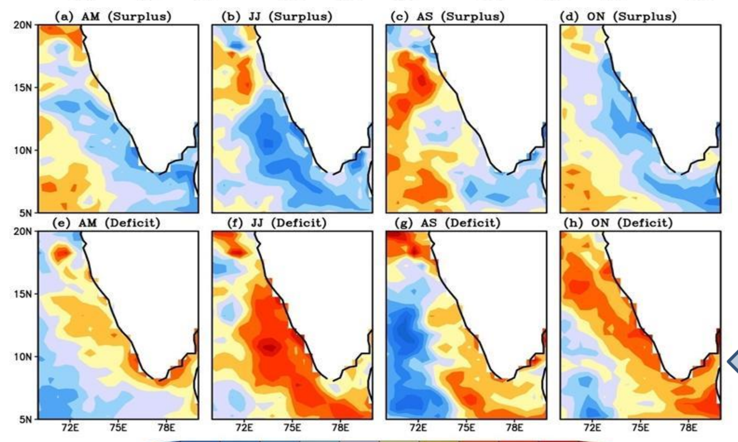
Average chl-*a* availability during surplus years of landing was higher in comparison with the deficit years of landing especially during the months of May, June, July, August and September

The seasonal fluctuation of salinity (contours) and temperature (shades) over the water column up to 30 m depth for surplus and deficit years of landings during different seasons



Bimonthly spatial distribution of wind stress curl anomalies as a measure of upwelling driven by surface winds during surplus and deficit landing years from April to November





Ocean Mixed layer depth

Shoaling of MLD was observed during surplus years

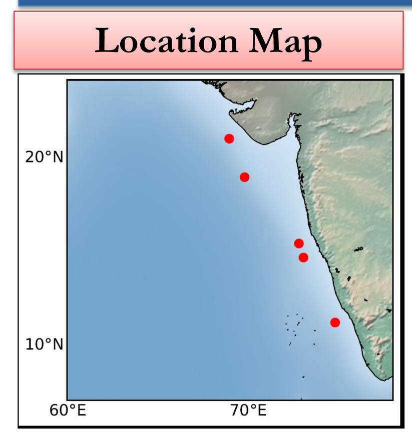
Connection of climatological indices to annual landing of *S. longiceps*

Indices	Annual landing data	Long cycle	Short cycle
SAM	0.11	0.13	-0.02
PDO	**-0.47**	**-0.39**	**-0.27**
NAO	-0.17	**-0.29**	0.14
AO	0.02	-0.18	**0.32**
AZM	0.03	0.15	-0.18
AMO	**0.32**	**0.43**	-0.1
DMI	0.11	0.12	0.01
Nino 3.4	-0.26	-0.12	-0.3

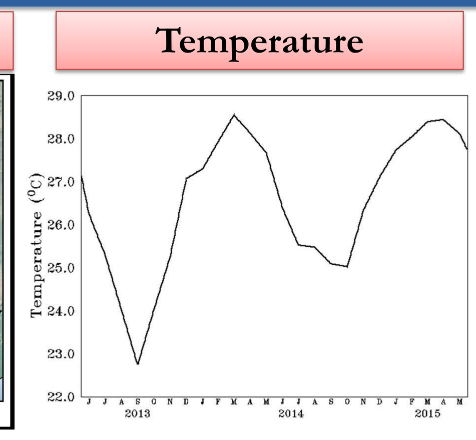
Numerical simulations of wet weight of oil sardine in the Indian west coast

Simulated Fish Weight by IO-NEMURO-FISH

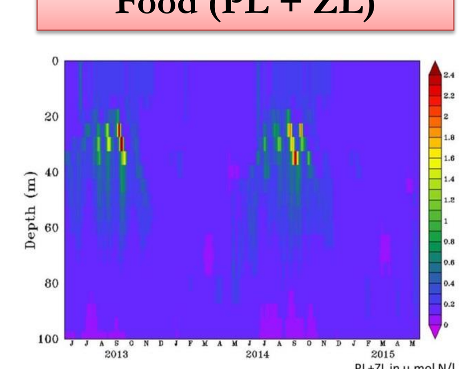
Location Map



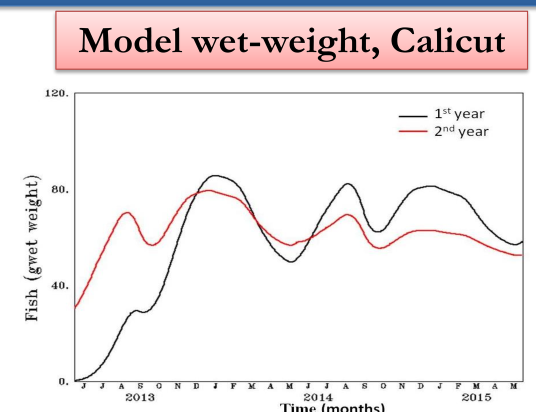
Temperature



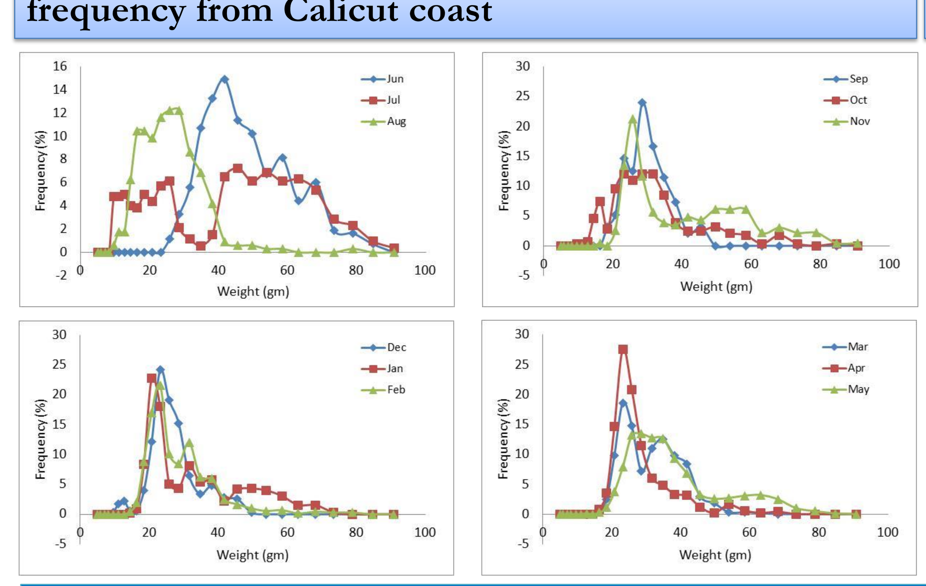
Food (PL + ZL)



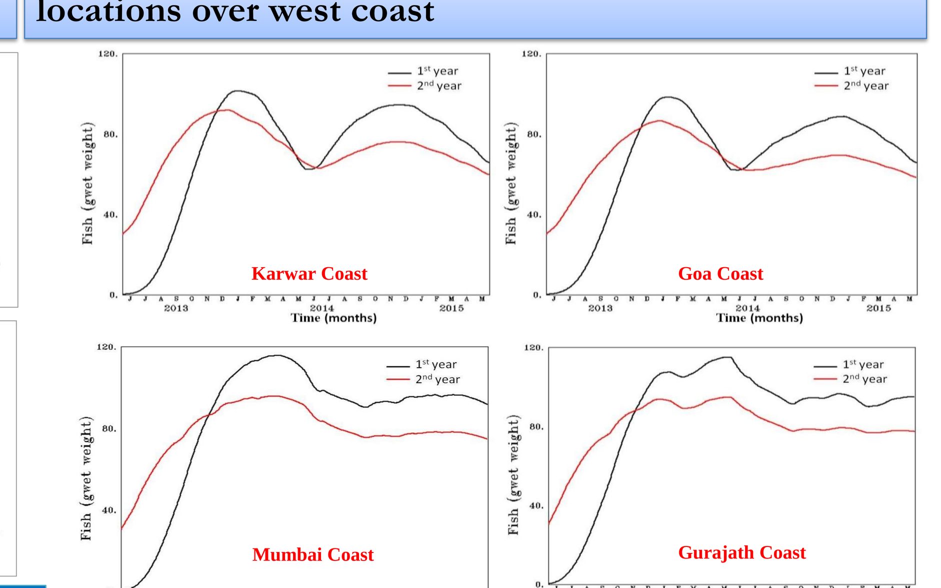
Model wet-weight, Calicut



Observed monthly weight of oil sardine along with its frequency from Calicut coast



Simulated wet-weight of oil sardine from different locations over west coast



CONCLUSIONS

- Climate variables plays a crucial role on the production of *S. longiceps*
- A numerical model was developed indigenously for Indian oil sardine
- A linkage between lower trophic food community (Diatom and Meso zooplankton) and sardines through numerical relations as a energy-flow model is adapted
- Results shows that sardines in the southwest coast is about 50 - 80 g in weight whereas, in the northwest coast it is about 80 - 110 g and has a clear seasonal cycle with weight loss of ~30 g according to temperature and availability of food

Observational ranges of wet-weight of oil sardine

Location (observation)	Weight (g)	Reference
Karnataka	30.12 to 85.26	Deshmugh et al., 2016
Goa	31 to 86.86	Deshmugh et al., 2016
Maharashtra	11.4 to 86.82	Sha et al., 2019

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