Climate change impacts on coastal lakes: an evaluation of the impact on Vembanad, Chilka and Pulicat lakes and their resources

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Coastal lakes are important breeding grounds of fish/shellfish which support artisanal fisheries. The changes in the immediate offshore regions are important as these regions also form spawning and nursery grounds of several species of fishes. Hence it is presumed that changes in the immediate offshore regions or in the inshore critical habitats might influence the phenology and recruitment success of fish/shellfish by affecting their growth and survival.

Study locations

Three major coastal lakes of the country such as Vembanad (south-west coast), Pulicat (south-east coast) and Chilka (north-east coast) were selected for the study as these are regions of rich biodiversity. The services they offer by providing breeding habitat and/or nursery grounds for a large number of high value finfishes and shellfishes including some migrant species which spend only part of their life in the coastal regions. A typical example is the Indian shrimp *Fenneropenaeus indicus* which spawns in the sea and completes its early life cycle in the estuaries/coastal lakes. They are known to support the major commercial fishery worth several millions of dollars. The lakes also support the livelihood of several coastal fishers who use simple non-mechanised /traditional gear to fish the resources in the lakes. The geo-locations of the three lakes and the immediate offshore regions are given in Table 1.

Table. 1. Geo-locations of the study area

	Lake	Offshore
Vembanad (south- west region)	76^0 E 9^0 N	75^0 E 9^0 N
PulicatLake (south-east region)	80^0 E 13^0 N	81^0 E 13^0 N
Chilka Lake (north-east region)	85^0 E 19^0 N	86^0 E 19^0 N

Methodology

The monthly SST (sea surface temperature) for the period from 1960 to 2009 was downloaded from ICOADS (provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their web site at http://www.esrl.noaa.gov/psd/database) and analysed.

Comparison of monthly surface water temperature during the five decade period, 1960-69 and 2000-2009

The average monthly variations in the parameters pertaining to 1960-69 and 2000-2009 were compared. The trend in variation was inferred and instances where Δt (variation in monthly decadal mean surface water temperature, SWT of 1960-69 and 2000-2009) was more than 0.5, (increase or decrease) was considered as significantly impacted.

Comparison of decadal mean surface water temperature

The mean decadal SWT of the six regions were compared. When the values were equal to or above 0.5, the difference was considered significant. Moreover, the percentages of impacted months in the region were calculated and the values were graded as given in Table 2. These grades were also used to evaluate the intensity of climate change (CC) impact in the specific region.

Table 2. Grades used for evaluating intensity of climate change

Value/range of percentage	Grade
0	No impact
1 to 33 %	Mildly impacted
34 to 67 %	Moderately impacted
68 to 100 %	Strongly impacted

Comparison of seasonal surface water temperatures during the decades 1960-69 and 2000-09

From the monthly data, the variations in seasons such as summer monsoon (June to September), inter-monsoon fall (October), winter monsoon (November-February) and Inter-monsoon spring (March to May) were also analysed. Here also, when the Δt values were above 0.5, it was considered as significantly impacted.

Evaluation of likely impacts on spawning or survival/ growth of eggs, larvae, juveniles (recruitment success) and possible impact on fishery

Published information on the spawning period (months) and/or the months when the eggs and larvae were obtained in large numbers of commercially important resources like shrimps and finfishes were collected. The intensity of climate change in these months as obtained from the results under section A was used and the inferences were made based on the grades obtained as indicated in the case of mean decadal SWT.

Results

Comparison of monthly surface water temperature during the five decade period, 1960-69 and 2000-2009

Vembanad Lake and offshore region of Vembanad Lake

In general it was observed that, there is significant change in surface water temperature during February and April to September (Table 3). A shift in peak during summer from April to May has been observed in Vembanad Lake. In the open sea, off Vembanad Lake, during the months February, June-September and November, there is significant increase in temperature.

Pulicat Lake and offshore region of Pulicat Lake

In Pulicat Lake, the temperature was found to decrease significantly during April, May and June. During the period from August to October, though there was increase in temperature, the increase was not significant (Table 4). In the offshore region, the temperature was found to increase significantly in April, June, July, October and December. Moreover, the peak observed in May was found to shift to June.

Chilka Lake and offshore region of Chilka Lake

In Chilka Lake, temperature was found to significantly increase during January, March, April, July, September and November and found to significantly decrease during May and August (Table 5). The peak in May was found to shift to April and peak in August was found to shift to July. In the offshore areas of Chilka Lake, SWT was found to increase significantly during January, February, April, June and from October to December. The peak in May was found to shift to April.

Comparison of decadal mean surface water temperature

Based on the decadal ΔSWT, the Vembanad Lake and offshore region did not show significant

Table 3. Month-wise evaluation of Δt in Vembanad Lake and offshore region

Vembanad lake			Vembanad off shore region		
Month	Shift observed	Intensity of change / Δt	Month	Shift observed	Intensity of change / Δt
Jan	No	↑ NS	Jan	No	↑ NS
Feb	No	↑ S	Feb	No	↑ S
March	No	No change	March	No	No change
April	Peak shifted to May	↓ S	April	No	No change
May	No	↑ NS	May	No	Almost same
June	No	↑ S	June	No	↑ S
July	No	↑ S	July	No	↑ S
Aug	No	↑ S	Aug	No	↑ S
Sept	No	↑ S	Sept	No	↑ S
Oct	No	↓ NS	Oct	No	↑ NS
Nov	No	↑ NS	Nov	No	↑ S
Dec	No	↑ NS	Dec	No	↑ NS

↑ indicates increase; ↓ indicates decrease; S = Significant; NS = Not significant

Table 4. Monthwise evaluation of Δt in Pulicat Lake and offshore region

Pulicat Lake			Pulicat offshore region		
Month	Shift observed	Intensity of change / Δt	Month	Shift observed	Intensity of change / Δt
Jan	No	No change	Jan	No	↑ N S
Feb	No	↑ N S	Feb	No	No change
March	No	No change	March	No	↑ N S
April	No	↓ S	April	No	↑ S
May	No	↓ S	May	Peak shifted to June	No change
June	No	↓ S	June	No	↑ S
July	No	No change	July	No	↑ S
Aug	No	↑ N S	Aug	No	↑ N S
Sept	No	↑ N S	Sept	No	↓ N S
Oct	No	↑ N S	Oct	No	↑ S
Nov	No	No change	Nov	No	↓ N S
Dec	No	Almost same	Dec	No	↑ S

↑ indicates increase; ↓ indicates decrease; S = Significant; NS = Not significant

difference, though the offshore region showed a higher value (0.44) compared to the lake (0.4). Based on the percentage of significantly impacted months, it can be inferred that both Vembanad Lake and corresponding offshore region are moderately impacted (Table 6).

The offshore region of Pulicat Lake showed an increase of 0.14 ^{o}C in ΔSWT than that of the Pulicat Lake. The Pulicat Lake showed a decrease in ΔSWT. This may be indicative of a possible decrease in mean SWT in this lake, in majority of the months of the recent decade compared to its SWT of the months of the decade before 40 years. Based on the percentage of significantly impacted months, it can be inferred that Pulicat Lake is only mildly impacted while the offshore region is moderately impacted.

The offshore region of Chilka showed an increase of 0.1 ^{o}C than the ΔSWT of Chilka Lake. Significant increase in ΔSWT was shown only in Chilka Deep.

Table 5. Monthwise evaluation of Δt in Chilka Lake and offshore region

Chilka Lake			Chilka offshore region		
Month	Shift observed	Intensity of change /Δt	Month	Shift observed	Intensity of change / Δt
Jan	No	↑ S	Jan	No	↑ S
Feb	No	↓ N S	Feb	No	↑ S
March	No	↑ S	March	No	↑ N S
April	No	↑ S	April	No	↑ S
May	Peak shifted to April	↓ S	May	Peak shifted to April	↓ N S
June	No	↑ N S	June	No	↑ S
July	No	↑ S	July	No	↑ NS
Aug	Peak shifted to July	↓ S	Aug	No	No change
Sept	No	↑ S	Sept	No	↑ N S
Oct	No	No change	Oct	No	↑ S
Nov	No	↑ S	Nov	No	↑ S
Dec	No	↑ NS	Dec	No	↑ S

↑ indicates increase; ↓ indicates decrease; S = Significant; NS = Not significant

Table 6. Comparison of decadal mean surface water temperature in Vembanad, Pulicat and Chilka lakes and corresponding offshore regions

	1960-69	2000-09	∆SWT	Likely climate change impact based on % of significantly impacted months
Vembanad Lake	28.11	28.51	0.4	Likely to be moderately impacted (50%)
Offshore Vembanad	28.34	28.78	0.44	Likely to be moderately impacted (50%)
Pulicat Lake	28.16	28.03	- 0.13	Likely to be mildly impacted (25%)
Offshore Pulicat	28.21	28.48	0.27	Likely to be moderately impacted (42%)
Chilka Lake	27.97	28.38	0.41	Likely to be strongly impacted (67%)
Offshore Chilka	27.89	28.4	0.51	Likely to be moderately impacted (58%)

Based on the percentage of significantly impacted months, it can be inferred that Chilka Lake is likely to be significantly impacted and offshore region moderately impacted.

Comparison of seasonal SWT during the decades 1960-69 and 2000-09

Vembanad Lake

Among the four seasons, the increase in temperature during the summer monsoon in the lake and offshore region were significant while increase in temperature during winter monsoon was significant only in the lake, while in the offshore region, it was not significant (Table 7). In the lake, the temperature during the inter-monsoon fall and inter-monsoon spring was found to be decreasing, though the values were not significant. In the offshore region, ∆SWT were not significant.

Pulicat Lake

In Pulicat lake, temperature during the summer monsoon and inter-monsoon spring was found to be decreasing and the ∆SWT during the latter season was significant (Table 8). However, in the offshore region, temperature showed an increasing trend and the ∆SWT was significant in the inter-monsoon fall.

Chilka Lake

The temperature was found increasing during summer monsoon and winter monsoon and the ∆SWT was significant during the latter in the lake and offshore region (Table 9). In the lake, the temperature was found to decrease during the inter-monsoon fall and inter-monsoon spring but the ∆SWT was not significant. In the offshore region, the ∆SWT during the inter monsoon fall was significant.

Table 7**.** Comparison of seasonal variation in ∆SWT in Vembanad Lake and offshore region

	Vembanad Lake			Offshore Vembanad Lake		
	1960-69	2000-09	∆SWT	1960-69	2000-09	∆SWT
Summer monsoon	26.8482	27.63	0.8	27.40	28.11	0.71
Inter-monsoon fall	28.003	27.91	-0.1	28.17	28.50	0.33
Winter monsoon	28.288	28.76	0.5	28.32	28.75	0.43
Inter-monsoon spring	29.6047	29.50	-0.1	29.70	29.80	0.10

Table 8. Comparison of seasonal variation in ∆SWT in Pulicat Lake and offshore region

	Pulicat Lake			Offshore Pulicat Lake		
	1960-69	2000-09	∆SWT	1960-69	2000-09	∆SWT
Summer monsoon	28.6017	28.4312	-0.2	28.71	28.75	0.05
Inter-monsoon fall	28.8683	29.2843	0.4	28.55	29.74	1.19
Winter monsoon	27.0366	27.1504	0.1	26.90	27.02	0.11
Inter-monsoon spring	28.8186	28.3225	-0.5	29.12	29.56	0.44

Table 9. Comparison of seasonal variation in ΔSWT in Chilka Lake and offshore region

Season	1960-69	2000-09	ΔSWT	1960-69	2000-09	ΔSWT
Summer monsoon	28.9591	29.3325	0.4	29.10	29.45	0.35
Inter-monsoon fall	29.2175	29.12	-0.1	28.50	29.24	0.73
Winter monsoon	26.0577	26.9429	0.9	26.11	26.73	0.62
Inter-monsoon spring	28.5606	28.4191	-0.1	28.44	28.76	0.32

Evaluation of likely impacts on spawning or survival/ growth of eggs, larvae, juveniles (recruitment success) and possible impact on fishery

Vembanad Lake

In general, it can be stated the spawning/recruitment success of fishes/shellfishes during February and April to September are likely to be impacted, since there is significant increase in temperature and shift in peak (April to May). Spawning/recruitment success of fishes/ shellfishes in the open sea, off Vembanad Lake, during the months February, June-September and November are likely to be impacted, since there is significant increase in temperature during this period.

Case studies

- The major spawning period of *Metapenaeus dobsoni* and *Metapenaeus monoceros* in the offshore region of Vembanad Lake is likely due to be moderately affected (Table 10).
- The major nursery period of *M. dobsoni*, *Fenneropenaeus indicus* and *M. monoceros* in Vembanad Lake will not be affected
- The secondary spawning of *M. dobsoni* and *F. indicus* in the offshore region of Vembanad Lake and corresponding nursery phase in the Vemband Lake are likely to be mildly affected
- The nursery phase of *Liza parsia* and *Liza macrolepis* in the Vembanad Lake is likely to be mildly affected
- The spawning and nursery phase of *Mugil cephalus* in the Vembanad Lake are likely to be strongly affected

Pulicat Lake

Case studies

- Spawning and nursery phase of *Penaeus monodon* and *Penaeus semisulcatus* during the summer monsoon and inter-monsoon fall are not likely to be impacted (Table 11)
- Spawning and nursery phase of *F. indicus* in the Pulicat Lake is likely to be mildly impacted
- Spawning and nursery phase of *P. semisulcatus* during the inter-monsoon spring are likely to be moderately impacted.

Table 10. Evaluation of likely impacts on spawning and early life history (ELH) of common species of Vembanad Lake

Species	Location	Stage	Period	%	Grade
M. dobsoni	VL	ELH	Nov-Dec	0	I
M. dobsoni	OVL	Spawning	Nov-Dec	50	III
M. dobsoni	VL	ELH	Mar-Jun	50	III
M. dobsoni	OVL	Spawning	Mar-Jun	25	II
M. monoceros	VL	ELH	Nov-Dec	0	I
M. monoceros	OVL	Spawning	Nov-Dec	50	III
M. monoceros	VL	ELH	May-Jun	50	III
M. monoceros	OVL	Spawning	May-Jun	50	III
F. indicus	VL	ELH	Oct-Dec	0	I
F. indicus	OVL	Spawning	Oct-Dec	33	II
F. indicus	VL	ELH	Feb-May	50	III
F. indicus	OVL	Spawning	Feb-May	25	II
Liza parsia	VL	ELH	Mar-May	33	III
Liza macrolepis	VL	ELH	Mar-May	33	III
Mugil cephalus	VL	ELH	Jun-Aug	100	IV

OVL-Offshore Vembanad Lake; VL –Vemabanad Lake; ELH –Early life history stages (eggs/larvae/juveniles); Grade I=0% No impact; I = 1-33% impacted; II=34 to 67% moderately impacted; IV-68 to 100% strongly impacted.

Source: Kuttyamma (1975)

Chilka Lake

Case studies

- Of the 11 species of fishes whose spawning periods were analysed, 64% (7 nos.) *viz.*, *Hilsa ilisha, Nematalosa nasus, Pseudosciaena coibor, Rhinomugil corsula, Rastrelliger kanagurta, Lates calcarifer* and *Eleutheronema tetradactylum* are likely to be severely impacted and 36% (4 nos.) such as *Liza macrolepis, Etroplus suratensis, Mugil cephalus* and *Sillago sihama* are likely to be moderately affected (Table 12).
- Of the four species of shrimps studied, the spawning of three species namely, *F. indicus, M. dobsoni* and *P. semisulcatus* is likely to be severely affected.
- The spawning and nursery phase of *M. monoceros* is likely to be moderately impacted.

Table 11. Evaluation of likely impacts on spawning and ELH of common species of Pulicat Lake

Species	Location	Stage	Period	%	Grade
F. indicus	PL	ELS	Jan-Apr	25	II
F. indicus	PL	ELS	Jun -Sep	25	II
P. monodon	PL	ELS	Jan-Apr	25	II
P. monodon	PL	ELS	Aug-Nov	0	I
P. semisulcatus	PL	ELS	Mar-Jun	75	III
P. semisulcatus	PL	ELS	Sep-Oct	0	I

PL –Pulicat Lake; ELH –Early life history stages (eggs/larvae/juveniles); Grade I=0% No impact; I = 1-33% mildly impacted; II=34 to 67% moderately impacted; IV-68 to 100% strongly impacted.

Source: Subramanyam and Rao (1968)

Table 12. Evaluation of likely impacts on spawning and ELH of common species of Chilka Lake

Species	Location	Stage	Period	%	Grade
F. indicus	CL	S & ELH	Apr-May	100	IV
F. indicus	CL	S & ELH	Jul-Sep	100	IV
M. dobsoni	CL	S & ELH	Apr-May	100	IV
M. dobsoni	CL	S & ELH	Jul-Aug	100	IV
M. dobsoni	CL	S & ELH	Jul-Aug	50	III
P. semisulcatus	CL	S & ELH	Jul-Sep	100	IV
M. monoceros	CL	S & ELH	May -Jun	50	III
Hilsa ilisha	CL	S	Aug-Nov	75	IV
Hilsa ilisha	CL	ELH	Nov-Jan	67	III
Nematalosa nasus	CL	S	Apr-Aug	80	IV
Nematalosa nasus	CL	ELH	May, Sep	100	IV
Pseudosciaena coibor	CL	S	Apr-Jul	75	IV
Pseudosciaena coibor	CL	ELH	Jul-Sep	100	IV
Liza macrolepis	CL	S	Oct-Feb	40	III
Liza macrolepis	CL	ELH	Nov-Feb	50	III
Etroplus suratensis	CL	S & ELH	Mar-May	100	IV
Etroplus suratensis	CL	S &ELH	Nov-Jan	67	III
Mugil cephalus	CL	S & ELH	Oct-Mar	40 -50	III
Rhinomugil corsula	CL	S & ELH	Jul-Nov	80	IV
Rastrelliger kanagurta	CL	S	Jul-Nov	80	IV
Lates calcarifer	CL	S & ELH	May-Jun	50	IV
Eleutheronema tetradactylum	CL	S	Jan-Jun	67	III
Eleutheronema tetradactylum	CL	ELH	Apr-Oct	71	IV
Sillago sihama	CL	S & ELH	Oct-Jun	56	III

CL - Chilka Lake