Simulated overhead photovoltaic shading buffers thermal stress and stabilizes water quality dynamics to boost shrimp growth.



Water Quality Dynamics and Growth Responses of Pacific White Shrimp *Penaeus vannamei* under Simulated Photovoltaic Shading During a Hot Dry Season in the Philippines

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Background

Rising energy costs and carbon emissions have driven the integration of photovoltaic (PV) systems into intensive Pacific white shrimp (*Penaeus vannamei*) farming. However, the potential shading effects of overhead PV arrays on pond water quality and shrimp productivity remain poorly understood.

Objectives

This study investigated the effects of simulated overhead photovoltaic (PV) panel shading on water quality dynamics and the growth performance of *P. vannamei* under hot dry season conditions in the Philippines.

Methodology



SHADED **UNSHADED**

56-day tank culture trial (March-May) in triplicate; post-larvae stocked at 58 shrimps/m²

Water quality monitored weekly

Growth parameters evaluated at harvest

Data visualization and statistical analysis

CONCLUSION & RECOMMENDATION



Stilt-mounted PV structures **buffered thermal stress** and **reduced water quality fluctuations**, potentially **improving shrimp productivity** by minimizing metabolic energy expenditure and **allowing more energy to be allocated toward somatic growth**, thereby supporting the development of **energy-neutral and climate-resilient shrimp culture systems**.

Further optimization of PV panel height, spacing, and coverage ratios, as well as large-scale and long-term evaluations across different seasons, are recommended.

Results & Discussion

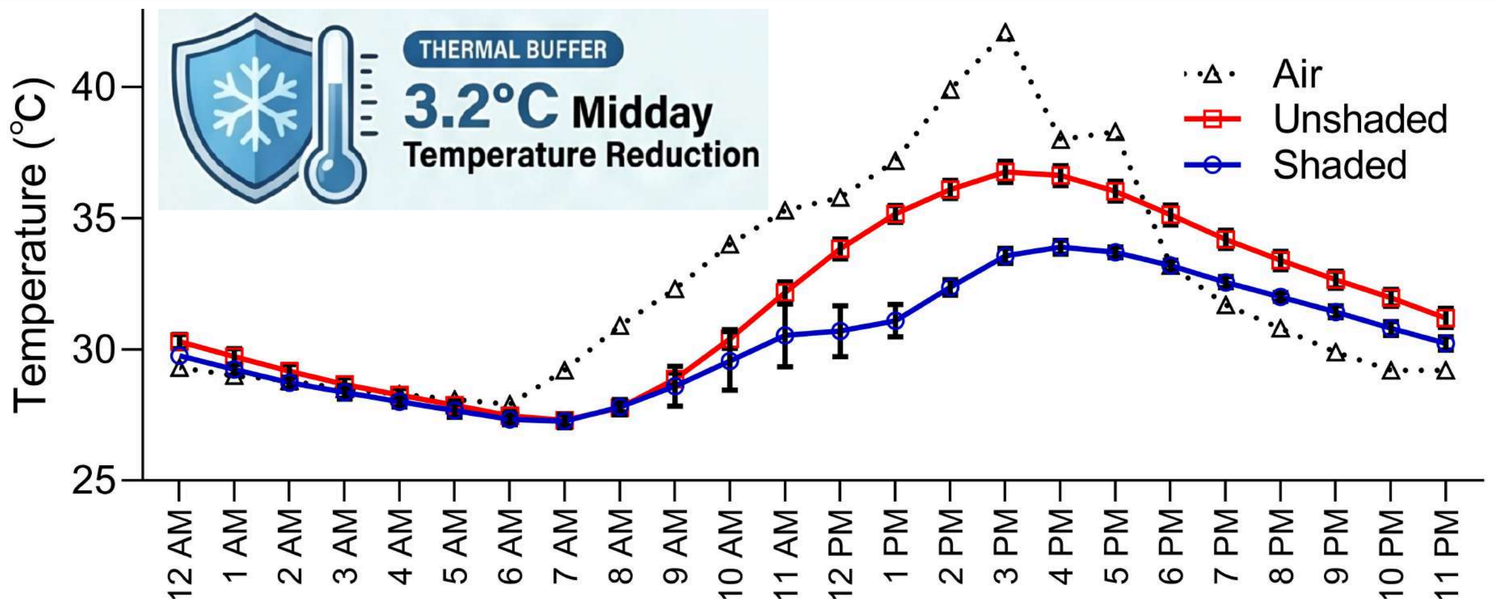


FIG.1 Diel water and air temperature profiles in shaded and unshaded tanks on the hottest day of the study. Values are presented as means and error bars represent SD.

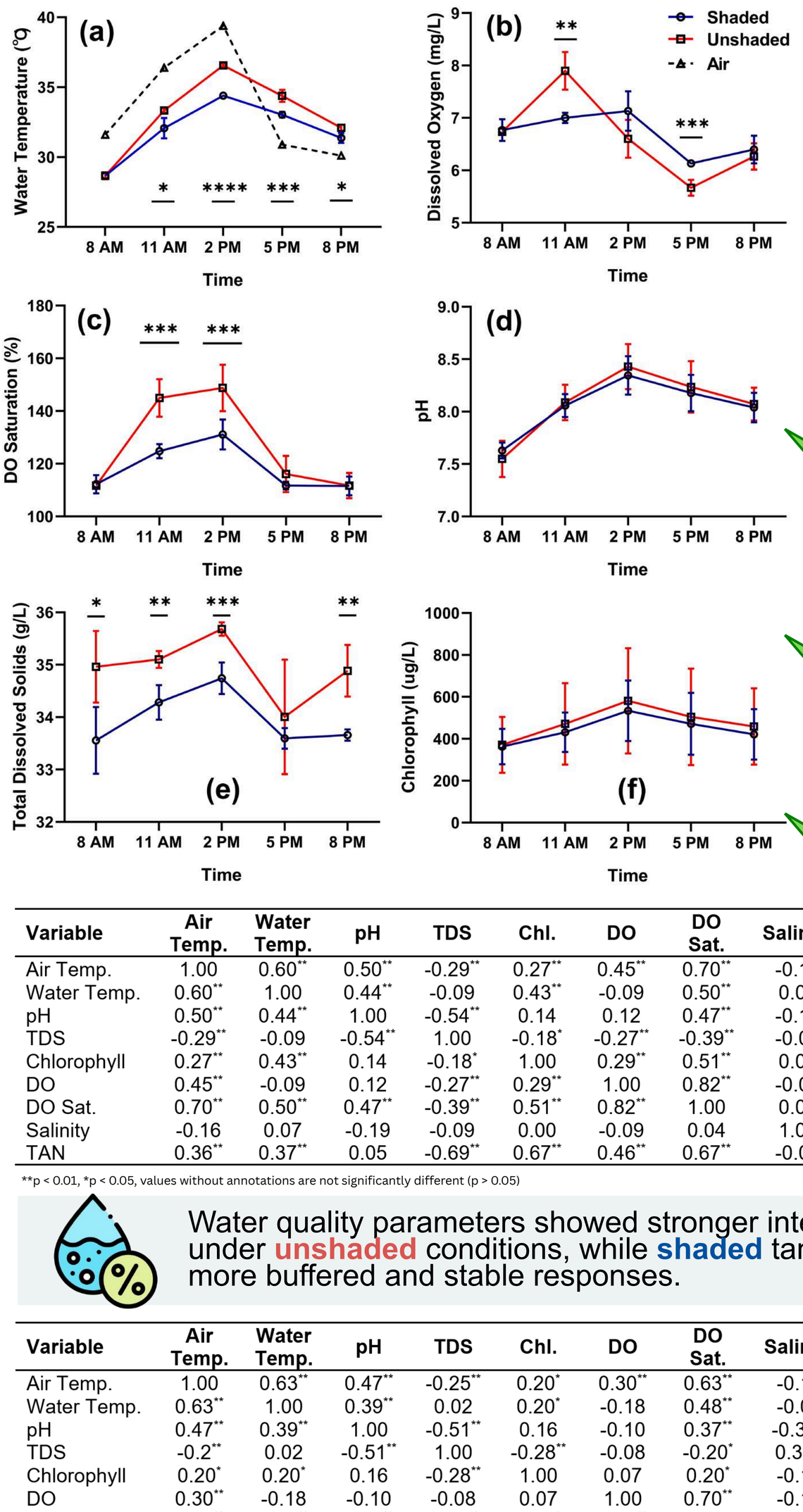


FIG.2 Diurnal water quality profiles during the hottest Week (April 12, 2025) with an air temp. of 39.4 °C.

**p < 0.01, *p < 0.05, values without annotations are not significantly different (p > 0.05)

Overhead PV Shading...

- Maintains active phytoplankton productivity
- Demonstrates lower variability and more stable water quality dynamics
- Reduces risks associated with sudden environmental changes

Variable	Air Temp.	Water Temp.	pH	TDS	Chl.	DO	DO Sat.	Salinity	TAN
Air Temp.	1.00	0.60**	0.50**	-0.29**	0.27**	0.45**	0.70**	-0.16	0.36**
Water Temp.	0.60**	1.00	0.44**	-0.09	0.43**	-0.09	0.50**	0.07	0.37**
pH	0.50**	0.44**	1.00	-0.54**	0.14	0.12	0.47**	-0.19	0.05
TDS	-0.29**	-0.09	-0.54**	1.00	-0.18*	-0.27**	-0.39**	-0.09	-0.69**
Chlorophyll	0.27**	0.43**	0.14	-0.18*	1.00	0.29**	0.51**	0.00	0.72**
DO	0.45**	-0.09	0.12	-0.27**	0.29**	1.00	0.82**	-0.09	0.46**
DO Sat.	0.70**	0.50**	0.47**	-0.39**	0.51**	0.82**	1.00	0.04	0.67**
Salinity	-0.16	0.07	-0.19	-0.09	0.00	-0.09	0.04	1.00	-0.02
TAN	0.36**	0.37**	0.05	-0.69**	0.67**	0.46**	0.67**	-0.02	1.00

TABLE.1 Pearson correlations among water variables under **shaded conditions**

**p < 0.01, *p < 0.05, values without annotations are not significantly different (p > 0.05)

Water quality parameters showed stronger interdependence under **unshaded** conditions, while **shaded** tanks exhibited more buffered and stable responses.

Variable	Air Temp.	Water Temp.	pH	TDS	Chl.	DO	DO Sat.	Salinity	TAN
Air Temp.	1.00	0.63**	0.47**	-0.25**	0.20*	0.30**	0.63**	-0.12	0.44**
Water Temp.	0.63**	1.00	0.39**	0.02	0.20*	-0.18	0.48**	-0.08	0.45**
pH	0.47**	0.39**	1.00	-0.51**	0.16	-0.10	0.37**	-0.38**	0.13
TDS	-0.2**	0.02	-0.51**	1.00	-0.28**	-0.08	-0.20*	0.38**	-0.66**
Chlorophyll	0.20*	0.20*	0.16	-0.28**	1.00	0.07	0.20*	-0.13	0.65**
DO	0.30**	-0.18	-0.10	-0.08	0.07	1.00	0.70**	-0.13	0.21
DO Sat.	0.63**	0.48**	0.37**	-0.20*	0.20*	0.70**	1.00	-0.36**	0.58**
Salinity	-0.12	-0.08	-0.38**	0.38**	-0.13	-0.13	-0.36**	1.00	-0.39**
TAN	0.44**	0.45**	0.13	-0.66**	0.65**	0.21	0.58**	-0.39**	1.00

TABLE.2 Pearson correlations among water variables under **unshaded conditions**

**p < 0.01, *p < 0.05, values without annotations are not significantly different (p > 0.05)

TABLE.3 Zootechnical parameters of *P. vannamei*

Variables	Shaded	Unshaded
Initial weight (g)	0.03±0.06	0.03±0.06
Final Weight (g)	11.68±0.34[a]	10.78±0.23[b]
Final Total Length (cm)	11.31±0.18	10.99±0.19
Fulton's Body Condition Factor (k)	0.80±0.03	0.81±0.02
Average Daily Weight Gain, ADWG (g/day)	0.20±0.01[a]	0.19±0.004[b]
Relative Weight Gain, RWG (%)	3783.81±114.62[a]	3486.49±76.25[b]
Specific Growth Rate, SGR (%/day)	6.65±0.05[a]	6.51±0.04[b]
Feed Conversion Ratio, FCR	1.92±0.02[a]	2.13±0.12[b]
Survival Rate, SR (%)	94.44±5.09	90.00±0.23
Final Biomass, FB (g)	330.61±13.99[a]	291.27±16.62[b]

Data are presented as mean ± SD (n = 3 independent tanks per treatment). Values in rows with different superscripts are significantly different, p < 0.05.

Overall, better growth!

9.9% better FCR; **8.4%** higher final weight; and **13.6%** greater final biomass

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