AQUACULTURE IN THE NEAR FUTURE

Advanced Aquaculture Practices: Enhancing Sustainability, Reducing Carbon Emissions, and Ensuring Animal Welfare

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AQUACULTURE

Biological knowledge to Mathematics or Equations

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Flow Rate Estimation and Biological Sizing in RAS

2.1 Tank size and biomass	Values	Units
Tank water depth	2	m
Tank radius	3.1	m
Tank volume	60.4	m^3
Maximum culture density	60	kg/m^3
Fish biomass	3624.3	kg
Fish count	6000	
Fish weight	604.1	g
Feed rate as % of body weight	1.25%	
Feed rate	45.3	kg/day
2.2 TAN mass balance calculations		
Feed protein content (%)	38%	
Total Ammonia nitrogen (TAN) production rate	1.12	kg/day
% TAN from feed	2.47%	
Desired TAN concentration in recirculated water	1.8	mg/L
Passive nitrification(%)	10%	
TAN available after passive nitrification	1.01	kg/day
Passive denitrification	0.00%	
Maximum nitrate concentration desired	150	mg/L
New water required maintain nitrate concentration	6714.1	L/day
TAN available to biofilter after effluent removal	1.0	kg/day
Biofilter efficiency for TAN removal	50.00%	
Flow rate to remove TAN to desired concentration	1105587.7	L/day
	767.8	L/min

Carbon Emissions

Carbon Emissions

Carbon Emissions and Offsets in Aquaculture

Assumption		
Feed production		
Feed production	2.0	kgCO2/kg of feed
Feed transportation	0.5	kgCO2/kg of feed
Feed conversion ratio (FCR)	1.5	kgCO2/kg of feed
Energy use		
Energy consumption	200.0	kWh per tone of fish produced
Carbon intensity of energy	0.5	kgCO2/kWh
Water use		
Water consumption	1,000.0	liters of water per kg of fish produced
Energy for water pumping	0.1	kWh per liter of water
Waste management		
Waste treatment	0.2	kg CO2/kg of fish produced
Transportation		
Carbon emissions from transporting inputs and products	0.1	kg CO2/kg of fish produced

ANIMAL WELFARE

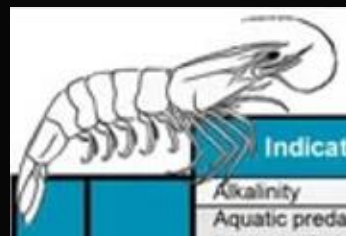
PHASE

- REPRODUCTION
- LARVAL REARING
- TRANSPORTATION
- GROW-OUT

DOMAIN

- ENVIRONMENT
- HEALTH
- NUTRITIONAL
- BEHAVIOURAL

Pedrazzani, A.S.; Cozer, N.; Quintiliano, M.H.; Tavares, C.P.d.S.; da Silva, U.d.A.T.; Ostrensky, A. Non-Invasive Methods for Assessing the Welfare of Farmed White-Leg Shrimp (Penaeus vannamei). Animals 2023, 13, 807.



DOMAIN		Indicators	PHASE: Reproduction	Larval rearing	Transport	Grow-out
	Environmental	Alkalinity	●	●		●
		Aquatic predators and interspecific inhabitants	●			●
		Stocking density	●	●	●	●
		Dissolved oxygen	●	●	●	●
		NH_3-Ammonia	●	●	●	●
		Nitrite	●	●		●
		pH	●	●	●	●
		Photoperiod	●	●		
		Salinity	●	●	●	●
		Temperature	●	●	●	●
		Terrestrial predators	●			●
		Transparency				●
	Health	Antennae	●			●
		Epibionts		●		
		Exoskeleton (cuticle)	●	●	●	●
		Eyes	●			●
		Gastrointestinal tract	●			
		Genetic Selection	●			
		Gills	●			●
		Health certificate		●		
		Hepatopancreas	●	●		●
		Invasive procedures	●			
		Luminescence	●	●		
		Malformations		●	●	
		Mortalities rates	●	●	●	●
		Motor appendages	●			●
		Musculature	●	●	●	●
		Rostrum	●			●
		Sexual maturation	●			
		Uniformity of stages		●		
	Nutritional	Amount of food	●			●
		Analysis of gastrointestinal tract	●	●		●
		Composition/type of diet	●	●	●	●
		Distribution of feed				●
		Feed conversion rate				●
		Feed crude protein	●	●		●
		Frequency of feeding	●	●	●	●
		Size of food		●		●
	Behavioural	Anaesthesia	●			
		Escape behaviour				●
		Phototaxis		●		
		Reaction to offered food	●			
		Stunning reflexes at slaughter				●
		Swimming behaviour	●	●	●	●

GROW-OUT STAGE

ENVIRONMENTAL INDICATORS

HEALTH INDICATORS

NUTRITIONAL INDICATORS

BEHAVIOURAL INDICATORS

ENVIRONMENTAL INDICATORS

Indicators	Score	Reference Values	References
Temperature (°C)	1	24.5–32.5	[73,74,75,76,77,78,79,80]
	2	15.6–24.4 or 32.6–35.4	
	3	≤15.5 or ≥35.5	
pH	1	7.5–8.5	[75,76,77,79,81,82,83,84]
	2	5.0–7.4 or 8.6–9.0	
	3	≤4.9 or ≥9.1	
Photoperiod (Light: Dark)	1	Natural or 12L:12D–14L:10D	[75,76,79,80,85,86]
	2	15L:9D–16L:8D	
	3	17L:7D or clearer; 11L:13D or darker	
Alkalinity (mg/L $CaCO_3$)	1	100–140	[81,83,87,88,89]
	2	51–99 or 141–199	
	3	≤50 or ≥200	
Dissolved oxygen (% saturation)	1	≥62	[80,81,83,87,88,90,91]
	2	46–61	
	3	≤45	

HEALTH INDICATORS

Indicators	Score	Description or Reference Values	References
Antennae	1	Healthy appearance, no changes	[105,106,107]
	2	A focal lesion, shortening, or darkening	
	3	Absence, blueness, wrinkling, multifocal dark spots	
Rostrum	1	Healthy appearance, no changes	[107,108,109]
	2	Mild injury, erosion, or necrosis	
	3	Severe injury, erosion or necrosis, deformity, bending to one side, upwards or downwards	
Eyes	1	Healthy appearance, no changes	[108,110,111]
	2	Unilateral lightening, injury, softening or swelling	
	3	Bilateral lightening, injury, softening or swelling, absence of one or both organs	
Gills	1	Healthy appearance, no changes	[112,113,114]
	2	Focal lesion or darkening	
	3	Pale, yellowish, general redness or darkening, whitish spots, erosion	

NUTRITIONAL INDICATORS

Indicators	Score	Weight (g)				References
		≤0.9	1.0–3.9	4.0–8.9	9.0–15.0	
Size of food (mm)	1	0.1–0.5	0.6–1.0	1.1–2.0	2.1–3.0	[149,206]
	2	≥0.6	≥1.1	≥2.1	≥3.1	
	3	<0.1	≤0.5	≤1.0	≤2.0	
Amount of initial food (% of biomass)	1	6.0–10.9	4.0–6.9	4.0–6.9	2.0–3.9	[75,87,126,206,207]
	2	4.1–5.9	2.1–3.9	2.1–3.9	1.1–1.9	
	3	≤4.0 or ≥11.0	≤2.0 or ≥7.0	≤2.0 or ≥ 7.0	≤1.0 or ≥4.0	
Frequency of feeding in the ponds (times/day)	1	≥4	≥2	≥2	≥2	[87,126,127,128,129,130,131,132,208]
	2	2–3	1	1	1	
	3	≤1	<1	<1	<1	
Feed crude protein (%)	1	≥35	≥35	≥32	≥32	[87,126,127,128,140,142,206]
	2	32–34	32–34	25–31	25–31	
	3	≤31	≤31	≤24	≤24	
Apparent feed conversion rate (FCR) *	1			≤1.5	≤1.7	[89,126,209,210,211,212,213]
	2	Does not apply	Does not apply	1.6–2.0	1.8–2.0	

BEHAVIOURAL INDICATORS

Management	Indicators	Score	Reference Values	References
Routine management	Swimming behaviour	1	No shrimp on the pond surface or irregular swimming	[91,144,145]
		2	Few animals on the pond surface or irregular swimming	
		3	Reduced, irregular or “spiral” swimming, accumulation of shrimp at the edges of the pond or near the water inlet, many animals exposing their bodies at the water surface	
Partial or complete harvesting	Escape behaviour (successive tail movements by flexion and extension of the abdomen)	1	Few jumping shrimps during harvest, with low frequency and intensity	[218]
		2	Few jumping shrimps, but with high frequency and/or intensity during harvesting	
		3	Many jumping shrimps, high frequency and/or intensity during harvesting	
Stunning at slaughter *	Clinical reflexes	1	Immediate loss of response to external stimuli; balance (with cephalothorax in horizontal and descending position); movement of pleopods and pereiopods; and movement of scaphognathites	[146,147,186,219,220,221]
		2	Progressive loss of response to external stimuli; balance (with cephalothorax in horizontal and descending position); movement of pleopods and pereiopods; and movement of scaphognathites in ≤30 s	
		3	Progressive loss of: Response to external stimuli; balance (with cephalothorax in horizontal and descending position); movement of pleopods and pereiopods; and movement of scaphognathites in >30 s	

WELFARE ASSESSMENT

Environment indicators		
Temp (C°)	38	3
pH	9.2	3
Trans (cm)	33	2
ALK (mg/L $CaCO_3$)	180	2
TAN (mg/L de NH_3)	0.34	3
DO (% saturation)	50	2
NO_2-N (mg/L NO_2)	1.9	3
Sal (psu)	0.5	3
Stocking density (shrimp/m^2)	30	1
Terrestrial predators *		Absence = 1, Controlled presence = 2, Uncontrolled presence = 3
Aquatic predators and interspecific inhabitants**		Absence = 1, Controlled presence = 2, Uncontrolled presence = 3

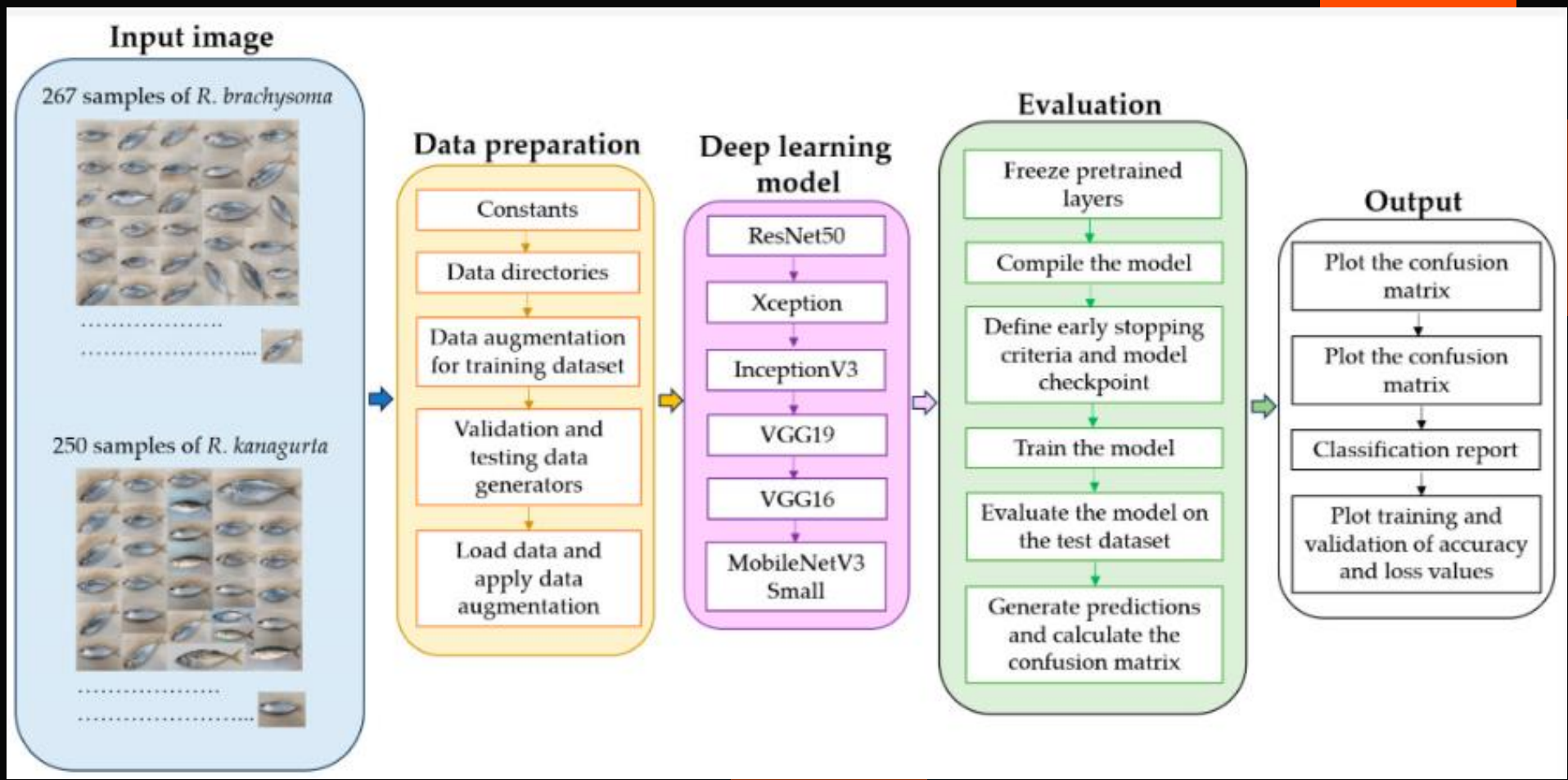
* Birds, mammals, and reptiles.

** Fish, other crustaceans, molluscs, amphibians, and reptiles.

Silva and Ostrensky (2023)

DEEP LEARNING, AI

EX: FISH CLASSIFICATION



Jongjaraunsuk, R.; Taparhudee, W.; Sirisuay, S.; Kaewnern, M.; Dulyapurk, V.; Janekitkarn, S. Transfer Learning Model Application for *Rastrelliger brachysoma* and *R. kanagurta* Image Classification Using Smartphone-Captured Images. *Fishes* 2024, *9*, 103. https://doi.org/10.3390/fishes9030103

DEEP LEARNING, AI

EX: WATER QUALITY

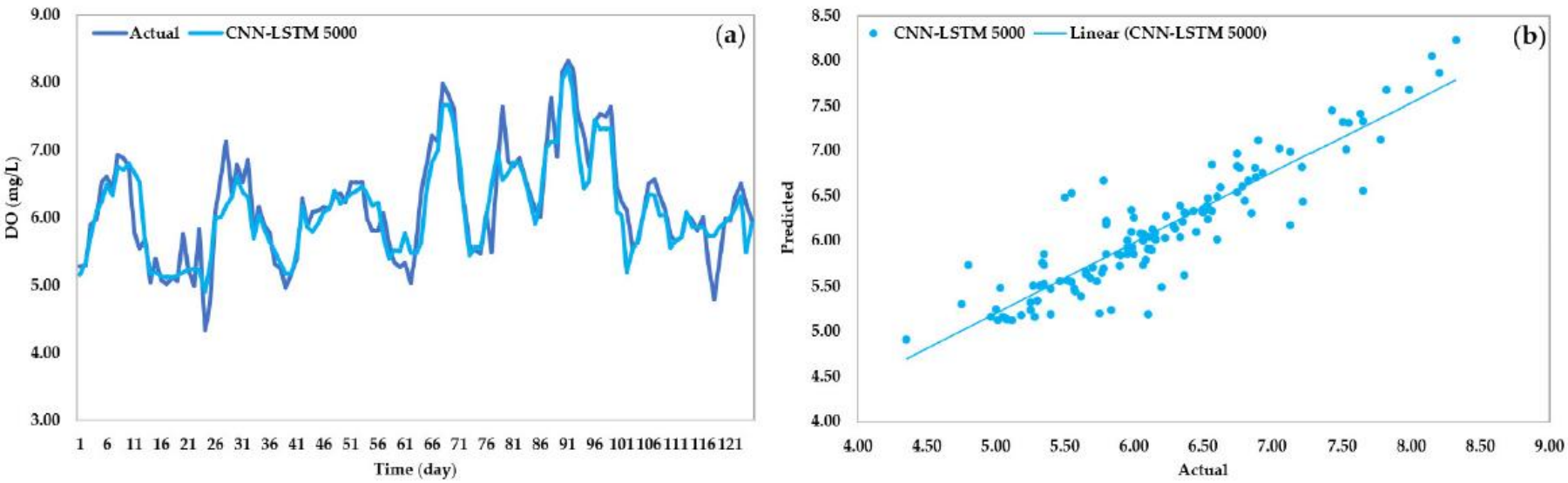
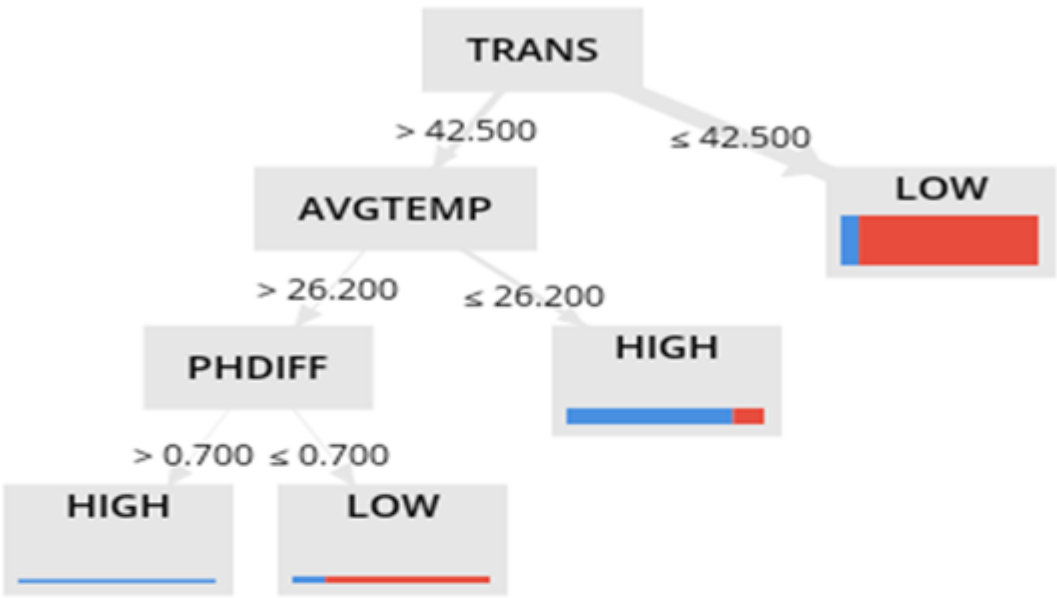


Figure 5. Actual and predicted values (**a**), along with a scatter graph (**b**), obtained from the CNN–LSTM model after 5000 epochs of DO.

Jongjaraunsuk, R.; Taparhudee, W.; Suwannasing, P. Comparison of Water Quality Prediction for Red Tilapia Aquaculture in an Outdoor Recirculation System Using Deep Learning and a Hybrid Model. *Water* 2024, *16*, 907. https://doi.org/10.3390/w16060907

DEEP LEARNING, AI

EX: FISH MORATLITY

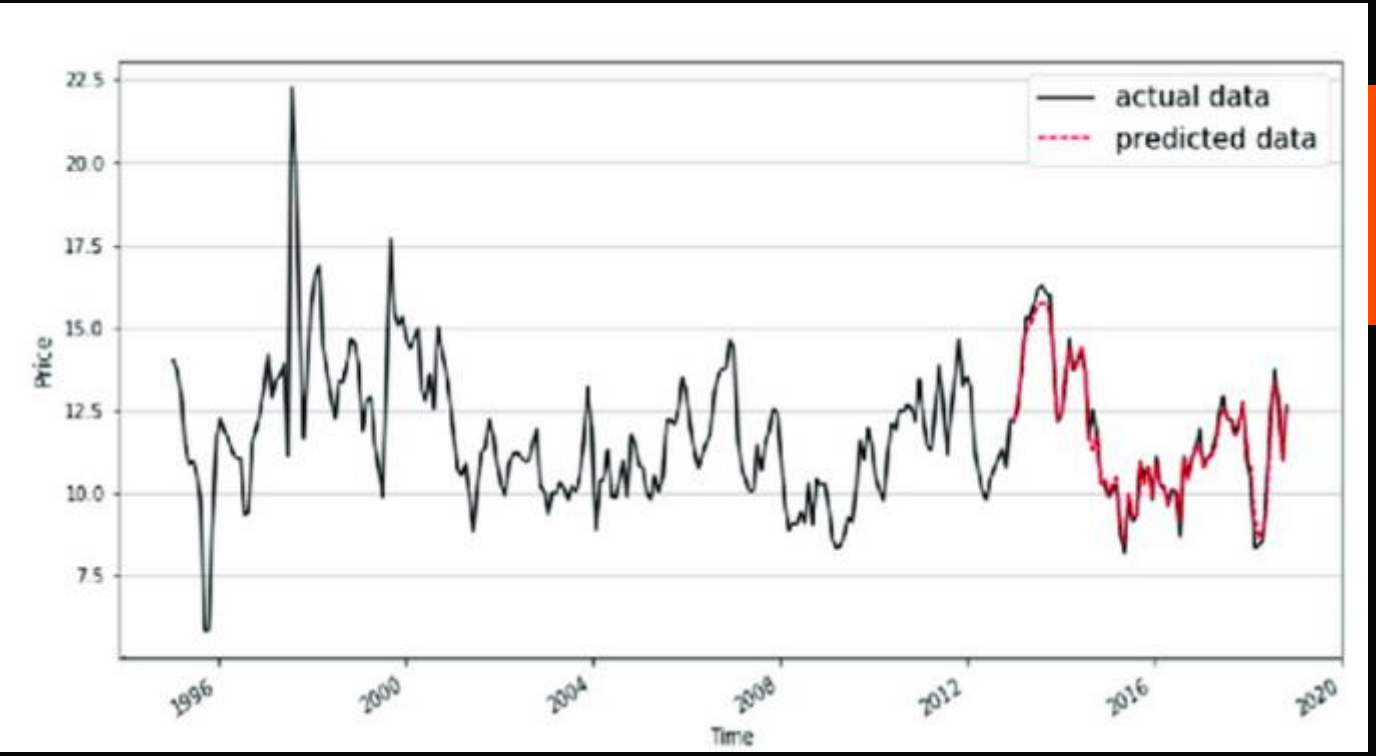


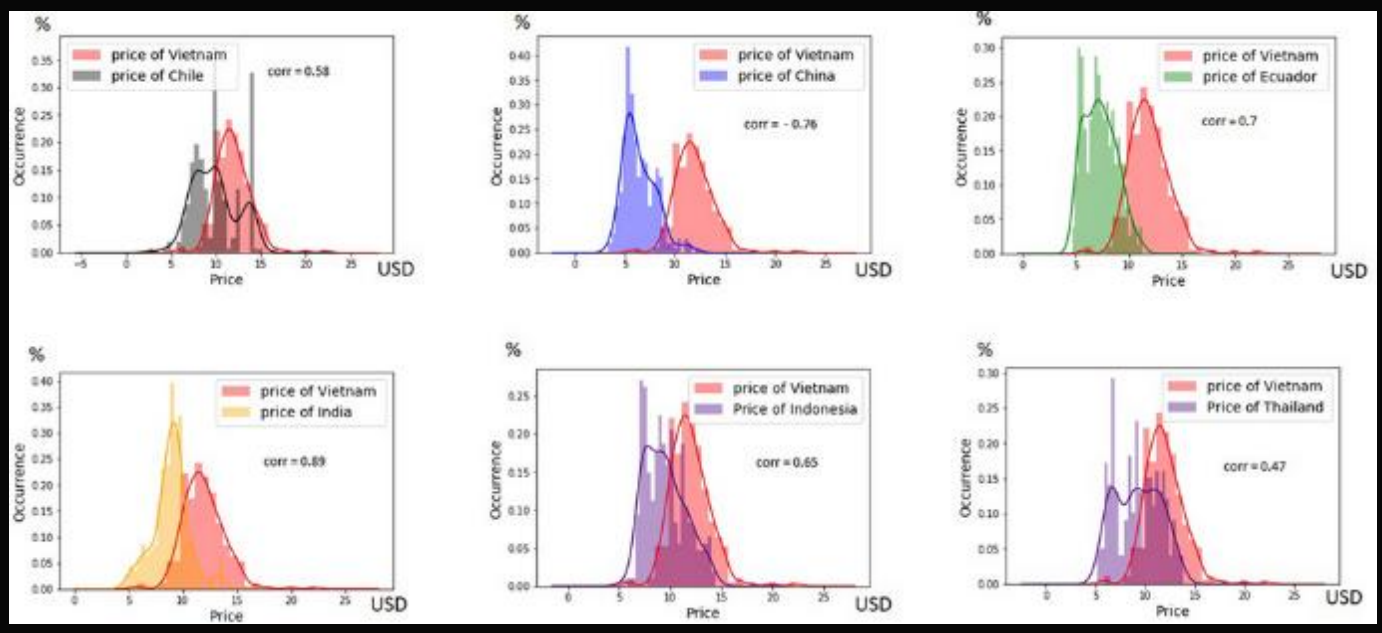
Emerald fish mortality

Trans (cm)	43
Average Temp (Morning & Afternoon)(C°)	27
pH diff (Morning & Afternoon)	0.3
Fish mortality rate: Less than 10 fish per day	Low

DEEP LEARNING, AI

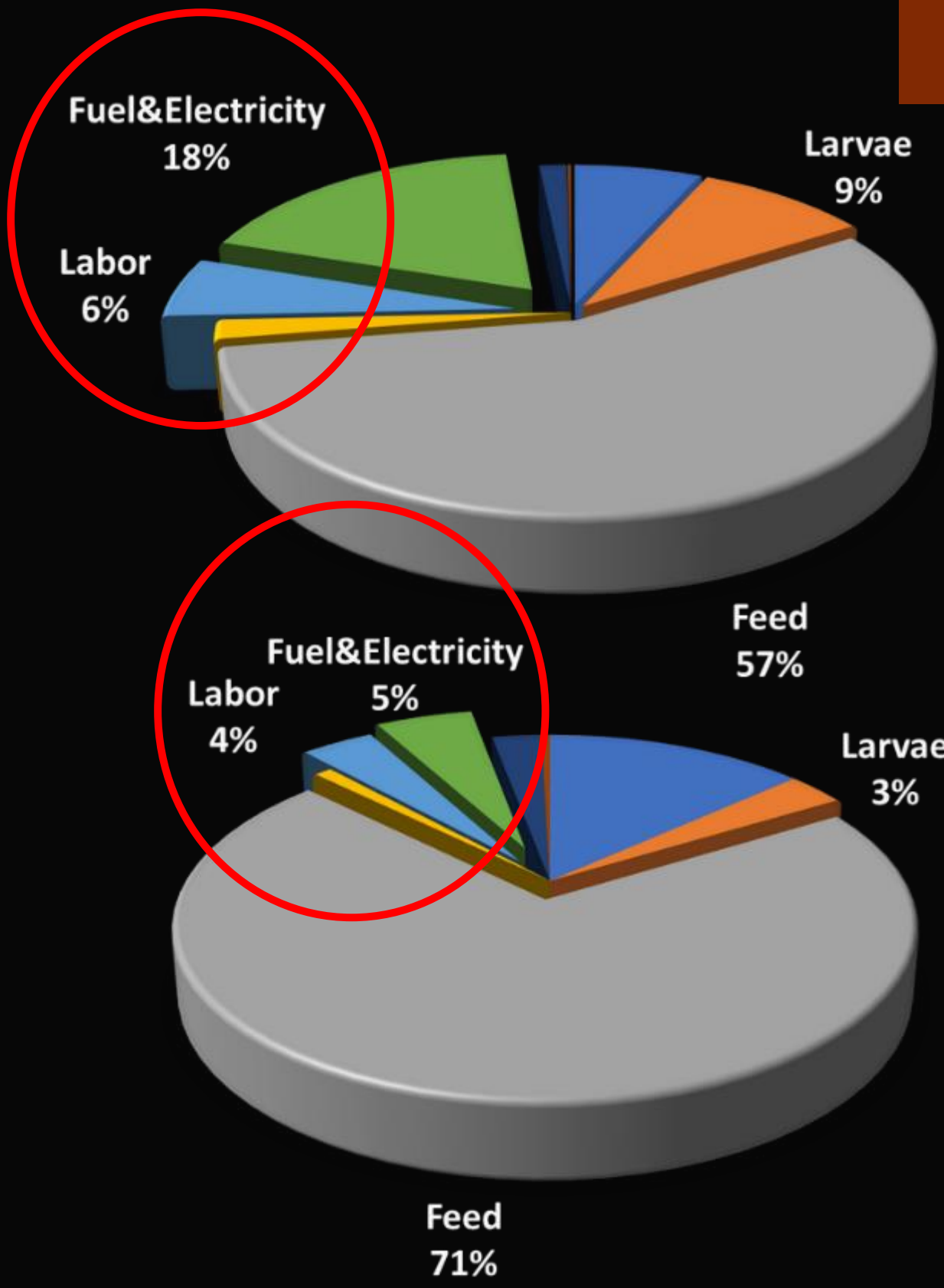
EX: MARKET AND PRICE PREDICTION





Khiem et al. (2022) A novel machine learning approach to predict the export price of seafood products based on competitive information: The case of the export of Vietnamese shrimp to the US market.

VARIABLE COSTS



Shrimp culture

Fish culture

AWARE BUT NOT MINDFUL