CLIMATE INFORMATION SYSTEMS (CIS) FOR AQUACULTURE: DEVELOPMENT OF A TEMPERATURE-BASED EARLY WARNING ALERT SYSTEM FOR FISH FARMERS IN ZAMBIA.

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Photo by Stefan Els

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1. Introduction:

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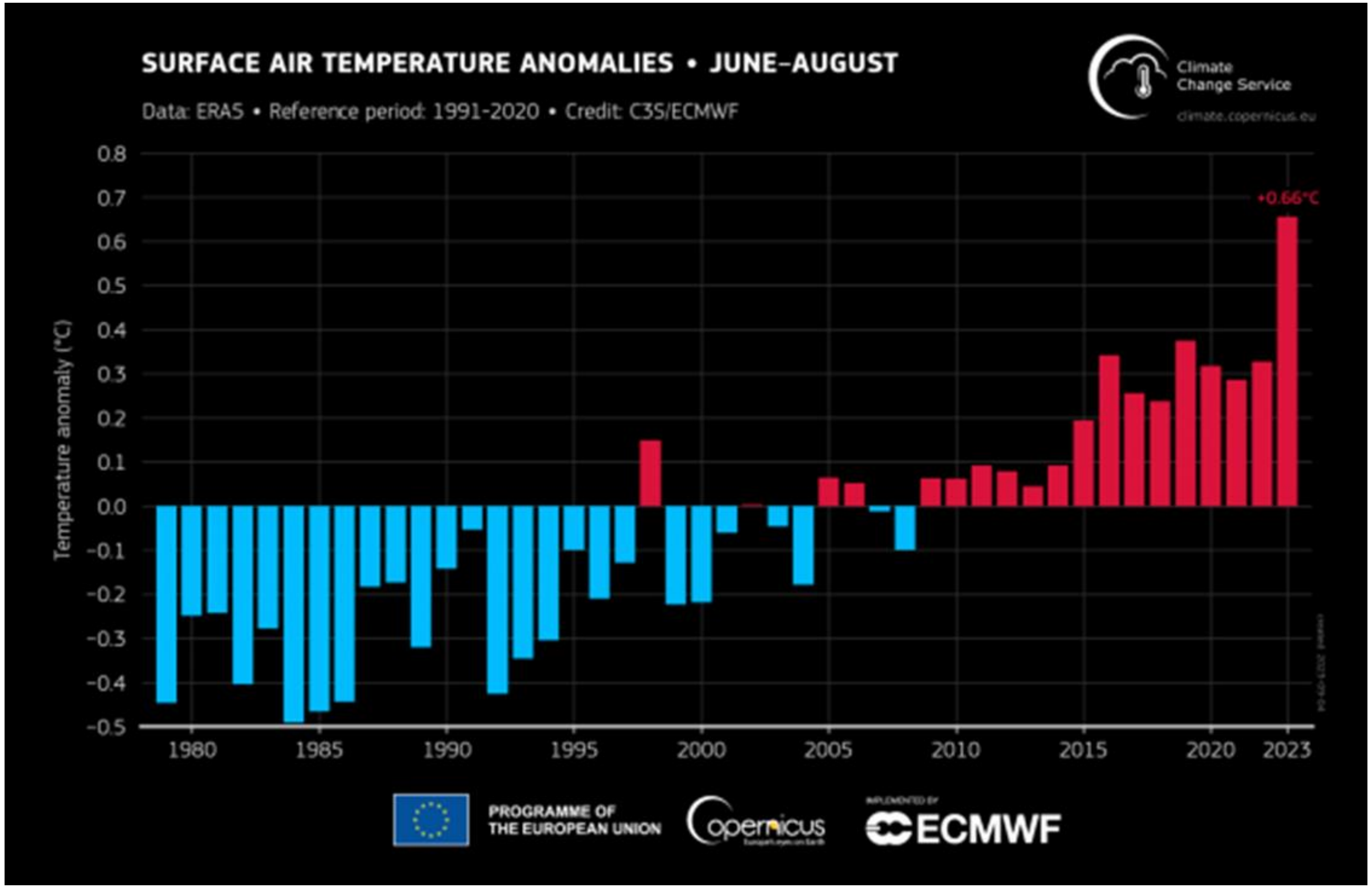

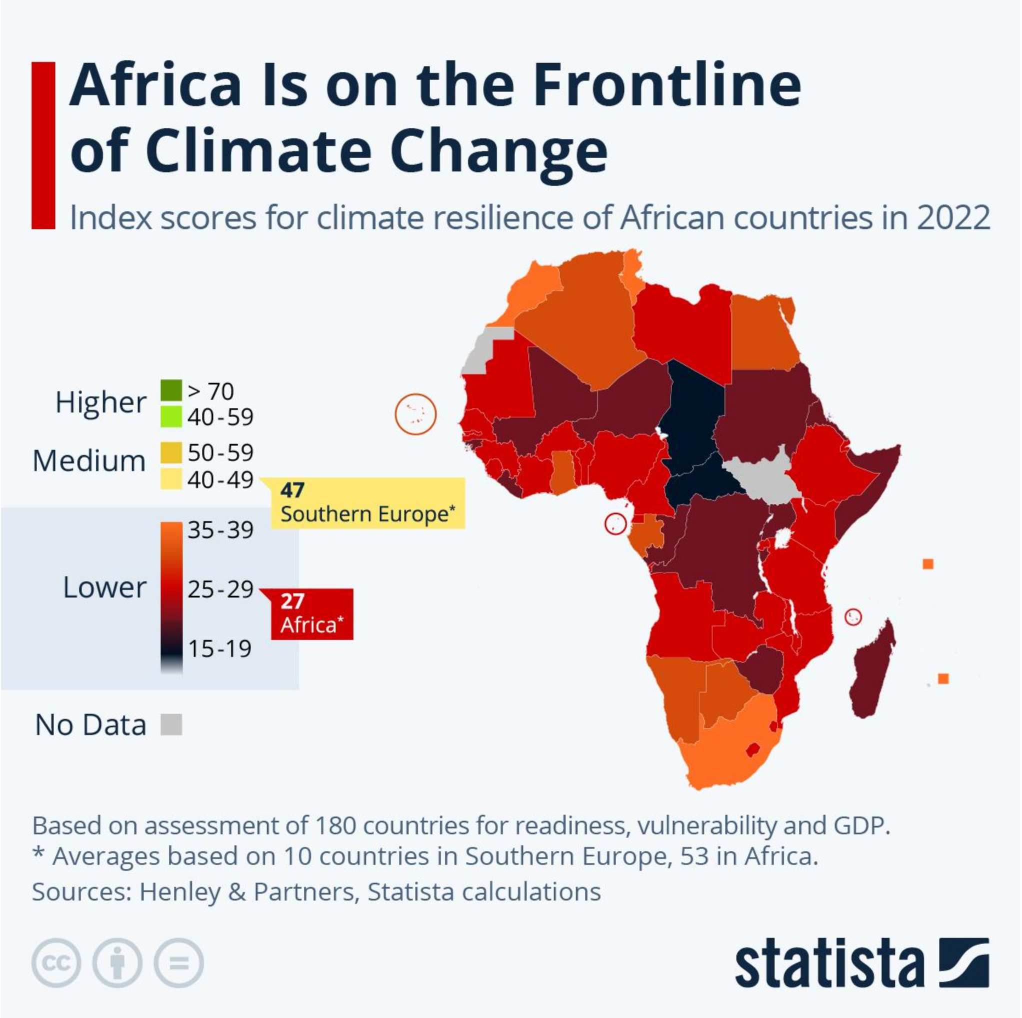

2. Tilapia Species farmed in Zambia:

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- Greenheaded tilapia (*Oreochromis macrochir)*
- Tanganyikan tilapia (*Oreochromis tanganicae)*
- Three Spotted tilapia *(Oreochromis andersonii)*
- Red-breasted tilapia *(Coptodon rendalii)*
- Banded tilapia *(Tilapia sparmanii)*
- Nile tilapia *(Oreochromis niloticus)*

3. Optimal Water Temperature for Nile Tilapia:

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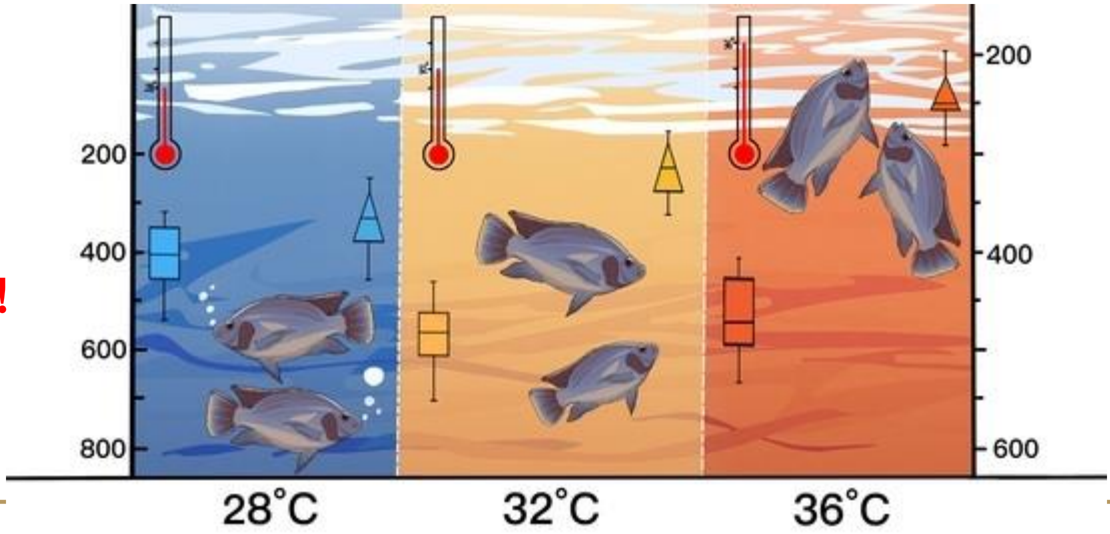
- Optimum temperature for Nile tilapia 28°C – 35 °C
- No reproduction below 20°C
- Growth is poor below 16°C
- Upper lethal limit are near 40°C - 42°C
- Lower lethal limit 8°-12°C
- When fish are fed to satisfaction, growth at the preferred temperature is typically 3 x greater than at 22°C

Focus on water temperature for optimum growth and not temperature tolerance spectrum!



3. Optimal Water Temperature for Nile Tilapia:

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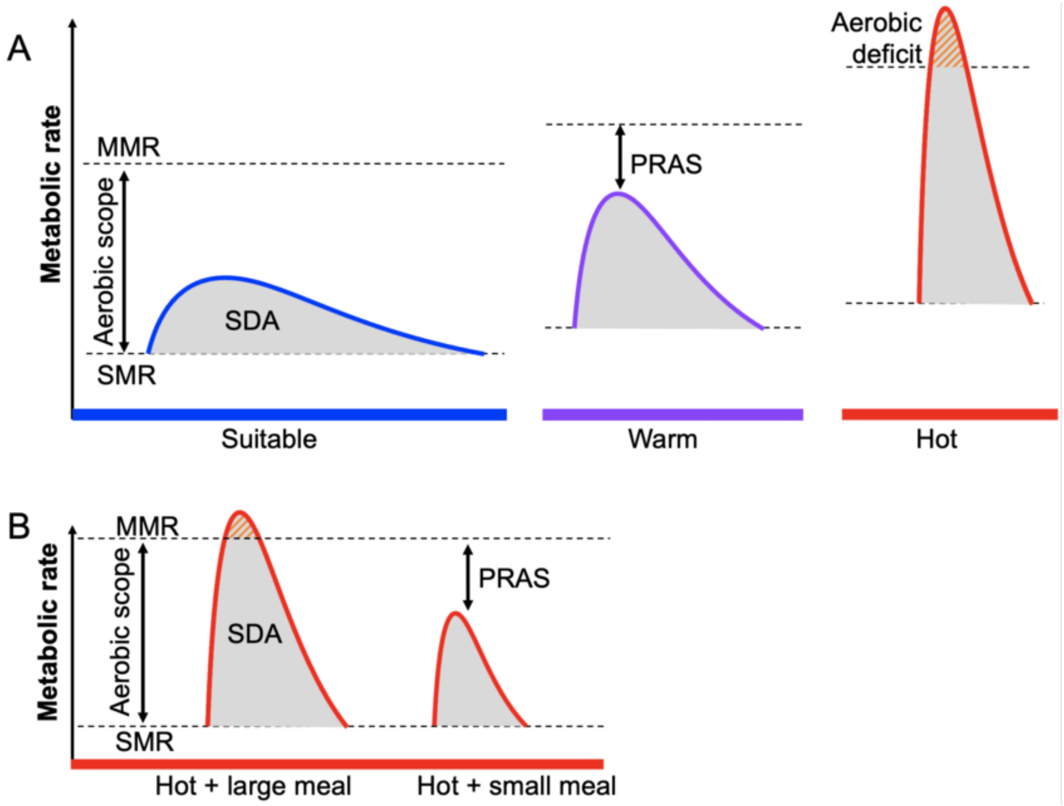
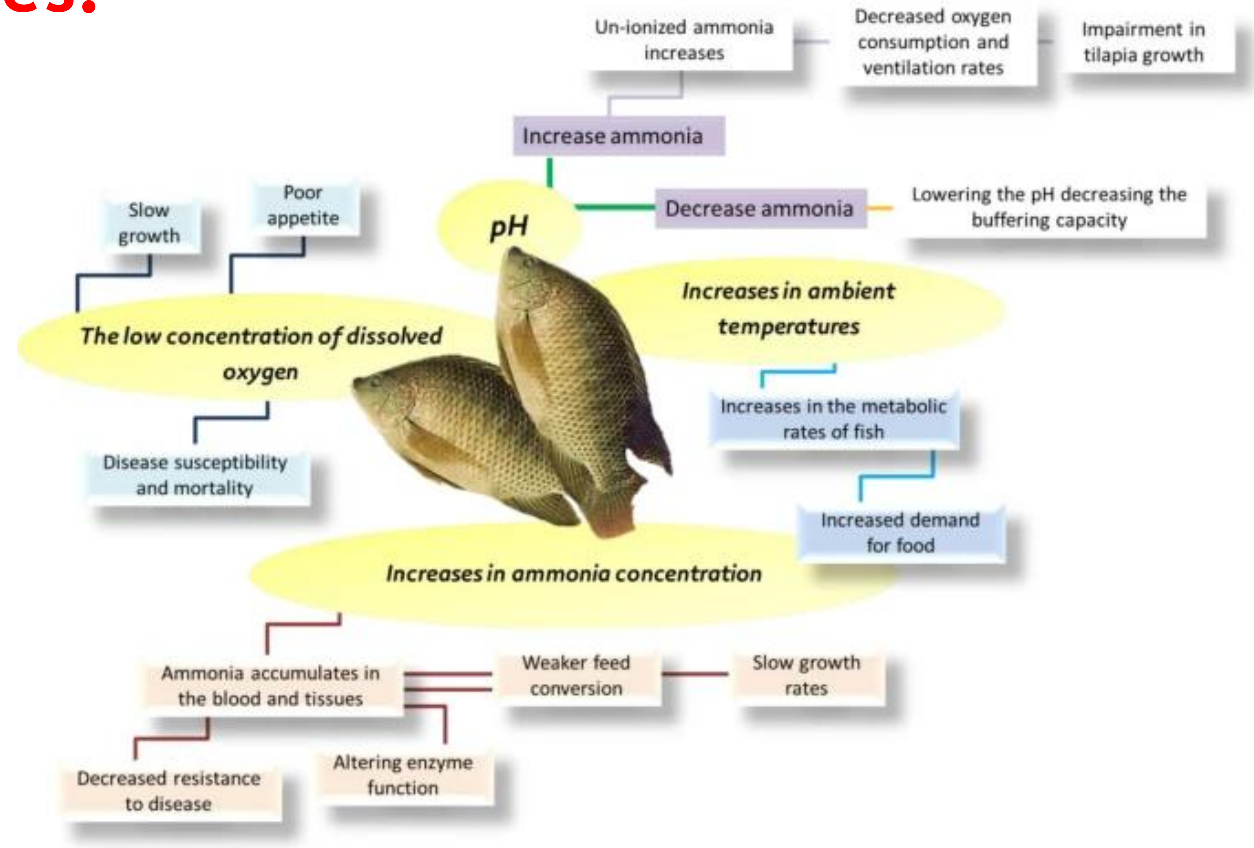
The effect of temperature changes:





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Abd El-Hack, M.E., El-Saadony, M.T., Nader, M.M. et al. Effect of environmental factors on growth performance of Nile tilapia (Oreochromis niloticus). Int J Biometeorol 66, 2183–2194 (2022). https://doi.org/10.1007/s00484-022-02347-6

4. Production Systems used:

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Smallholder/Smallscale aquaculture in the north practice integrated farming systems by combining fish farming with crops and livestock farming to obtain optimal productivity in their land use, despite seasonal unfavourable weather conditions.

5. Key objectives of the project:

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- Development of an air-water temperature relationship algorithm to enable forecasting of pond water temperatures using air temperature trend data.
- Development of a decision support tree that translates water temperature forecasting risk scenarios into an early-warning alert system with associated mitigation measures.
- Integrate the alert system into iSAT with the ability to send real-time alerts to farmers in the Northern and Luapula Provinces of Zambia.
- Optimization of environmental monitoring protocols and equipment and conceptualization of medium- and long-term interventions needed to build resilience to climate change trends.

6. Data Collection:

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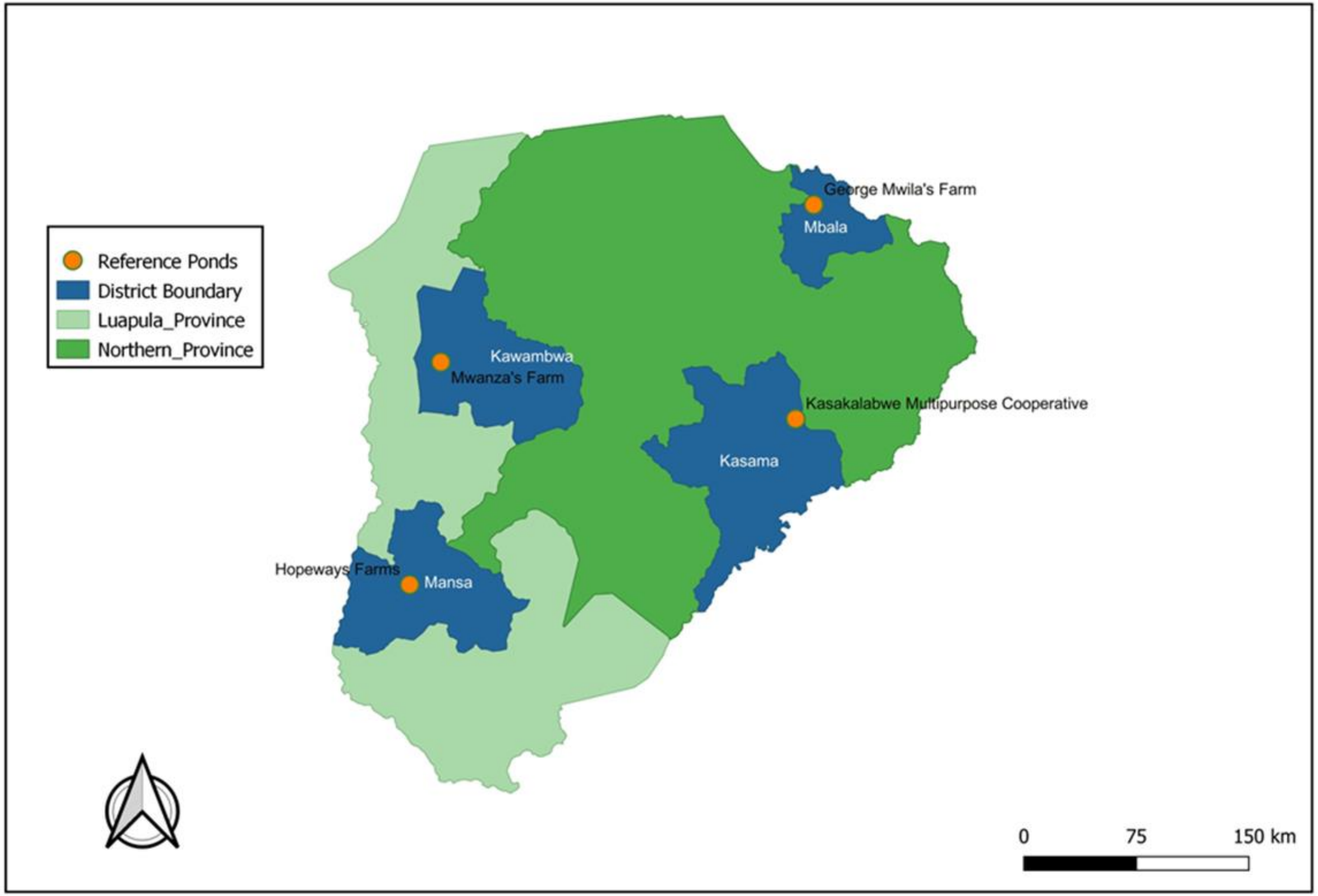

6. Data Collection:

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- Tilapia farmers supplied the raw data to WordFish and WorldFish to SU.
- A total of 4 reference points were used.
- Air temperature minimum and maximum and water temperature data were collected at each point at 9h00 and 17h00 every day.
- We have decided to use the data set from the beginning of March to the end of August 2023, this was the most complete data set.
- The data set was first cleaned, and missing data points were filled by using the mean in a calculation.
- Program used – Python Programming
- Language used – Jupiter notebook environment

7. Data Science:

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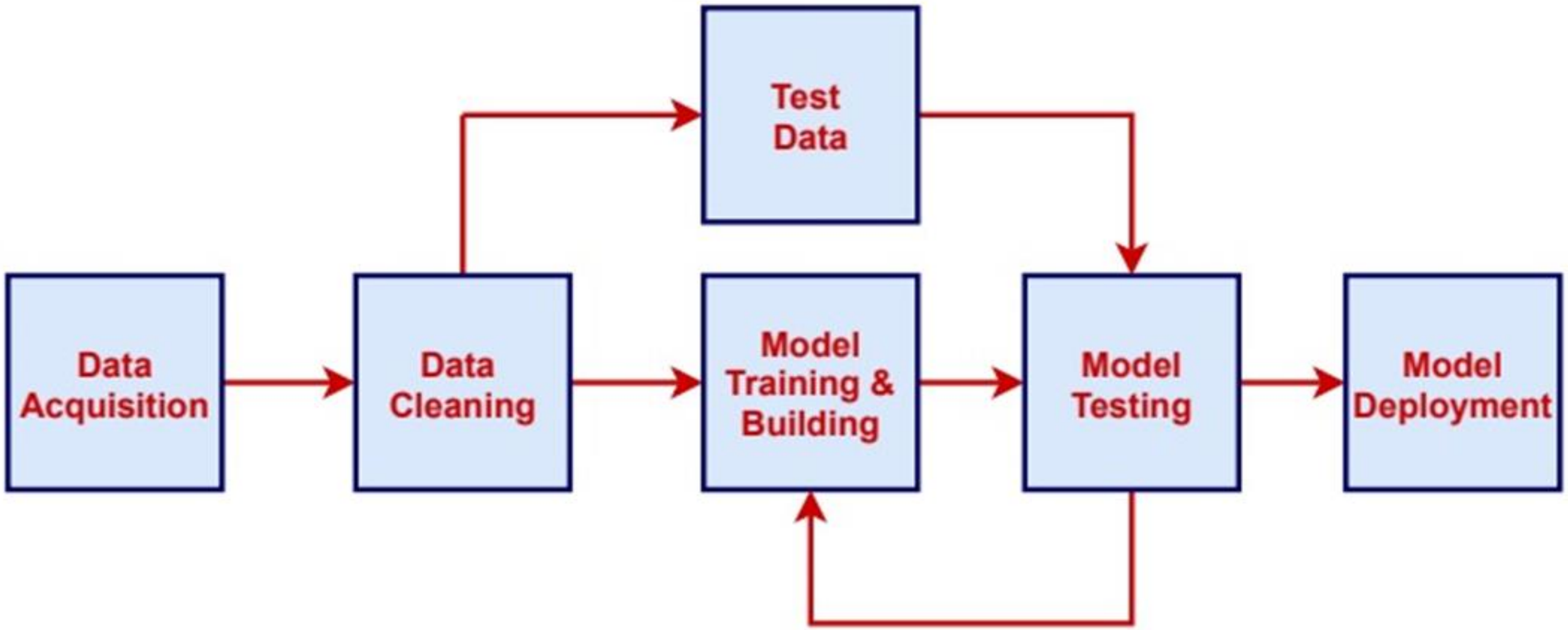
The process followed:



7. Data Science:

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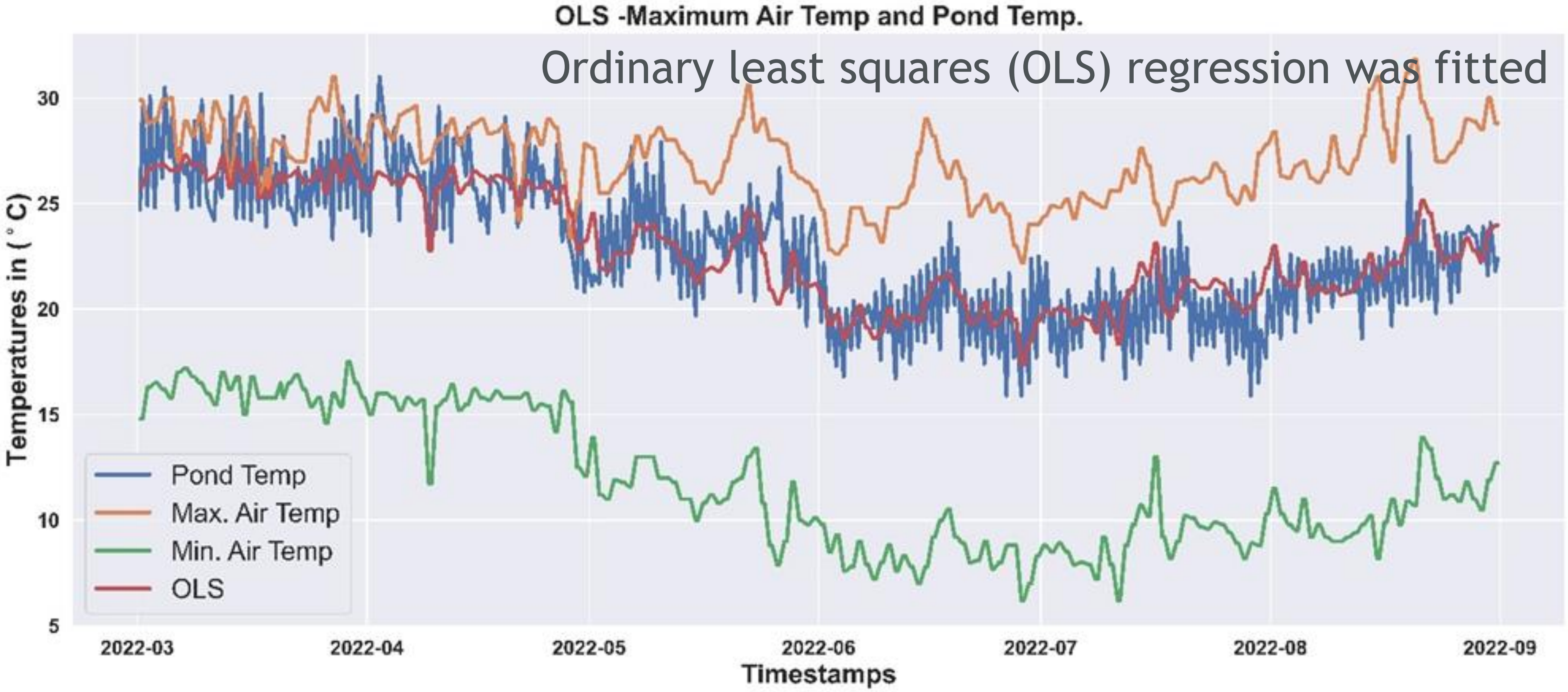
- During model development, five models were compared, including linear regression, stochastic regression, deep learning, random forest, and decision tree.
- The data was modelled for a pond designed according to best aquaculture practices, and therefore, pond size and pond depth are constants.
- A linear regression model for pond temperature is expressed as:

$$Y(t) = \alpha X1 \quad + \beta X2 + C + \Upsilon$$

$$(y = mx + c)$$

- where α and β are the gradients (coefficients) of the maximum and minimum air temperature features, respectively. Additionally, C denotes the intercept and ϒ is the error coefficient. Y(t) is the predicted pond temperature in degrees centigrade at time t. The R-squared value for the linear regression was 0.6, hence the linear regression was a good fit.

7. Data Science



Seasonal pattern of the air temperature, pond temperatures, and predicted pond temperatures using the linear regression model.

7. Data Science

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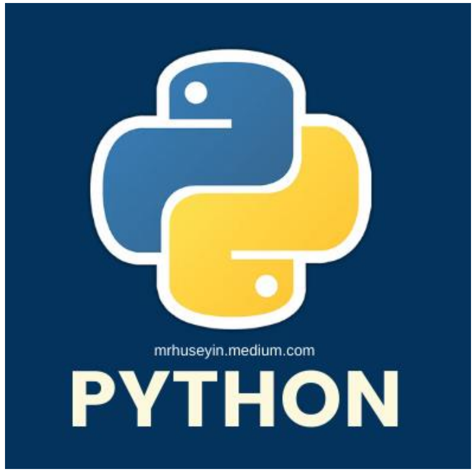
- **Statistical modeling**
- Used two Python models:
    1) Statsmodels
    2) SciKit-Learn (SK-Learn)
- **Machine Learning**
- Used three Python models:
    1) Deep Learning
    2) Random Forest
    3) Decision Trees



7. Data Science:

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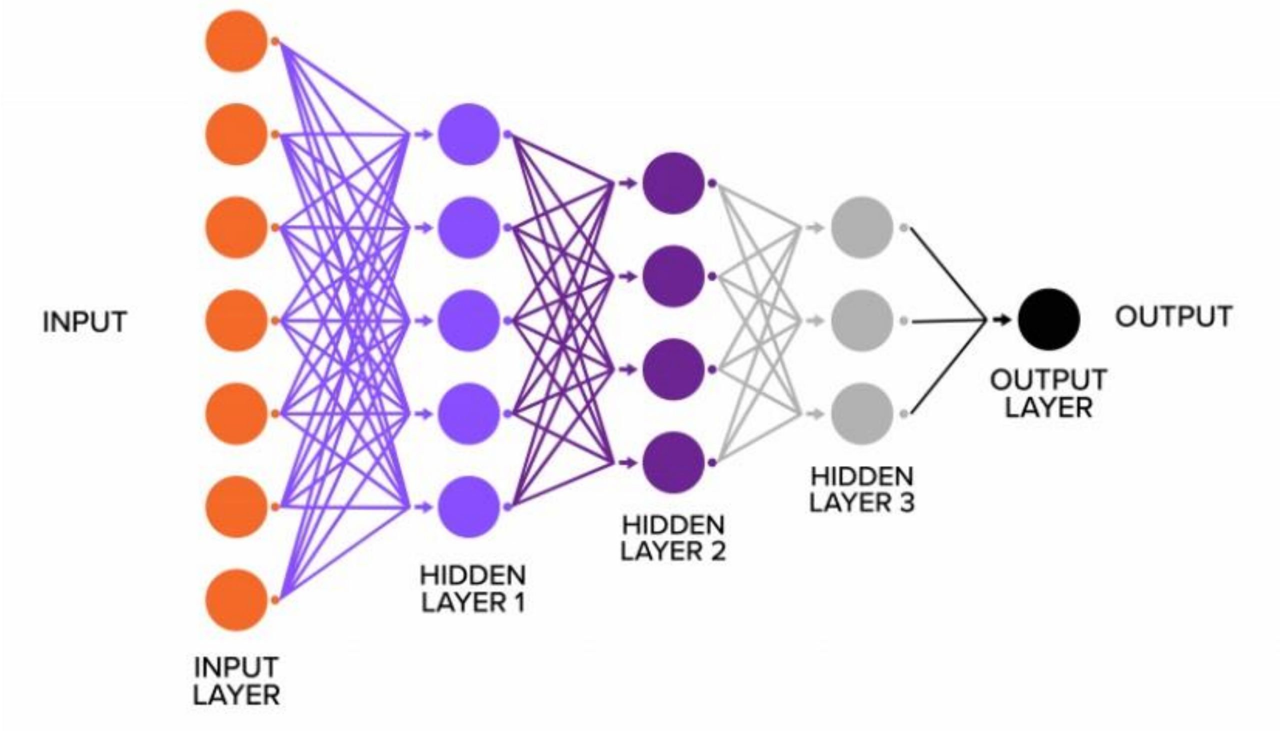
An illustration of the DNN architecture (Smartboost, 2020)



- There were 368 data points in time, 1 day have 2 points at 9h00 and 17h00
- The data set was split after cleaning (Training 70% and Testing 30%)
- 4 hidden layers in this model

8. Results:

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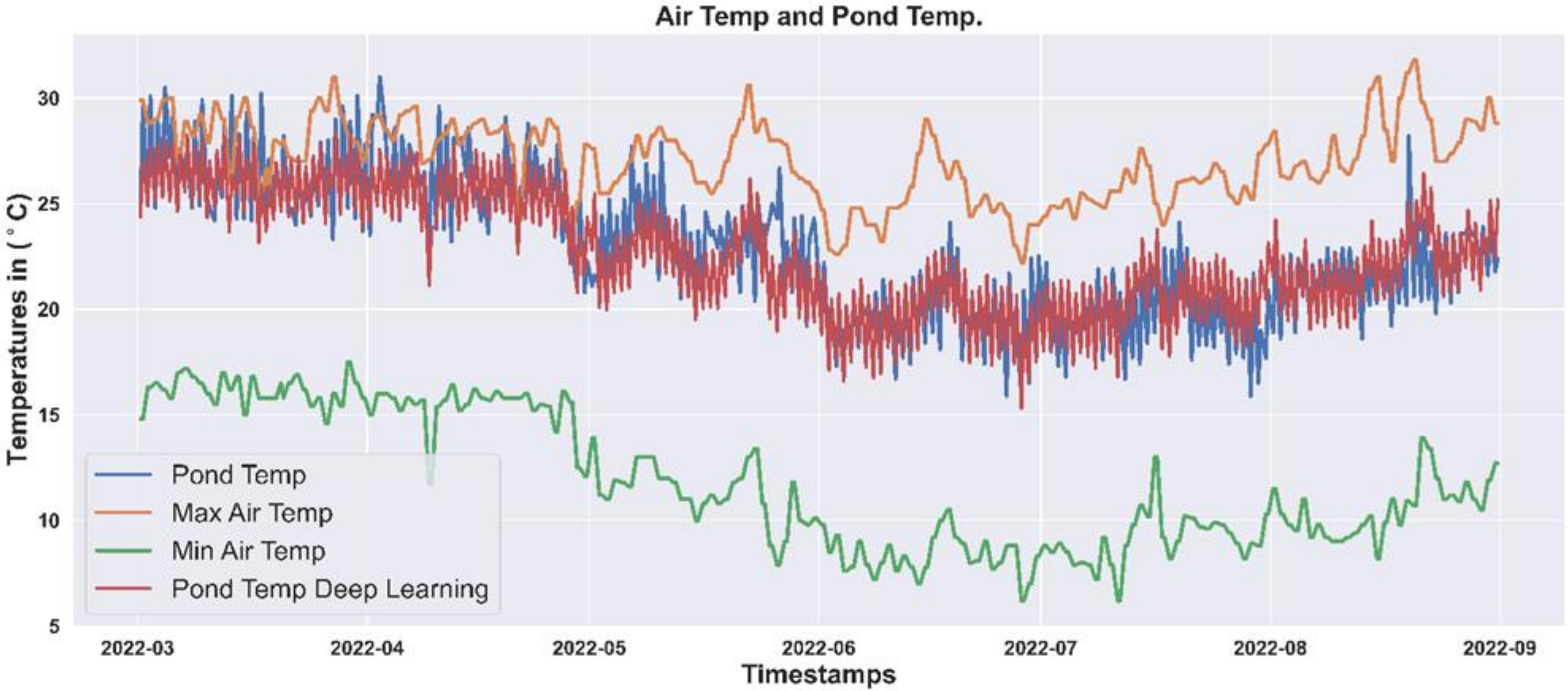

Seasonal pattern of the air temperature, pond temperatures, and predicted pond temperatures using a deep learning model.

8. Results:

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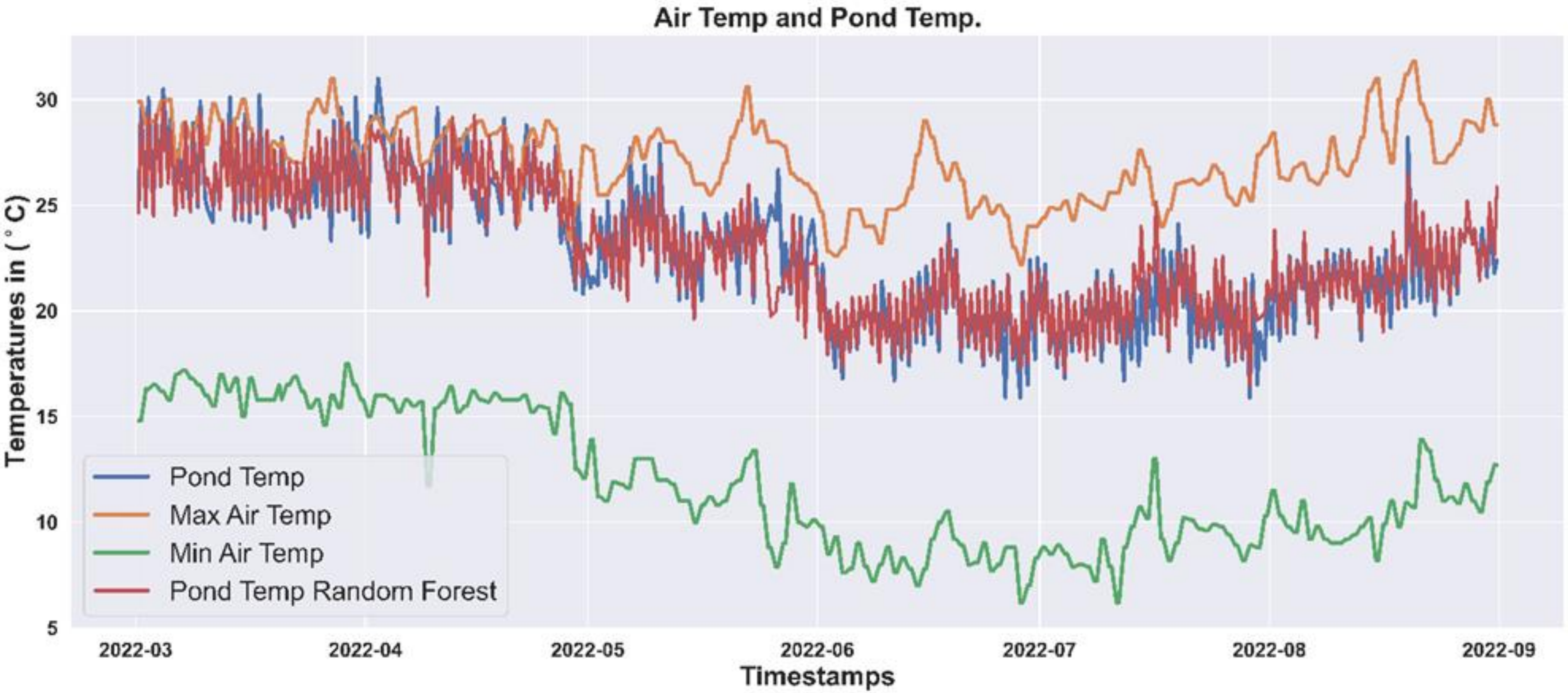

Seasonal pattern of the air temperature, pond temperatures, and predicted pond temperatures using a random forest model.

8. Results:

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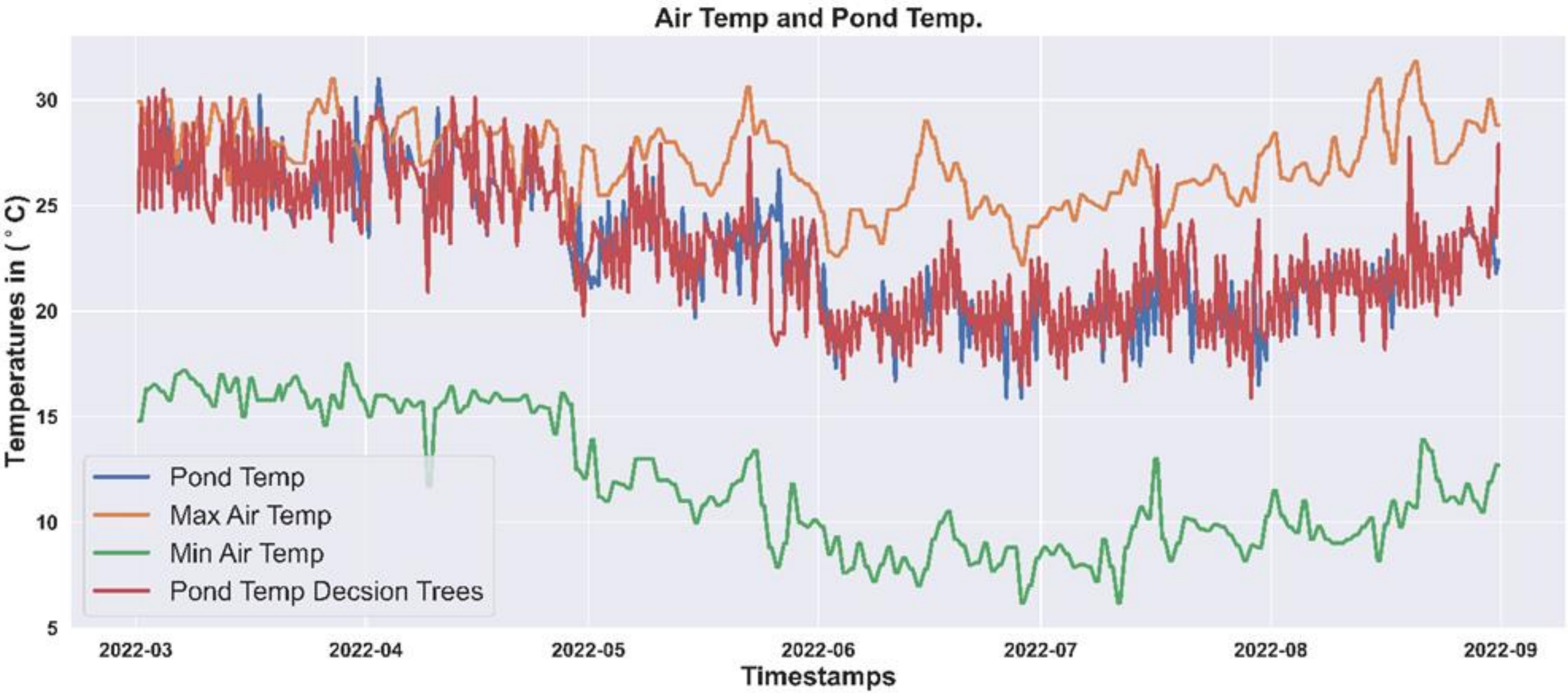

Seasonal pattern of the air temperature, pond temperatures, and predicted pond temperatures via a decision tree model.

8. Results:

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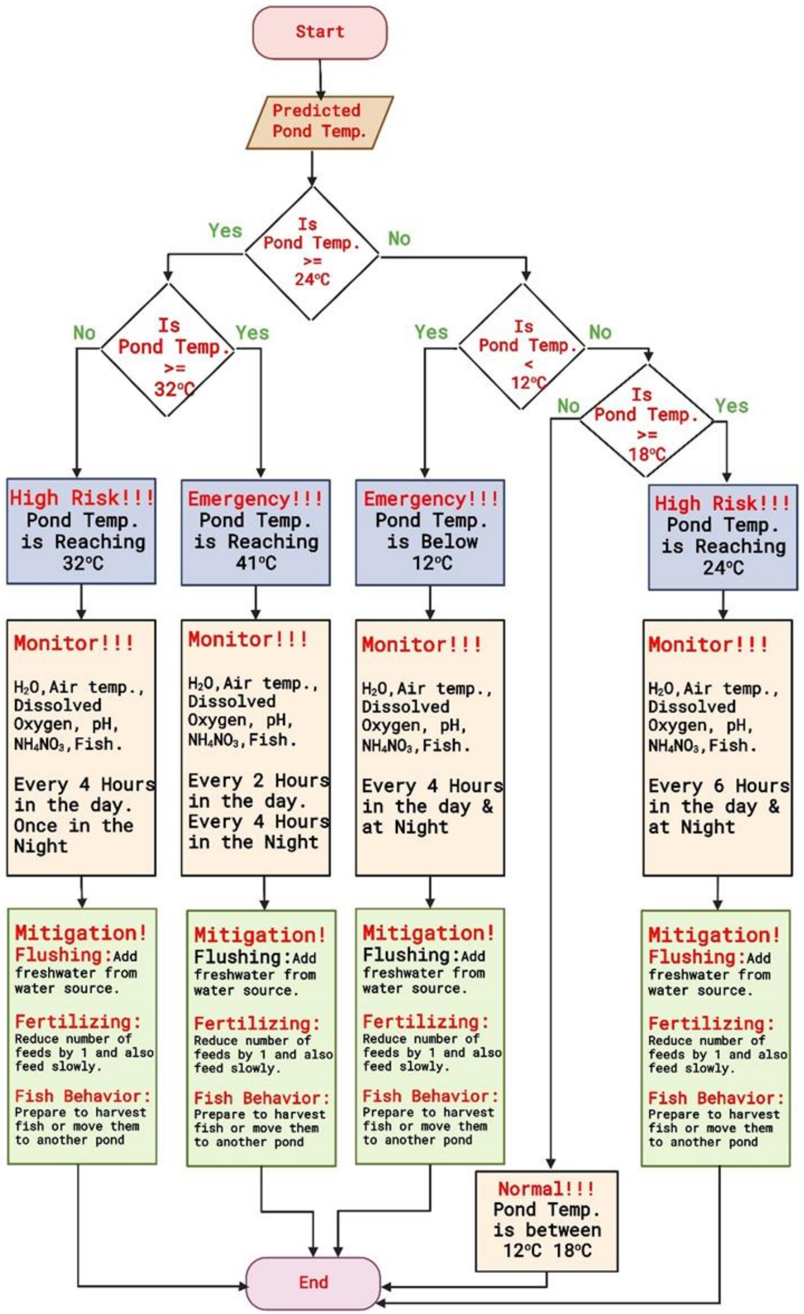
DECISION TREE MODEL:

The decision support tool indicating the conditions under which air temperatures may result in a normal, high risk or emergency scenario, combined with the monitoring and management mitigations recommended under each scenario. The diagram was created with BioRender (https://biorender.com/).



8. Results:

The summary statistics displaying the different model performance metrics are displayed.

Model	R^2	MSE	RMSE	MAE	MAPE
Linear Regression	0.61	4.37	2.09	1.75	0.08
Stochastic Regression	-17.6 -4.52	9.66 41.91	3.11 6.47	2.50 5.34	0.11 0.26
Deep Learning	0.84	1.83	1.35	1.07	0.05
Random Forest	0.77	2.89	1.70	1.28	0.06
Decision Tree	0.61	4.89	2.21	1.54	0.07

9. Discussion:

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- The Deep Learning model is the top performer with the highest R^2 value, followed closely by the Random Forest model.
- The choice between these two models may depend on other factors such as interpretability, computational resources, and specific requirements of the task at hand.
- However, the decision tree model is a good foundation for farmers to understand and predict pond temperatures on their farms. This model is flexible and can be refined for specific operations so that farmers can update scenarios, actions and their predicted outcomes.

10. Conclusion:

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Short-term recommendations:

- Integrate the algorithm and DST into iSAT and link to live weather data
- Pilot the early-warning system with a set of selected farmers
- Selected farmers to be provided with in-situ monitoring equipment for continuous monitoring of temperature as a minimum
- Initiate a project and team to conduct regular review and improvement of the algorithm to include temperature data from more ponds, as well as start to include data on pond-specific variables
- Selected farmers to be provided with other monitoring equipment to take intermittent readings of other critical variables such as pH, EC, ammonia, dissolved oxygen of pond and source water, as well as flow-through rates and overall water availability over time, and integrate into the existing algorithm
- Improve the farmer interface to allow for farmer-led data input (pond information and water quality and flow-through data)

Thank you
Enkosi
Dankie

Photo by Stefan Els