CHAPTER

04

SPECIES DISTRIBUTION MODELLING OF SEAWEEDS IN INDIAN SEAS

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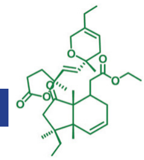
ABSTRACT

Seaweeds, the green pastures of the ocean, hold immense potential for India's coastal communities and its burgeoning blue economy. These marine macroalgae are not just ecological keystones, responsible for oxygen production and forming the base of marine food webs, but also a multi-billion-dollar industry offering a cornucopia of products, from food supplements to hydrocolloids. With projections for exponential growth in the coming decades, harnessing the potential of seaweeds requires precise and sustainable approaches. While India stands strong as a seaweed cultivating nation, identifying suitable regions for this marine bounty remains a complex puzzle. The vast and diverse coastline demands advanced tools to unlock hidden opportunities. The realm of species distribution modelling (SDM) aids in identifying the suitable habitats along our coast. This book chapter offers a comprehensive exploration of how SDM can illuminate the path for a thriving seaweed industry in India. Through a real-world case study of an SDM exercise, we paint a vivid picture of how this technology can translate knowledge into action.

Key words: Marine food webs, Species distribution models, Ecosystem services

INTRODUCTION

Seaweeds, pivotal components of marine ecosystems, represent a burgeoning opportunity for India's coastal communities within its expanding blue economy. Beyond their ecological roles, seaweeds offer a multi-billion-dollar industry with diverse applications, from food supplements to hydrocolloids. To harness this potential, precise and sustainable approaches are imperative. Despite India's status as a seaweed cultivating nation, identifying optimal regions for cultivation remains complex due to the vast and varied coastline. This chapter explores the application of Species Distribution Modelling (SDM) as a tool to unlock hidden opportunities. Through a case study, the chapter demonstrates how SDM can guide the development of a thriving seaweed industry in India. The text delves into the ecological significance of seaweeds, the current state of the industry in India, and the potential impacts of anthropogenic activities on seaweed distribution. It introduces SDM as a novel technology capable of identifying suitable habitats along India's coastline, emphasizing its role in informed decision-making



for sustainable seaweed cultivation. The chapter outlines the steps involved in SDM, using a real-world exercise focused on *Asparagopsis taxiformis*, a red algae with cosmopolitan distribution on the Indian coast. The results showcase the spatial predictions, variable importance scores, and response curves, providing insights into the distribution patterns and ecological requirements of this seaweed species. This comprehensive exploration serves as a valuable guide for policymakers, researchers, and stakeholders interested in leveraging seaweeds for economic and ecological benefits in the context of India's blue economy.

SEAWEEDS AND SPECIES DISTRIBUTION MODELLING

Seaweeds are the primary producers of the sea and comprise a diverse set of marine macroalgae. They form the backbone of the marine ecosystem as a major source of oxygen production and forming the base of marine food webs (Seth & Shanmugam, 2016). Seaweeds mainly attach to solid substratum and grow in shallow waters, but there are exceptions. Generally, they are classified into three classes based on their pigment composition, i.e., red, green and brown algae. In addition to the ecosystem services provided by these algae, seaweeds are sources of numerous products utilised in the pharmaceutical, food and cosmetics industries. Seaweeds are a multibillion-dollar industry that has projections for exponential growth in the coming decades (Winberg et al., 2014). The common products obtained from seaweeds include fertilizers, food supplements and hydrocolloids like agar and carrageenan. The most commonly commercially exploited species of seaweeds are kelps (*Saccharina japonica* and *Undaria pinnatifida*), tropical red algal species (*Kappaphycus* and *Eucheuma*), nori (including *Porphyra* and *Pyropia* sps.), and the red algal agarophyte species known as *Gracilaria.*

China is the leading producer of seaweeds globally followed by Asian countries like Japan, Korea and some European countries. Seaweed cultivation is also becoming popular in developing and underdeveloped nations as a means of generating foreign currency and expanding economic opportunities for coastal communities (Ask & Azanza, 2002; Ask et al., 2003). The seaweed industry had its dawn in India in 1966 with the states of Tamil Nadu and Gujarat as frontrunners (Kaladharan & Jayasankar, 2003). The country is in the process of developing and expanding a full-fledged and established seaweed industry to other states, pitching it as a sustainable and alternative source of livelihood for the fisher community. Understanding and identifying suitable regions for seaweed culturing is an arduous task considering the vast and varied coastal stretch of India.

Species distribution is a novel tool capable of identifying suitable habitats for species using computer-generated models. Species Distribution Models (SDMs) can assist in determining suitable habitats for a specific species and can also be utilised to understand the impact of future climatic changes. The results can lay the foundation for expanding the seaweed industry of the country and equip the nation to take a sizeable portion of the billion-dollar industry in future. Such new-age techniques can minimise the monetary and manpower expenditure and increase the output with minimal effort. Thus the application of SDM technology in the Seaweed industry will be a step in the right direction.

In the Indian coast ecological studies on seaweed species have been carried out since the 1950s in the Mahabalipuram (Srinivasan, 1946) and since then have been focused on either coasts of India. These studies focused on the environmental conditions, the seasonal and annual variations of seaweeds and their zonation. Typically, in the case of numerous seaweeds examined, the highest growth rate occurs during two specific periods of the year: one from June to August, and the other from November to December or January (Rao, 1970).

The distribution of seaweed is influenced by various physical, chemical, and biological factors, as well as the intricate interplay among these factors. Physical elements encompass substrate composition, temperature fluctuations, light intensity, tide patterns, wind dynamics, and storm occurrences. The crucial chemical parameters are salinity, pH, nutrient concentrations, gas levels, and pollution levels (Baweja et al., 2016). Environmental and geo-climatic factors significantly impact the growth, development, and health of seaweed. Features such as tidal emergence and submergence, coastal landscape, surf action, and plant growth levels have a substantial influence on the growth of these species. Seawater temperature and salinity have been shown to have a significant influence on the growth of seaweeds with particular effects observed during low salinity that is accompanied by heavy rainfall. The effect of light attenuation and increasing grazers with depth are also important factors (Paula, & Pereira, 2003).

The increasing pressure of anthropogenic activities and their influence on marine ecosystems are manifesting in the form of rising seawater temperature, ocean acidification, sea level rise and erratic climate patterns and natural calamities. These impacts will affect the ecology, distribution and growth of marine algae with long-term effects. Changes in the seaweed community can have a cascading effect on the marine food web since seaweed forms the base of the trophic levels. Thus utilising a species distribution modelling approach for seaweed species would provide valuable insights into probable disitribution and the impact of bioclimatic factors on their distribution in both present and future climate conditions.

Species distribution models (SDM) are empirical techniques that establish a relationship between field observations or species data from museums and environmental predictor variables. These models utilise response curves, which can be derived statistically or theoretically, to accurately represent the ecological requirements of a species (Guisan & Zimmermann, 2000; Guisan & Thuiller, 2005). The steps in SDM are generally divided into five steps, and are as follows:

1. Conceptualisation
2. Data collection and preparation
3. Model calibration
4. Model evaluation
5. Spatial predictions

The precision and accuracy of the SDM depend upon the availability of species occurrence data and relevant marine bioclimatic variables for the species in question. Numerous models are available for predicting the distribution such as Machine learning models, Regression models and Neural networks. Another approach in SDM modelling is to use a group of models and build an ensemble model to predict the species distribution. The steps of modelling will be explained using an actual Species distribution modelling exercise of a seaweed species.

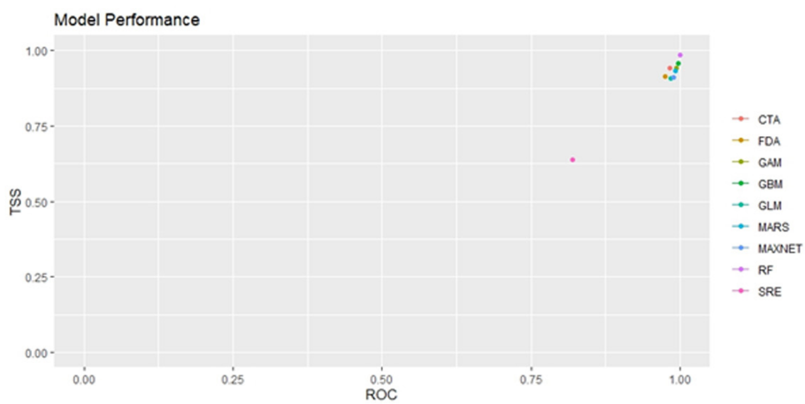
SPECIES DISTRIBUTION MODELLING OF *ASPARAGOPSIS TAXIFORMIS*

An ensemble Species distribution modelling exercise was conducted to identify the distribution of Asparagopsistaxiformis, a red alga with cosmopolitan distribution on the India Coast. This forms the first step of SDM, Conceptualisation.

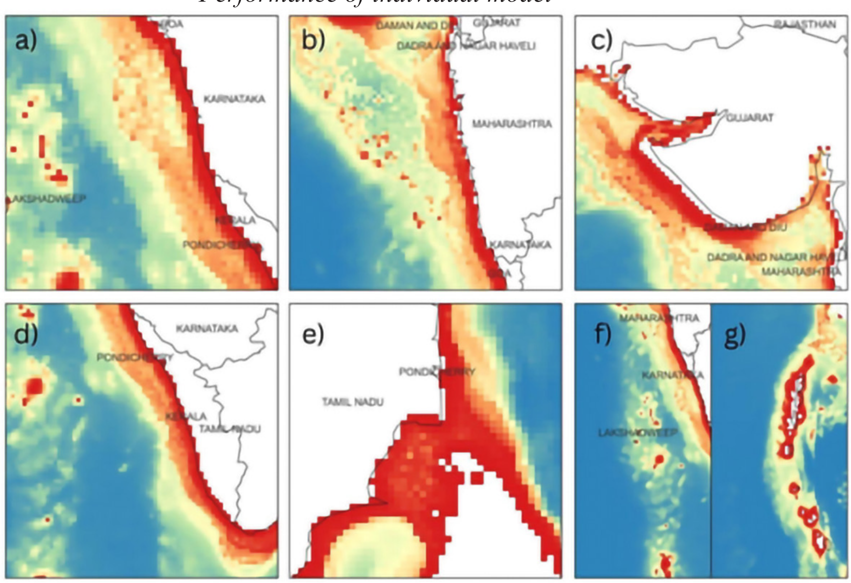
Asparagopsis taxiformis

The second step involves collecting and data preparation. Distribution records and environmental data for modelling were obtained from the GBIF database and Bio-ORACLE. Data cleaning and statistical analyses were conducted on the input datasets. Pearson correlation and Variance Inflation factor analyses were conducted to identify and remove variables with correlation and multicollinearity. Due consideration was also given to the ecology of seaweeds while selecting the environmental variables.

In the third step, 10 model algorithms were used to build individual distribution models initially, later combined into a single ensemble model. The 'biomod2' package in the R platform was used for model building and ensembling along with a suite of other packages. After building the individual models, the evaluation matrices are used to analyze the performance of the built models and the same are filtered with a threshold value for the matrices, here TSS(0.85) AND AUC(0.9). The individual models are selected for building the models if they have TSS and AUC values equal to or above the threshold. The above forms the fourth step, model calibration and model evaluation

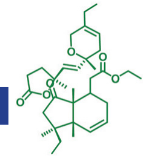


Performance of individual model

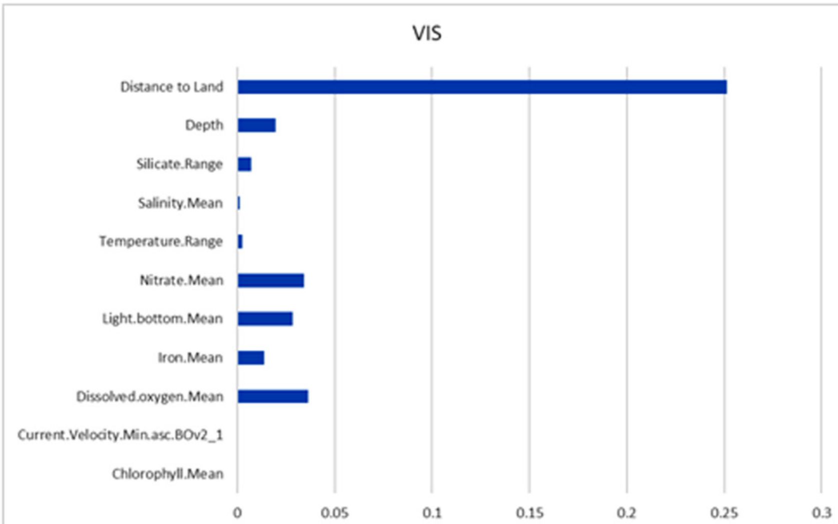


Habitat suitability of Asparagopsis taxiformis in a) Karnataka coast b) Maharashtra coast c) Gujarat coast d) Kerala coast e) Palk Strait f) Lakshadweep Islands g) Andaman & Nicobar Islands.

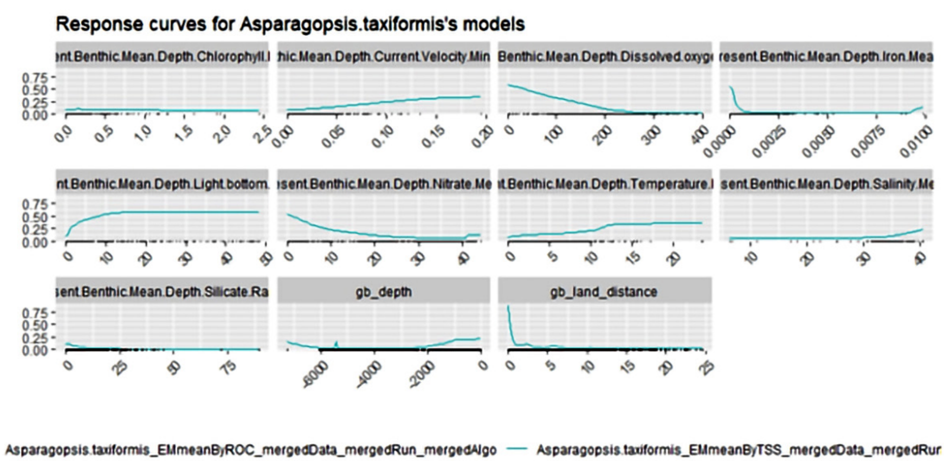
The fifth and last step of the modelling is spatial prediction, where the model is used to predict the distribution of *Asparagopsis taxiformis*.



The results of the modelling also include a response curve, performance analysis metric graph, and variable importance scores. The variable importance score indicates the variable's



Variable importance score of predictor variables



Response curve of predictor variables in the ensemble model

influence in determining the distribution of the species in the model. The variable with the highest values has the most significant influence. Response curve on the other hand shows the trend or level of influence of the species on the model predictions.

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