# The effect of global ocean factors on the crown-of-thorns starfish (*Acanthaster planci*, Linnaeus, 1758) population in the Great Barrier Reef, Australia

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**Abstract**. The Great Barrier Reef (GBR) is the world's largest coral reef ecosystem, internationally recognized as a highly significant World Heritage Area. The emergence of the crown-of-thorns starfish (*Acanthaster planci*, Linnaeus, 1758), known as a coral predator, has caused damage to the coral reefs in the GBR area. Various hypotheses have been proposed to explain the increase in COTS population, one of which is the change in sea surface temperature and salinity. This study aims to model the COTS population influenced by ocean atmospheric predictors in the GBR using the multiple regression (MR) model with the stepwise method. The data used in this study is divided into two categories: observational data and prediction data. Observational data consists of the COTS population in the GBR from 1992 to 2021, while prediction data includes sea currents, sea surface temperature (SST), and salinity data from 1991 to 2022. Based on the research results, five significant predictors were identified: SST 11, CUR 9, CUR 8, SALT 7, and CUR 1, with a Pearson correlation value (R) of 0.64 and a Root Mean Square Error (RMSE) of 218.26±13.69 cases.
**Key Words**: crown-of-thorns starfish, multiple regression, sea surface temperature, salinity, sea current.

**Introduction**. The Great Barrier Reef (GBR) is the largest coral reef ecosystem in the world, containing spectacular scenery, both above and below water, stretching 2300 km along the coast of Queensland, Australia. The GBR has about 3000 individual reefs and 1050 islands and is one of the few living structures visible from outer space. This reef is also one of the richest and most complex ecosystems in the world, and it is crucial for biodiversity conservation. Its size and the diversity of its steep water depths make it a globally unique area of ecological communities, habitats, and species, home to thousands of species of plants and animals, including turtles, whales, dolphins, dugongs, and other iconic animals.

The crown-of-thorns starfish (*Acanthaster planci*, Linnaeus, 1758) (COTS) has become one of the most famous creatures in coral reef ecosystems. Its fame arises not from its beauty or commercial value, but because it forms high aggregations or populations, which can cause extensive damage to coral areas (Moran 1988). The high populations COTS are considered one of the main causes of significant and sustained declines in living hard coral cover in the Indo-Pacific reefs (Baird et al 2013).

On the GBR, the first documented high abundance of COTS was detected in 1962 on Green Island, although high abundance of COTS was reported on other GBR reefs in the 1950s and earlier. Since 1962, there have been three additional episodes of high abundances of COTS on the GBR, in 1979, 1993, and 2010 (Vanhatalo et al 2016). Over 27 years (1985 to 2012), the GBR had lost about half of its initial coral cover, with 42% of this loss due to repeated high abundances of COTS (Wilmes et al 2016; Hall et al

2017). Significant losses in coral cover occur especially when the COTS population increases by as much as 10 times in one year (Kayal et al 2012).

Population abundance of the COTS undergoes significant decade-scale variation, and this population has been attributed to natural fluctuations, related to anthropogenic factors in increasing the planktonic food supply, which also increases larval survival (Fabricius et al 2010), or by the removal of COTS predators. Some COTS populations have also been linked to El Niño events, as these atmospheric factors act as contemporary stressors on corals, leading to higher mortality. Additionally, the high sea surface temperatures (SST) associated with El Niño events can support the survival of COTS larvae (Lamare et al 2014).

Previous research conducted by Rajalau (2020) stated that several ocean-atmospheric factors influence the reproduction of COTS, namely SST, salinity, watercourse discharge (WD), sunspot number (SSN), ocean heat content (OHC), monsoon, Pacific Decadal Oscillation (PDO), Niño 3.4 or El Niño Southern Oscillation (ENSO), Madden-Julian Oscillation (MJO), Indian Ocean Dipole (IOD), and West Pacific Index (WPI) with a correlation of 0.58. Therefore, this research only focuses on modeling the effect of ocean conditions on the abundance of the COTS population in the GBR using a statistical model analysis, namely multiple regression (MR) with the stepwise method.

## Material and Method

***Description of the study sites***. This research is limited to the GBR region in Australia, which comprises a total of 127 occurrences from its population across (127 outbreak phenomena) in 11 observation sectors affected over the period from 1992 to 2021. as many as 127 outbreak phenomena in 11 observation sectors

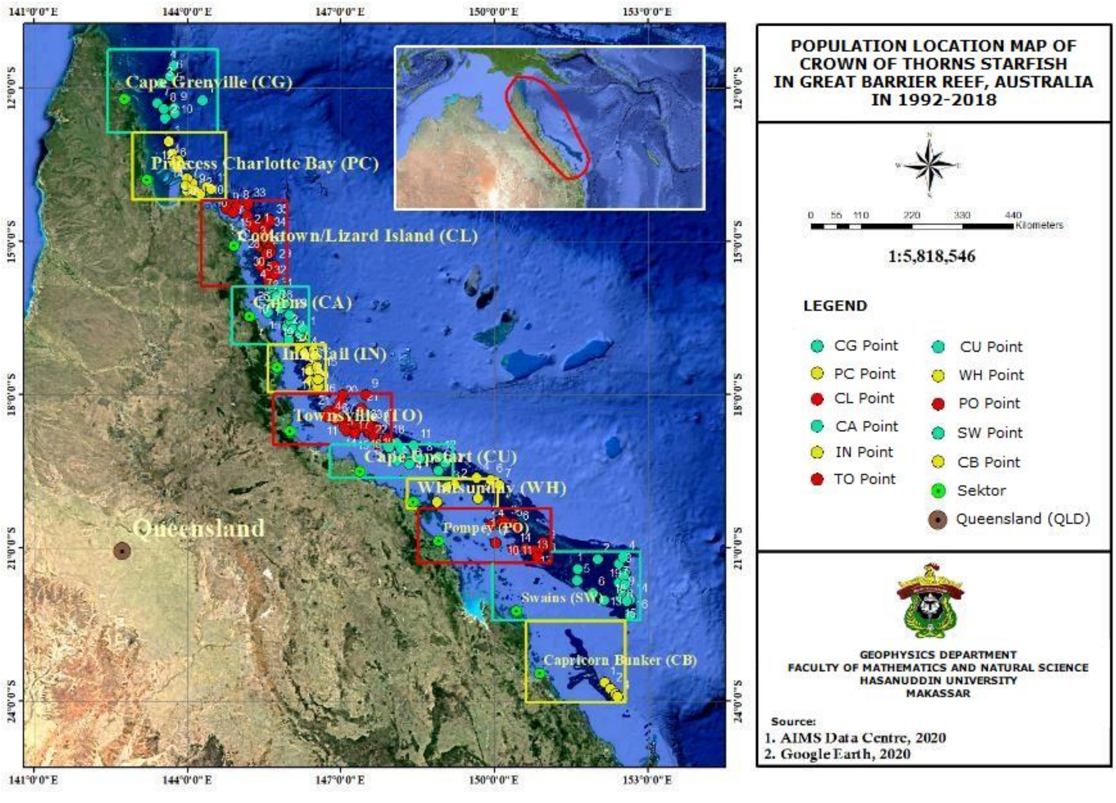


Figure 1. The distribution locations of occurrence points and the population of crown-of-thorns starfish (*Acanthaster planci* Linnaeus, 1758) in the Great Barrier Reef, Australia.

***Data collection***. The data needed and used are monthly secondary data per year for 29 years (1992-2021) for data on the incidence of the COTS population, and for 30 years

(1991-2021) for data regarding oceanic factors. The predictors can be seen in Table 1, as follows:

1. COTS abundance data in the GBR used from 1993 to 2021, obtained from the site Australian Institute of Marine Science (AIMS): https://apps.aims.gov.au/metadata/view/5bb9a340- 4ade-11dc-8f56-00008a07204e
2. Sea current velocity data used from 1993 to 2021, obtained from the site National Oceanic and Atmospheric Administration (NOAA): https://www.psl.noaa.gov/data/gridded/data.godas.html
3. SST data used from 1993 to 2021, obtained from the site National Oceanic and Atmospheric Administration (NOAA): https://psl.noaa.gov/data/gridded/data.cobe.html
4. Salinity data in GBR, Australia used from 1993 to 2021, obtained from the site National Oceanic and Atmospheric Administration (NOAA): https://www.esrl.noaa.gov/psd/data/gridded/data.godas.html

Table 1

The predictors used in this study

| *No* | *Predictor category* | *Predictor name* | *Description* |
|---|---|---|---|
| 1 | Sea current velocity (m $s^{-1}$) | x1 (CUR 12) | CUR 12 means the current sea velocity in the 12 months before the peak of COTS abundance. |
| | | x2 (CUR 11) | CUR 11 means the current sea velocity in the 11 months before the peak of COTS abundance. |
| | | x3 (CUR 10) | CUR 10 means the current sea velocity in the 10 months before the peak of COTS abundance. |
| | | x4 (CUR 9) | CUR 9 means the current sea velocity in the 9 months before the peak of COTS abundance. |
| | | x5 (CUR 8) | CUR 8 means the current sea velocity in the 8 months before the peak of COTS abundance. |
| | | x6 (CUR 7) | CUR 7 means the current sea velocity in the 7 months before the peak of COTS abundance. |
| | | x7 (CUR 6) | CUR 6 means the current sea velocity in the 6 months before the peak of COTS abundance. |
| | | x8 (CUR 5) | CUR 5 means the current sea velocity in the 5 months before the peak of COTS abundance. |
| | | x9 (CUR 4) | CUR 4 means the current sea velocity in the 4 months before the peak of COTS abundance. |
| | | x10 (CUR 3) | CUR 3 means the current sea velocity in the 3 months before the peak of COTS abundance. |
| | | x11 (CUR 2) | CUR 2 means the current sea velocity in the 2 months before the peak of COTS abundance. |
| | | x12 (CUR 1) | CUR 1 means the current sea velocity in the 1 months before the peak of COTS abundance. |
| | | x13 (CUR 0) | CUR 0 means the current sea velocity in the month when the COTS abundance occurred. |
| 2 | Sea surface temperature (°C) | x14 (SST 12) | SST 12 means the sea surface temperature in the 12 months before the peak of COTS abundance. |
| | | x15 (SST 11) | SST 11 means the sea surface temperature in the 11 months before the peak of COTS abundance. |
| | | x16 (SST 10) | SST 10 means the sea surface temperature in the 10 months before the peak of COTS abundance. |
| | | x17 (SST 9) | SST 9 means the sea surface temperature in the 9 months before the peak of COTS abundance. |
| | | x18 (SST 8) | SST 8 means the sea surface temperature in the 8 months before the peak of COTS abundance. |
| | | x19 (SST 7) | SST 7 means the sea surface temperature in the 7 months before the peak of COTS abundance. |
| | | x20 (SST 6) | SST 6 means the sea surface temperature in the 6 months before the peak of COTS abundance. |
| | | x21 (SST 5) | SST 5 means the sea surface temperature in the 5 months before the peak of COTS abundance. |
| | | x22 (SST 4) | SST 4 means the sea surface temperature in the 4 months before the peak of COTS abundance. |
| | | x23 (SST 3) | SST 3 means the sea surface temperature in the 3 months before the peak of COTS abundance. |
| | | x24 (SST 2) | SST 2 means the sea surface temperature in the 2 months before the |

| | | | |
|---|---|---|---|
| | | | peak of COTS abundance. |
| | | x25 (SST 1) | SST 1 means the sea surface temperature in the 1 months before the peak of COTS abundance. |
| | | x26 (SST 0) | SST 0 means the sea surface temperature in the month when the COTS abundance occurred. |
| | | x27 (SALT 12) | SALT 12 means the salinity in the 12 months before the peak of COTS abundance. |
| | | x28 (SALT 11) | SALT 11 means the salinity in the 11 months before the peak of COTS abundance. |
| | | x29 (SALT 10) | SALT 10 means the salinity in the 10 months before the peak of COTS abundance. |
| | | x30 (SALT 9) | SALT 9 means the salinity in the 9 months before the peak of COTS abundance. |
| | | x31 (SALT 8) | SALT 8 means the salinity in the 8 months before the peak of COTS abundance. |
| | | x32 (SALT 7) | SALT 7 means the salinity in the 7 months before the peak of COTS abundance. |
| 3 | Salinity | x33 (SALT 6) | SALT 6 means the salinity in the 6 months before the peak of COTS abundance. |
| | | x34 (SALT 5) | SALT 5 means the salinity in the 5 months before the peak of COTS abundance. |
| | | x35 (SALT 4) | SALT 4 means the salinity in the 4 months before the peak of COTS abundance. |
| | | x36 (SALT 3) | SALT 3 means the salinity in the 3 months before the peak of COTS abundance. |
| | | x37 (SALT 2) | SALT 2 means the salinity in the 2 months before the peak of COTS abundance. |
| | | x38 (SALT 1) | SALT 1 means the salinity in the 1 months before the peak of COTS abundance. |
| | | x39 (SALT 0) | SALT 0 means the salinity in the month when the COTS abundance occurred. |

**Results and Discussion**. The time series graph model predicting the population of COTS is presented in Figure 2, which is a multiple regression model using the stepwise method with a blue line, and the observational data of the COTS population with a red line.

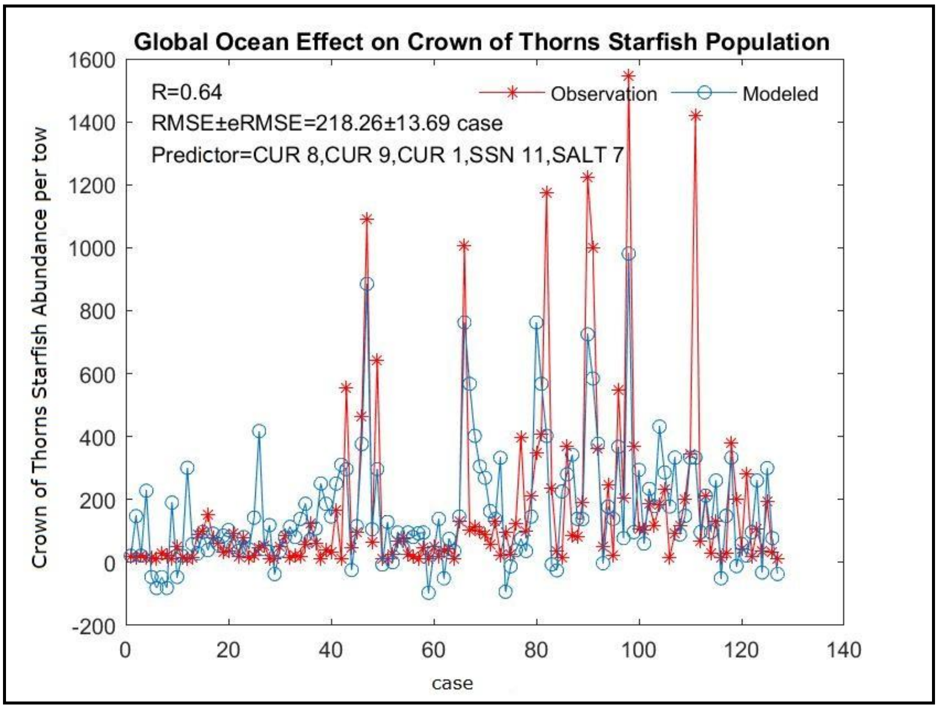


Figure 2. Modeling ocean effect on crown-of-thorns starfish (*Acanthaster planci*, Linnaeus, 1758) population.

The MR model using the stepwise method provides significant predictors in predicting the population of COTS. Out of the 39 predictors used, which consist of 13 ocean current predictors, 13 SST predictors, and 13 salinity predictors, 20 predictors were found to be significant with p-values less than 0.05 according to Table 2. This is the result of the stepwise method applied to the 39 predictors used, with a Pearson correlation value (R) of 0.64, and a RMSE value of 218.26±13.69 cases.

Table 2

The significant model inputs extracted by the stepwise model

| *Inputs* | *Model* | *Pearson Correlation R* | *RMSE (Cases)* |
|---|---|---|---|
| x12*32(-4592918)<br>x12 (193647.1)<br>x5 (-39421)<br>x32 (30404.94)<br>x15*32 (4647.672)<br>x5*15 (1420.403)<br>x12*15 (-1138.77)<br>x4 (-1111.21)<br>x15 (-223.612) | Crown-of-thorns starfish population =360850-54748*x12*x32+21811*x12-38441*x5-10129000*x32+37797*x15*x32+1386.1*x5*x15 -889.64*x12*x15-1150.9*x4-13453*x15 | 0.64±0.05 | 218.26±13.69 |

Based on Table 2, there are 4 interaction variables, indicating that there is also an influence between the independent variables, in addition to their effect on the COTS population as an independent variable. These 4 variables are x12*32 or cur1salt7, x15*32 or sst11salt7, x5*15 or cur8sst11, and x12*15 or cur1sst11.

For example, the variable cur1salt7 indicates an interaction and correlation between the predictor CUR 1 and the predictor SALT 7 or serves as the main correlation controller between them. Similarly, the variable sst11salt7 indicates an interaction and relationship between the predictor SST 11 and SALT 7. The last interaction variable, cur1sst11, indicates an interaction and correlation between the predictor CUR 1 and SST 11. It is also indicated that these 4 interaction variables contribute to the formation of the multiple regression model and its coefficients, making them necessary to be included. If these 4 interaction variables are removed from the model equation, it will affect the value of the regression coefficients.

The standardized coefficient values (β) in Table 2 for the 4 predictors, in descending order, range from the highest value of -4592918 for the variable cur1salt7 to the lowest value of -223.612 for the variable SST 11. The negative Beta value for the variable x12*32 or cur1salt7 indicates that the relationship between them is inverse; in other words, the smaller the value of cur1salt7, the larger the occurrence of the COTS population. This inverse relationship is also present in the predictors CUR 8, cur1sst11, CUR 9, and SST 11. Meanwhile, the positive Beta value for the predictor x12 or CUR 1 indicates a direct correlation, where the larger the value of this predictor, the larger the occurrence of the COTS population, or possibly the opposite.

Based on Table 2, the cause of the occurrence of COTS populations in the GBR region in terms of the influence of ocean conditions was significantly influenced by SST 11, CUR 9, CUR 8, SALT 7, and CUR 1 with different Beta weights from each other, and with a Pearson correlation value of 0.64. This indicates that during the 11 months before the emergence of COTS, sea surface temperatures were low and this condition was certainly unfavorable for phytoplankton blooms (food for COTS larvae), resulting in low chlorophyll concentrations in the Western Pacific, especially in the GBR region. This naturally low availability of food (phytoplankton), in terms of size/value tolerance thresholds (beta weights), indicates that COTS well adapted to these conditions. Then, 9 months earlier, the slowing ocean currents in the GBR area were favorable for the breeding of COTS, confirming the results of Aziz (1995), according to which COTS is generally found in waters with slow currents. This condition also continued in the previous 8 months, when the ocean currents in the GBR area slowed down. Then, in the previous 7 months, COTS increased due to the condition of GBR waters with low salinity. Furthermore, a month before the emergence of COTS, it was found that fast currents can increase the population of COTS, because currents carry COTS larvae that can spread to various locations, thus allowing an increase in the COTS population itself.

When compared with research by Rajalau (2020) regarding the effect of ocean-atmospheric conditions on COTS abundance which produced a correlation of 0.58, this research indicates that the correlation could increase if we focus on ocean factors alone, which produced a correlation of 0.64.

**Conclusions**. Overall, from the analysis of the crown-of-thorns starfish model in the Great Barrier Reef area, 5 significant predictors were obtained, namely SST 11, CUR 9, CUR 8, SALT 7, and CUR 1, with a correlation value of 0.64 and a Root Mean Square Error (RMSE) of 218.26±13.69 cases.

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**Conflict of Interest**. The authors declare that there is no conflict of interest.

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