INVESTIGATING THE EFFECTS OF OZONE LAYER DEPLETION: A SERIOUS THREAT TO THE SURVIVAL OF SOME MARINE ORGANISMS

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ABSTRACT

It has been established beyond all doubts that ozone shield efficiency is changing because of natural as well as artificial causes, which also affects the increased radiations, inflicting damage to DNA of living organisims. In this situation, we can well conceive the danger of annihilation of various animal and plant species because of Ozone Layer Depletion (OLD). In this context, the direct and indirect affects of OLD and UV radiations on marine organisims, especially the fish and the food-chain that supports their yield, phyto-plankton, zooplankton and fish-larvae, are particularly studied with reference to Pakistani coasts.

1. INTRODUCTION

A 4% decrease in ozone-content causes a 10 % increase in radiation in the range between 280 and 320 nm. Damage suffered by DNA from UV radiation is cumulative, and the integrated dose over many years produces skin cancer in human and causes mutations in the animals and plants. DNA molecules undergo most intense absorption of UV radiation in the range of 265 nm to 300 nm. Proteins have absorption-maxima around 275 to 285 nm and these bands also extend to 300 nm. Plants are sensitive to UV radiation below 310 nm [1-8][9][10][11].

It has been observed from our studies on marine organisms that there is a remarkable increase in the flux of UV radiation reaching the Arabian sea through the ozone filter.

It is effective in particular in Pakistan Atmospheric Region (PAR) that is situated in the west and north-west of South Asia. It lies from 23.45° to 36.75° in the northern latitudes, and from 61° to 75.5° eastern longitudes. This region is critical because of the existence of a large positive correlation between the potential vorticity deviations and the ozone-mixing-ratios in its stratosphere. It makes the transport of ozone (along with the seasonal variations) possible to Pakistan's atmospheric region.

The coastal region of Pakistan is spread from 24° to 26° north and 62° to 68° east. It includes Karachi coast (Sindh) and Makran coasts (Balochistan) as shown in Figure 1. These coastal regions and the adjoining seas are full of resources that have a potential to contribute to our economy substantially.

Marine fisheries are a considerable part of these resources. If there is any threat to their survival, it should be given due consideration and the reasons and causes deserve to be deeply studied. OLD and leads to the consequent increase of UV radiations and its effects on our marine fisheries, thus, appear as the focus of our study. Here we will stress on the study of direct and indirect effects of OLD and UV radiations on marine organisms. Fish are of our particular interest and the food chain that supports their yield. Phyto-plankton, zoo-plankton and fish-larvae contribute considerably to this food-chain so have worth to be studied in the above-mentioned UV scenario. Studies of the effects of OLD on vertical migration of fish appear in [12][13][14], we will study the effects of OLD via UV flux increase on fish yield. This appears to be the first attempt of its kind for Pakistan coasts as to the best of our knowledge; no formal or informal study of the effects of OLD on marine organisms for Pakistan's coastal line is available yet.

2. UV RADIATION AND MARINE ORGANISMS

Now we will use the quantification of the UV flux for Pakistani air space to study the effects of UV radiation on marine organisms. We will start with studying the effects of UV on plankton. Plankton is the terminology applied to all those animals and plants that survive on water (ocean or fresh) with less power of locomotion. Mostly, the motion is that by the drift of water currents. However, some forms such as arrow worm, many crustacea and fish-larvae can swim with slow speed. Much of their movement is in the vertical plane from place to place and very limited in the horizontal plane. There are two main categories of planktons:

i. Phyto-plankton that are all plant-like organisms, plant-like in the sense that they are auto-trophic and contribute to the food available in the surface-waters by building up their protoplasm and food reserves directly from carbon dioxide and salts in the sea.

ii. Zoo-plankton that consists of animals such as protozoans (microscopic one-celled animals living chiefly in water, sometimes parasitic). Practically every major group of animals has its representation in the zoo-plankton either as adults or as larvae.

The division into phyto-plankton and zoo-plankton is taxonomic, so the border-line nature of the organisms

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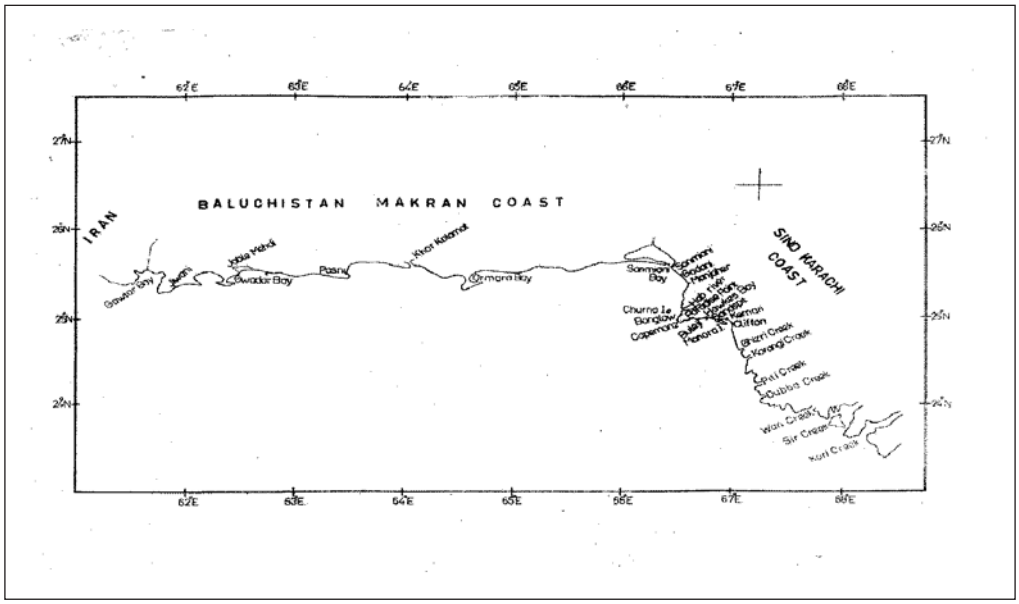

Source: M. Ayub Khan Yousaf Zai, 2004

Figure - 1: Coastal Regions of Pakistan

can be neglected to deal with the zoo-plankton and phyto-plankton groups. Effects and toxicology of UV on aquatic ecosystems are studied by Haggan & Ozaki [15] and Cleveland & McGill [16].

In this section, we will estimate the effects of UV radiation via ozone layer depletion on phyto-plankton, zoo-plankton and fish, using the time series of a bivariate population. The fish-yield data of Sindh and Baluchistan coasts are correlated with the intensity of UV radiation reaching the Arabian sea. The prediction using our constructed models will be helpful for various public, private and governmental organizations.

3. PHYTO-PLANKTON

The synthesis of organic carbon in the marine surface-waters is governed by the phyto-plankton activity. The rate of change of phyto-plankton concentration in the euphotic zone is a balance between growth and losses from cell respiration, carbon excretion, sedimentation and grazing. Also, advection and diffusion can locally increase or decrease the phyto-plankton. Algal growth depends on the carbon input by phytoplankton and is influenced by environmental conditions, as well as ecological factors [9]. Carbon uptake is affected by quality and quantity of light, nutrient availability and temperature. Therefore, phyto-plankton are limited to surface-waters as they are dependent on the visible light (400-700nm) for photosynthesis. The requirement for solar radiation makes them susceptible to UVR (280-400nm) exposure [18], particularly UV-B (280-320) is more damaging per photon. UV-B accounts for approximately 0.01% of the photons absorbed by phyto-plankton and is damaging to different molecular targets. Its effect is usually measured by screening UV-B from the sunlight [19]. Some other studies related to the effects of UVR on marine organisms, such as phytoplankton are discussed by Delcourt, P.A. & Delcourt H.R [20] and Gates [21]. Pigment bleaching which is a common response of the UVR has presently been studied. The effects of UV-B on the growth of specific species of marine phyto-plankton of tropical and temperate regions are studied by Henderson-Sellers [22].

As discussed by the Delcourt [20], the seasonal distribution of chlorophyll-a shows a decreasing trend as it moves from high values above 0.4 μg per litre in January to very low values of about 0.05 μg per litre in May (at about 30 meters ocean depth), as discussed in detail by Yousuf Zai [13].

We have found a correlation between the chlorophyll-a (for a depth of 30 meters and shallower) data and our data for UV-B flux due to OLD, as shown in Figures 4.1 and 4.2 of Yousuf Zai's 'A Quantitative Study of effects of Ozone Layer Depletion on Marine Organisms with reference to coastal regions of Pakistan' [13]. This shows a decreasing trend for both the cases. The

respective trend equations are:

$$Y_t = 0.351 - 0.0502\,t + \varepsilon$$

and

$$Y_t = 1.95 - 0.33\,t + \varepsilon$$

which can be used for future predictions. Using these equations, the rate of decrease of Chlorophyll-a with UV-B comes out to be 0.01 μg Chl /litre/watt /square meter.

4. ZOO-PLANKTON

The damaging effects of solar UV radiation on aquatic organisms, such as sunburn (erythema) in fish, have been reported in 'Frontiers in Probability and Statistics' [17]. Seasonal variations and abundances of two species of zoo-plankton, copepoda and chaetognatha of the Arabian Sea (along the Karachi coastal regions) are discussed by Basu and Srivastava [17,23]. These findings are based on monthly analyses of plankton samples collected from three different stations from January 1983 to December 1985. We have found a correlation between the above-mentioned data of Basu and Srivastava and our computed UV–B data. The relative abundances in percentage of the two species of zooplanktons are plotted as a function of UV-B radiation reaching the Arabian Sea as shown by Yousuf Zai in the figures 4.3 & 4.4 of his study 'A Quantitative Study of effects of Ozone Layer Depletion on Marine Organisms with reference to coastal regions of Pakistan' [13]. We have observed that the relative abundance decreases with increasing intensity of UV-B radiation.

The model equations for the Copepoda and Chaetognatha are:

$$Y_t = 132.806 - 0.811\,t + \varepsilon$$

and

$$Y_t = 5.77 - 0.04\,t + \varepsilon$$

In order to strengthen our claim on the damaging effects of UV-B radiation on the marine organisms, we have also assessed the effects of UV-B radiation on the population of Windowpane Oyester Plaucuna Placenta in the Arabian Sea [24]. The 12-point data ranges from February 1990 to January 1991 that we have plotted against corresponding the data of UV-B flux intensity by Yousuf Zai [13].

It is obvious that the population decreases with the enhancement of UV flux at sea-level. Fitted time series model equation is given by the following equations:

$$Y_t = 1190.047 - 12.225\,t + \varepsilon$$

5. EFFECT OF OZONE LAYER DEPLETION ON FISH YIELD AT COASTAL REGIONS OF PAKISTAN

There exists a large number of causes affecting fish-yield that are also the point of concern of an equally large number of studies. What is the proportion of OLD in this saga of cause and effect? We are not at present in a position to answer this question with certainty. We are not claiming that this is the only cause or a major cause of decreasing fish-yield. Our only concern is to spot out that it is one of the serious causes that need attention and to be the focus of future studies. There are various modes of OLD affecting fish-yield. Due to OLD the probability of UV incidence increases that increases the production of hydrogen peroxide (H_2O_2). This in turn raises the danger of diminishing the available hatching sites. OLD is considered to be one of the causes of Global Warming and the rise in the temperature of the ocean creating hot waves that can cause erosion of the harbour. In addition to the increase in expenditure made on necessary repairs and restructuring of the harbours, fish yield will be affected as well [17].

As mentioned above, the infiltration of UV radiation results in the production of H_2O_2. It intoxicates the surrounding seawater abandoning the growth of zoo-plankton and phyto-plankton. In turn the predator-prey ecological processes are disturbed. Consequently the whole food chain is affected. Two time-plots are constructed for Balochistan and Sindh coasts and their trend analyses are given below:

i. Trend Analysis for Coastal Line along Balochistan

Data N = 420.00, Fitted Trend Equation

Yt = 169.320 + 22.3376*t, accuracy measures, MAPE: 15.7922, MAD: 469.051,
MSD: 20378

ii. Trend Analysis for Sindh coast

Data N = 420
Fitted Trend Equation

Yt = 2297.80 + 55.3585*t, accuracy measures,

MAPE:10.3563,
MAD:1188.61,

MSD: 2581372. These figures are reflected in Figures 4.6(a) and 4.6(b) of Yousuf Zai's paper 'A Quantitative Study of effects of Ozone Layer Depletion on Marine Organisms with reference to coastal regions of Pakistan' [13].

6. SAMPLING DISTRIBUTION OF THE MEANS FOR FISH-YIELD DATA

a. Baluchistan Coast

For the sampling distribution of the mean for the Bauchistan fish-yield data, we have randomly selected one sample consisting of 102 points with mean: 1975.22 and variance: 909.69 and testing the null hypothesis H_o: μ = 1975.220 against the alternative hypothesis H_1: μ < 1975.220. We found that the null hypothesis should be rejected. This concludes that the standardized mean fish-yield for Balochistan coast is less than 1975.220 metric tons.

This also reflects the high non-stationarity of the respective data. Note that the coefficient of variation for this data comes out to be 0.5687. This shows that the data are sufficiently consistent.

b. Sindh Coast

For the sampling distribution of the mean for the Sindh fish-yield data, we have randomly selected one data consisting of 102 points with 13950.77 and 6909.698 and testing the null hypothesis H_o: μ = 13950.77 against the alternative hypothesis H_1: μ < 13950.77. In this case also we found that the null hypothesis should be rejected. This concludes that the standardized mean fish-yield for Sindh coast is less than 13950.77 metric tons.

As observed earlier, this is also a reflection of the high non-stationarity of the respective data. Note that the coefficient of variation for the data is 0.4952. This shows that the data are sufficiently consistent.

7. EFFECTS OF OLD AND UV FLUX ON FISH-YIELD

Now we come to find the correlations between fish yield data of Balochistan and Sindh, and ozone layer depth, ozone layer depletion and UV flux reaching the Arabian Sea.

8. CORRELATIONS OF BALOCHISTAN FISH-YIELD DATA

In the correlation between fish-yield data of Balochistan coast with ozone layer depth, ozone layer depletion and UV flux reaching the Arabian Sea respectively, the corresponding correlation coefficients 'r' come out to be 0.72, -0.37, and 0.51, respectively. The positive correlation of fish-yield indicates that to uphold the current status of fish-yield, steadiness in the ozone layer depth could prove to be favourable. However, the negative correlations in the other two cases are the indicators of the unfortunate stance of scarce fish-yield.

9. CORRELATIONS OF SINDH FISH-YIELD DATA

The correlations of fish-yield data of Sindh coast with ozone-layer depth, ozone layer depletion (OLD) and UV flux reaching the Arabian sea, respectively, show that the situation in Sindh is not different from that of Balochistan and the OLD can be held responsible for worsening the fish-yield scenario.

It can be easily computed that the coefficient of correlation is found to be calculated for both the cases mentioned above using the mathematical relationship. The value of 'r' for the figures above-mentioned are 0.32, - 0.63, and -0. 37.

The negative correlation shows that as the UV-B increases, the yield of fish decreases. Similarly, the value of 'r' for both the cases represents the negative correlation and it can be observed that the fish-yield decreases with increasing UV flux that reaches the Arabian Sea. The positive correlation shows that, as the depth of ozone increases, the yield of fish increases. It also depicts the dependence of ozone-layer depth on the fish-yield for Balochistan-Makran coast. It can be concluded that as the depth magnitude increases the depletion of ozone decreases, which in turn, shows that the yield of fish increases. It can be observed that as the depletion of ozone layer reduces then it prevents the UV-B entering Pakistan's atmosphere and thus to have little effects on the marine eco-system.

Similarly, the dependence of ozone-layer depletion on the fish-yield for Karachi-Sindh coast would show that as the depletion of ozone layer increases, the yield of fish decreases, because of increase in UV flux at sea-level. It can be observed that as the depletion of ozone layer reduces, it prevents the UV-B from entering Pakistan's atmosphere and thus decreases their

effects on the marine eco-system.

It has been seen that the scatter diagrams mentioned above can also be utilised to acquire probability forecasts of the events, such as the effects of ozone-layer depletion on the biosphere. It is sufficient to indicate that this procedure can accommodate several predictors and provides the meteorologists or the forecasters with a considerable degree of flexibility in analysing relationships between these variables.

Trend equations are given as:

$Y_t = 16,397.04 - 31.075\, t + \varepsilon$ (Sindh coast)

$Y_t = 55,71.197 - 08.889\, t + \varepsilon$ (Balochistan coast)

Thus, we have a 1:1 correspondence with fish-yield and the ozone layer depletion, and the UV flux penetrating through the ozone filter. Now we can argue that the fish or other inhabitants of sea cannot be saved without urgent action.

The UV component of solar radiation is found to be a significant and pervasive selective force in aquatic ecosystems. The new challenge for future UVR research is to incorporate present knowledge of UV flux reaching sea level into a broader ecological context.

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