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VARIATION OF SIGNIFICANT WAVE PERIODS DURING SOUTHWEST MONSOON IN PHITTI CREEK, NORTHERN ARABIAN SEA, PAKISTAN

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ABSTRACT: To study the wave characteristics a Waverider buoy was deployed in Phitti Creek of northern Arabian Sea at 24º 33′ N and 67º 03′ E for wave measurements during south-west monsoon (April-July) 1985 and 1986. Wave records in terms of significant wave period (T_z) were collected using Tucker's method. Percentage frequency distribution, standard deviation (σ), mean (μ), highest significant wave period (HT_z) and lowest significant wave period (LT_z) values were computed for statistical analysis. For the year 1985 T_z were ranged between 5.05 s to 12.03 s; the lowest μ value of 5.05 s (with a σ 0.50 s, HT_z 5.85 s and LT_z 4.35 s) was observed in the 3rd week of May and the highest μ 12.03 s (with a σ of 3.45 s, HT_z 15.38 s and LT_z 8.96 s) was observed in the first week of August. In the year 1986 T_z were ranged between 6.65 s to 10.70 s; the lowest μ value of 6.65 s (with a σ 1.12 s, HT_z 10.00 s and LT_z 6.00 s) was observed in the 3rd week of April and the highest μ 10.70 s (with a σ of 1.78 s, HT_z 14.28 s and LT_z 7.89 s) was observed in the 3rd week of June.

KEYWORDS: Significant wave period, Phitti Creek, northern Arabian Sea, Pakistan.

INTRODUCTION

Waves are most obvious phenomena of the ocean surface but their mechanism of formation is complex and the concept is not yet fully developed (Thurman, 1989). A wave is an undulating movement in a body of water enhanced by an alternate rise and fall of the surface (Bhat, 1978). The oscillatory movement of water surface may be caused by light breeze or may have originated in a storm located thousands of nautical miles away (Sverdrup *et al.*, 1970; Times, 1983). The coast in the vicinity of Karachi constitutes a system of shallow creeks amongst which the Phitti Creek is of much importance due to the location of Port Muhammad Bin Qasim at its mouth. About 50 km away in the south-east (Latitude 24º41′-46′ N and Longitude 67º09′-21′ E) of the heart of bustling city of Karachi, the Arabian Sea breaks into the sand dunes of Bin Qasim desert (Valeem, 1993). The Port Qasim is the first industrial port (2nd in Sindh and 3rd in Pakistan) of Pakistan having modern and multipurpose facilities.

An approach channel for navigation was dredged in 1978-79 through the Phitti Creek in order to develop the Port Qasim. The navigational channel is about 45 km long from approaches to Port Complex and known as Ehsan Channel. It has an outer approach channel, which is entirely exposed to the Arabian Sea having length of 15 km and 2nd inner channel, which is surrounded by numerous creeks and islands and is about 30 km long. The channel runs through Phitti Creek, Kadiro Creek and ends up in Gharo Creek at the port. At the start of Ehsan Channel, which is an approach channel passing through the Phitti Creek to meet Port Qasim area, there is a Fairway site (Fig. 1). The depth of the water at this site is 17 m while the depth maintained in approach channel is 12.4 m, which is lowered as 11.3m when the channel enters into the Phitti Creek area. From Fairway to Phitti Creek, its depth is 12.4 m, at Phitti and Kadiro Creek 11.3 m and at Gharo Creek and Turning Basin of Port Qasim 10.0 m.

The width of the entire channel varies from 185 m to 280 m and marked with navigational buoys on either side to provide safer navigation. Dredging is continuously in progress to maintain the depth as far as possible but cannot be relied upon the data given in navigational maps (Haslam, 1990). To monitor the channel infill for dredging requirements, several surveys were undertaken by the Port Qasim Authority. Since 1979, the Hydrography Department of Port Qasim Authority have been deploying a Waverider buoy at Fairway site (Latitude 24º33′01″ N and Longitude 67º02′09″ E) to study the waves pattern (Valeem, 1993).

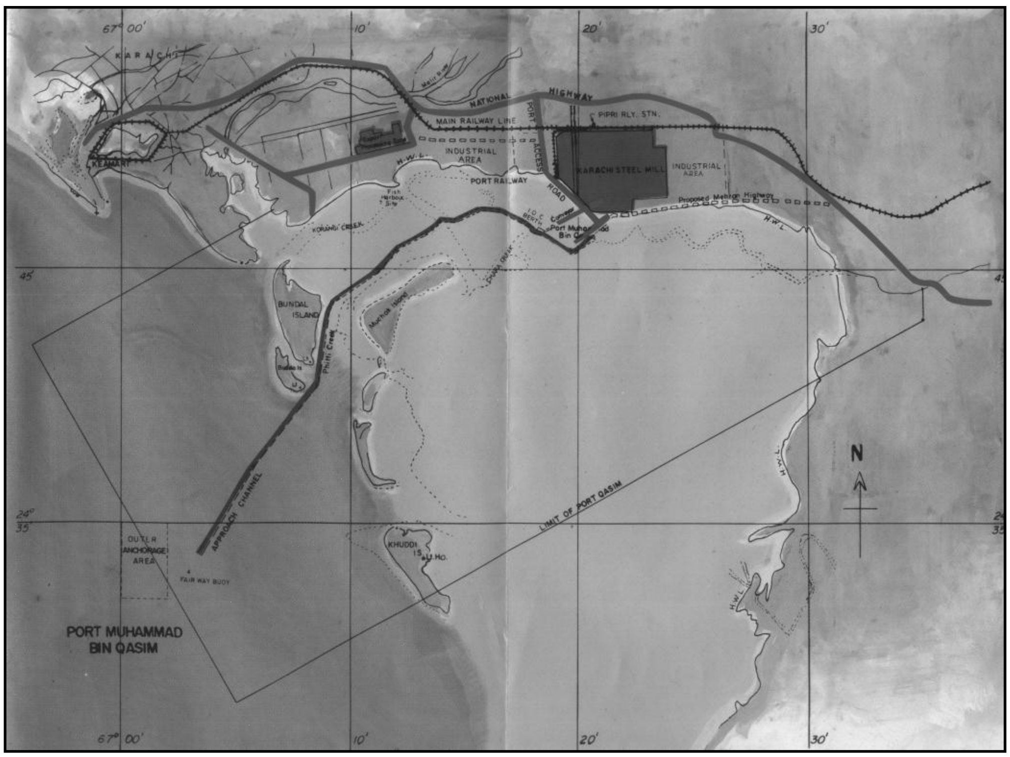


Fig.1. Study area showing the Fairway site.

MATERIALS AND METHODS

Since wave period of smaller waves are of short duration, hence, it is much difficult to record the variable wave periods and a variety of wave heights passing through a fixed point. One such visual observation along Karachi Coast was made while studying the shore erosion. Wave heights and wave periods were observed and recorded against a fixed point and time was noted down with the help of a stop watch for ten waves passing through the fixed point. In this way mean time for one wave was calculated (Tirmizi, 1983). Later on Valeem (1993) conducted research on variation of waves and their effect during southwest monsoon (SWM) near Phitti Creek and published his work as Tirmizi *et al.*, (1993, 1995). However, a number of methods can be used for measuring wave parameters. Some of them are approximate and some accurate. The simplest among them is the visual method. It involves a lot of practice to obtain reliable results. Water surface is to be kept under visual observations mounting a vertical scale on a pier in the water having a large deep horizontal plate (Pond and Pickard, 1983).

A more reliable and accurate method of wave measurement is the use of instrument like Waverider buoy (Draper, 1961, 1967, 1980, 1991). The Waverider is a surface buoy (Fig. 2), which following the movements of water surface, measures waves by measuring the vertical accelerations of the buoy. Before transporting Waverider buoy the mooring package is prepared. The mooring system is a major and integral part of the Waverider buoy, which is prepared in a manner to facilitate handling and avoid entanglement of the suspension that may occur at the time spun of Waverider buoy more than ten times or faster than one turn in ten seconds. So, the Waverider buoy is placed upright and the rope is laid in loops with alternate left and right turn *i.e.* figure of eight (8) shaped loops (Fig. 3a,b). The Waverider buoy that is fitted with the 5 kg chain ballast attached to the mooring eye provides sufficient stability for use in free floating condition. It is moored in shallow water to prevent excessive pitch and roll. To keep a moored Waverider buoy from being pulled under the passing waves a rubber cord is used as part of mooring. The low stiffness of this rubber cord allows the Waverider buoy to follow waves up to 20 meters. Eventually the complete mooring package is packed together in the order in which it has to be run out. The package is stowed on a deck with buoy end up and the anchor end down, the two ends are connected to buoy and chain anchor (Fig. 3c) and then transported to the study site (Fig. 1) where it is anchored down and tethered to sea bed by an elastic mooring. The moored Waverider buoy rises and falls with the movement of waves. The movement of waves activates the stabilized accelerometer suspended in a plastic sphere at the bottom of the buoy. The Waverider, by means of internal accelerometer begins to measure the vertical oscillations. This accelerometer, in fact, acts as a potentiometer from the electronic point of view. The out of balance voltage is amplified and integrated twice electronically resulting into wave height signal. This signal is converted into field modulated (FM) signals. The FM signal is amplified and fed into the antenna. The supply of all electronic functions including flash light is taken from 26 Leclanche cells placed inside the Waverider buoy. The Leclanche cells are regulated to provide a low impedance constant voltage source over the cell voltage range of 1.6 to 0.6 volt. The wave signals are automatically transmitted to Waverider receiver placed at the shore based station where the wave profile is recorded intermittently on a graphical paper roll at regular intervals of fix time (Anon., 1986).

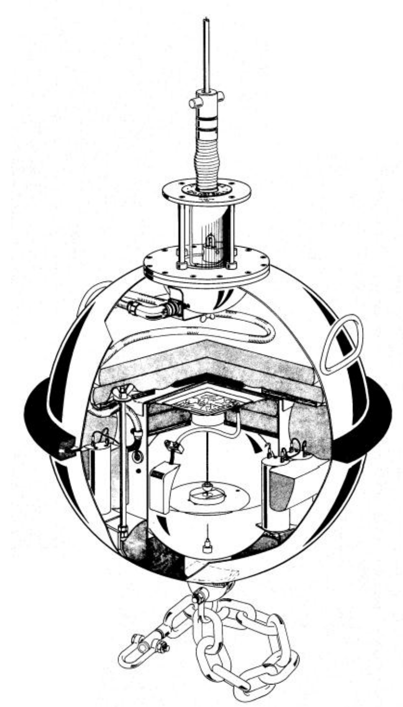


Fig. 2. Waiverider buoy.

After thorough satisfaction and calibration of Waverider buoy together with mooring package is brought on boat by taking all precautionary measures (as mentioned above) to the Fairway site, which is about 35 km away from Port Qasim Complex. This buoy anchored down and tethered to seabed by an elastic mooring measuring 20 m. It transmits the wave height signals to Waverider receiver placed in the laboratory at the shore. The wave spectrum is recorded and drawn on recording paper with the help of a labyrinth pen for 20 min. duration at six hourly intervals *i.e.* four records per day at 00:00, 06:00, 12:00 and 18:00 h in analog form on a recording paper roll. The data from the observations were taken throughout the South West Monsoon during the period from 1985 and 1986. The speed of recording paper is maintained at 18 mm/h.

Amongst the various methods put forward for analyzing wave records, the Tucker's (1963) and Draper's (1961, 1967, 1980, 1991) method is most efficient and reasonably accurate in arriving at different statistical parameters. In the present study the routine analysis of wave profile record received from Fairway Waverider buoy is carried out yielding different statistical parameters like number of waves (N_z), and Significant Wave period (T_z) using Tucker's (1963) method.

Significant wave period (T_z): The zero crossing period or significant wave period (T_z) is calculated, dividing the duration of record by Number of Waves, *i.e.*, $T_z = t/N_z$

where t = duration of record

N_z = Number of waves or number of upward zero crossings

Frequency distribution: The distribution of total number of observations among the various categories (Classes) is termed as frequency distribution. The frequency distribution for significant wave period (T_z) percentage frequency distribution is presented graphically by means of three dimensional bar graphs (Fig. 4a-j, 5) where the height of each bar is proportional to the frequency in the class represented.

Population mean: The mean is the most widely used measure of central tendency. The mean of population is denoted by the Greek small letter mu (μ). Its calculation can be by the formulae *i.e.*, $\mu = \Sigma X_i/N$ (Zar, 1974), which are represented in figures 6a, b.

where Σ = Summation

X_i = any integer value up through N

ΣX_i = Sum of all values

N = Total number of values

Standard deviation: The positive square root of the variance is known as standard deviation (The mean of the sum of squares of deviation from mean is known as variance); therefore, it has a same unit as the original measurements. Thus for a population the Standard deviation (SD) is abbreviated as Greek small letter sigma (σ) and calculated by the formulae (Zar, 1974) *i.e.*, $\sigma = \dfrac{\sqrt{\Sigma X_i^2 - (\Sigma X_i)^2/N}}{N}$. This measure is also represented in error bar graphs in figures 6a, b.

RESULTS AND DISCUSSION

Percentage frequency distribution: In 1985 Significant wave period (T_z) ranged from 4.6 s to 8.89 s in April, 4.35 to 10.52 s in May, 5.8 to 9.23 s in June and 6.0 to 12.0 s in July and the highest significant wave period of 12.0 s was observed on July 15, 1985. Month wise and yearly percentage (%) distribution of Significant wave period (T_z) for 1985 are shown in figures 4a-d, i, 5.

The significant wave period persisted most of the time in the range of 5.0-6.0 s. However, in the range of 4.0-5.0 s, they occurred 14 % of the time in April and 21 % of the time in May. In the range of 5.0-6.0 s, 77 % of the time in April, 53.5 % of the time in May, 6 % in June and 2 % of the time in July; in the range of 6.0-7.0 s, 5 % of the time in April, 13.5 % in May, 19 % in June and 7 % of the time in July. In the range of 7.0-8.0 s, the T_z occurred 2 % of the time in both April and May, 42 % in June and 12 % of the time in July. In the range of 8.0-9.0 s, they occurred 2 % of the time in April, 2 % in May, 25 % in June and 32 % of the time in July. In the range of 9.0-10.0 s, T_z occurred 4.5 % of the time in May, 7 % in June and 33.5 % of the time in July. In the range of 10.0-11.0 s, T_z occurred 3.5 % of the time in May, 1 % in June and 9 % of the time in July and in the range of 11.0-12.0 s, T_z occurred 4.5 % of the time in July only (Figs. 4a-d).

In the SW Monsoon period of 1985 the Significant Wave period occurred 8 % of the time in the range of 4.0-5.0 s, 31.8 % of the time in 5.0-6.0 s, 11.6 % in 6.0-7.0 s, 16.5 % in 7.0-8.0 s, 16 % in 8.0-9.0 s, 11 % in 9.0-10.0 s, 3.4 % in 10.0-11.0 s and 1 % of the time it occurred in the range of 11.0-12.0 s and 0.26 % of the time the T_z occurred in both of the ranges of 14.0-15.0 s and 15.0-16.0 s (Fig. 5).

In 1986 Significant wave period (T_z) ranged from 6.0 to 10.0 s in April, 6.0 to 15.38 s in May, 6.0 s to 14.28 s in June and 6.45 to 11.76 s in July and the highest significant wave period of 15.38 s was observed on May 11, 1986. Month wise and yearly percentage distribution of significant wave period (T_z) for 1986 are shown in figures 4e-h, j, 5.

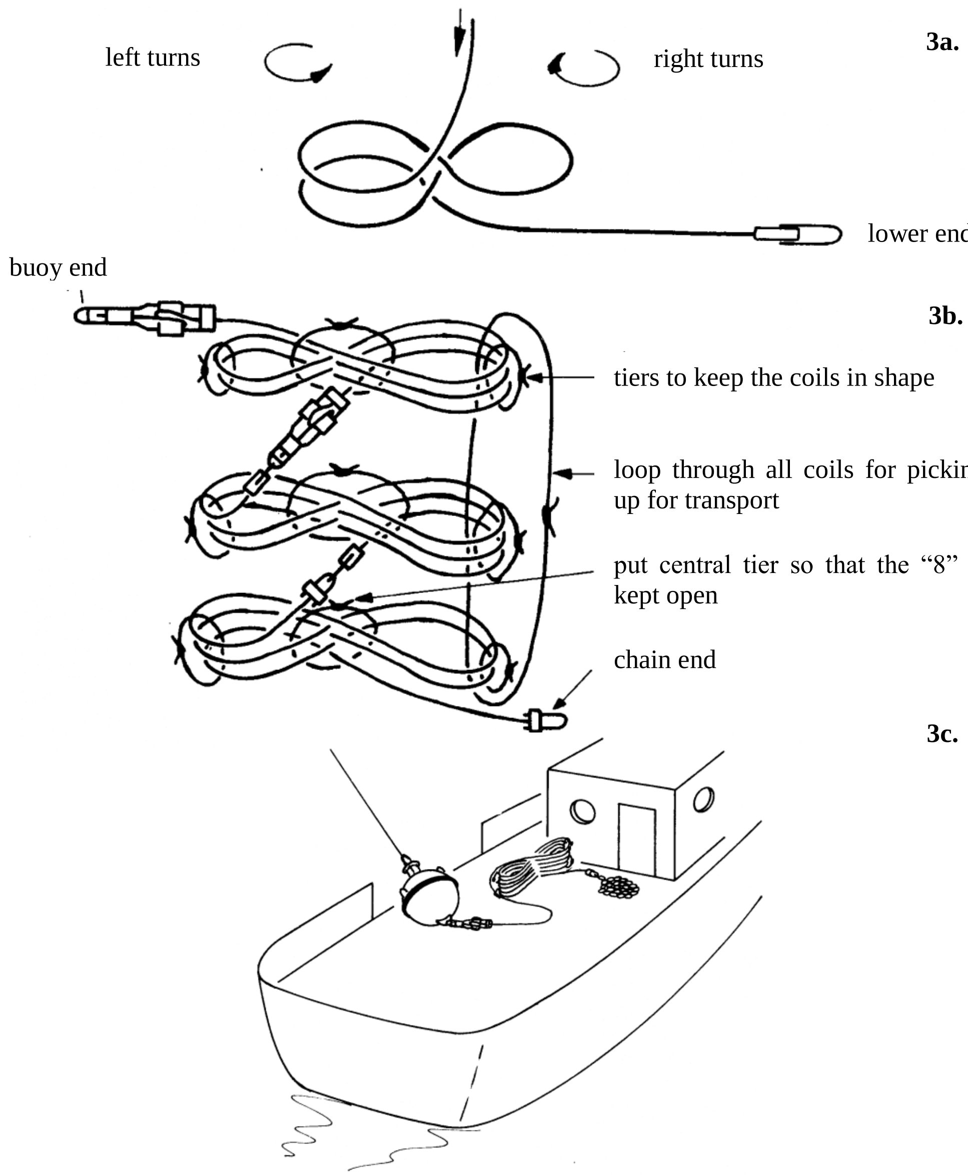


Fig. 3. a. Loop of figure 8, **b.** Loop formation, **c.** Boat carrying the mooring package.

The significant wave period persisted most of the time in the range of 7.0- 8.0 s. However, in the range of 5.0- 6.0 s, they occurred 43 % of the time in April, 11 % of the time in May and only 1 % of the time in June; and in the range of 6.0-7.0 s, 34 % of the time in April, 30 % in May, 6.12 % in June and 7 % of the time in July. In the range of 7.0-8.0 s the T_z occurred 10 % of the time in April, 35 % in May, 13.26 % in June and 31 % of the time in July. In the range of 8.0-9.0 s, they occurred 8 % of the time in April, 12 % in May, 21.43 % in June and 31 % of the time in July. In the range of 9.0-10.0 s, T_z occurred 5 % of the time in April, 4.5 % in May, 18.4 % in June and 18 % of the time in July. In the range of 10.0-11.0 s, T_z occurred 2 % of the time in May, 21.43 % in June and 10.5 % of the time in July. In the range of 11.0-12.0 s, T_z occurred 3.5 % of the time in May, 12.25 % in June and 2.5 % of the time in July. In the range of 12.0-13.0 s, the T_z occurred 3.1 % of the time in the month of June only. In the range of 13.0-14.0 s, the T_z occurred 2 % of the time in the month of June only. In the range of 14.0-15.0 s, the T_z occurred 1 % of the time in both May and June and in the range of 15.0-16.0 s, the T_z, occurred 1 % of the time in May only (Figs. 4e-h, j).

In the SW Monsoon period of 1986 the significant wave period occurred 11 % of the time in the range of 5.0-6.0 s, 17.6 % in 6.0-7.0 s, 23.3 % in 7.0-8.0 s, 19 % in 8.0-9.0 s, 12 % in 9.0-10.0 s, 9.5 % in 10.0-11.0 s, 5.1 % in 11.0-12.0 s, 0.9 % in 12.0-13.0 s, 0.6 % both in 13.0-14.0 s and 14.0-15.0 s ranges and 0.3 % of the time it occurred in the range of 15.0-16.0 s (Fig. 5).

Weekly Mean, SD, Highest and Lowest Values: The mean weekly off-shore significant wave period (T_z) during 1985 SW Monsoon with the SD of each week is shown in figure 7a. Weekly highest and lowest values are also shown in the same figure. The mean value of 5.99 s of T_z occurred during second week of April with an SD of 0.79 s. The highest and lowest T_z for the week were 6.94 s and 5.0 s. In the third week of April the mean value of T_z was 5.69 s with an SD of 0.7 s. The highest and lowest values for the week were 7.64 s and 4.7 s. In the fourth week the mean T_z was 5.66 s with an SD of 1.01 s, the highest of 8.89 s and the lowest of 4.6 s.

The mean value for T_z of 5.5s occurred during the first week of May with an SD of 0.48 s, highest of 6.32 s and lowest of 4.8 s. In the second week of May the mean T_z was 5.57 s with an SD of 0.44 s, highest of 6.42 s and the lowest of 4.95 s. In the third week the mean T_z was 5.05 s with an SD of 0.5 s, highest of 5.85 s and lowest of 4.35 s. In the fourth week of May the mean was 5.58 s with an SD of 0.73 s, highest of 6.67 s and the lowest of 4.5 s. In the fifth week of May the mean T_z was 7.95 s with an SD of 1.89 s, highest of 10.52 s and lowest of 5.3 s.

The mean T_z of 7.22 s occurred during the first week of June with an SD of 0.98 s, highest of 9.23 s and lowest of 5.9 s. In the second week the mean T_z was 7.19 s with an SD of 0.94 s, highest of 9.23 s and the lowest of 5.8 s. In the third week of June the mean T_z was 7.49 s with an SD of 0.63s , highest of 8.8 s and lowest of 6.56 s. In the fourth week the mean T_z was 8.21 s with an SD of 0.6 s, highest of 9.23 s and lowest of 7.23 s.

The mean T_z of 8.89 s occurred during first week of July with an SD of 1.05 s, highest of 10.71 s and lowest of 6.0 s. In the second week the mean was 9.2 s with an SD of 0.91 s, highest of 10.71 s and lowest of 7.79 s. In the third week the mean T_z was 9.22 s with an SD of 1.05 s, highest of 12.0 s and the lowest of 7.79 s. In fourth week the mean T_z was 8.49 s with an SD of 1.86 s, highest of 11.76 s and lowest of 6.0 s. In the fifth week of July the mean T_z was 8.25s with an SD of 0.2 s, highest of 8.39 s and lowest of 8.11 s.

The highest T_z in the month of April was 8.89 s and the lowest was 4.6 s. In the month of May the highest was 10.52 s and the lowest was 4.35 s. In the month of June the highest T_z was 9.23 s and lowest of 5.8 s was occurred. In July the highest T_z of 12.0 s and the lowest of 6.0 s observed. The highest value of 12.0 s for T_z during the SW Monsoon of 1985 occurred in the third week of July and the lowest of 4.6 s in the fourth week of April with a mean of 9.22 s and 5.66 s respectively (Fig. 6a).

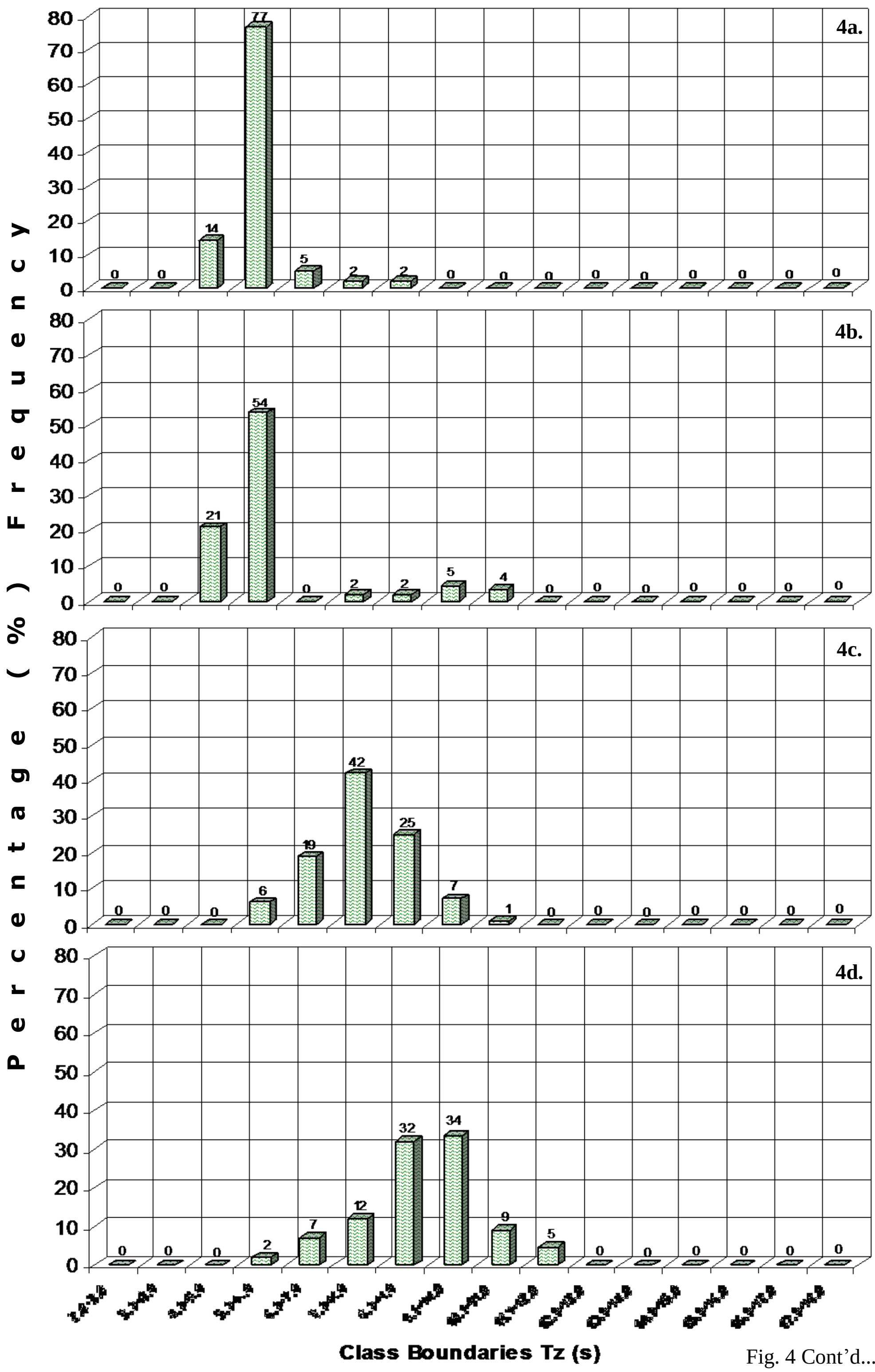


Fig. 4 Cont'd...

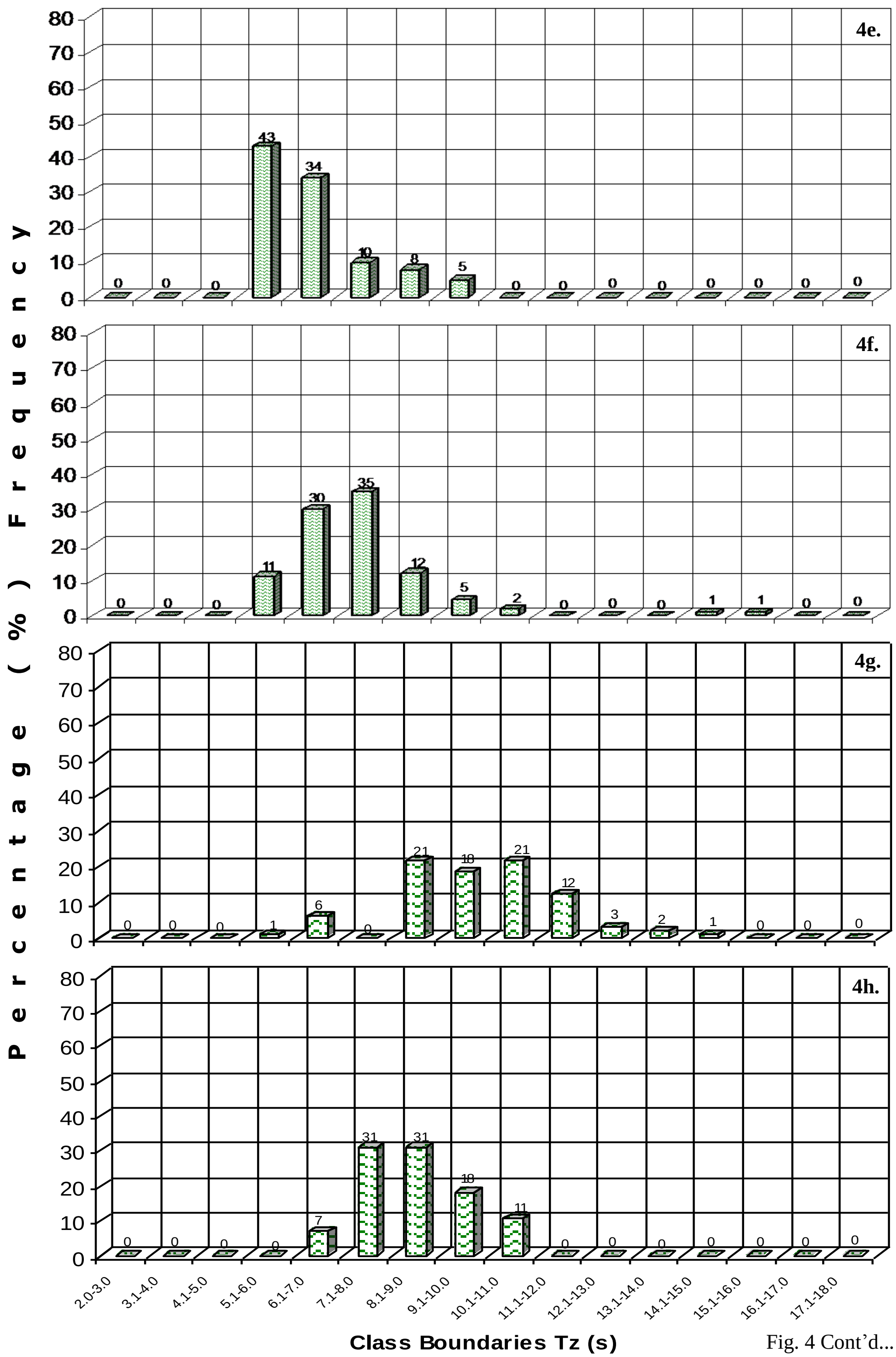
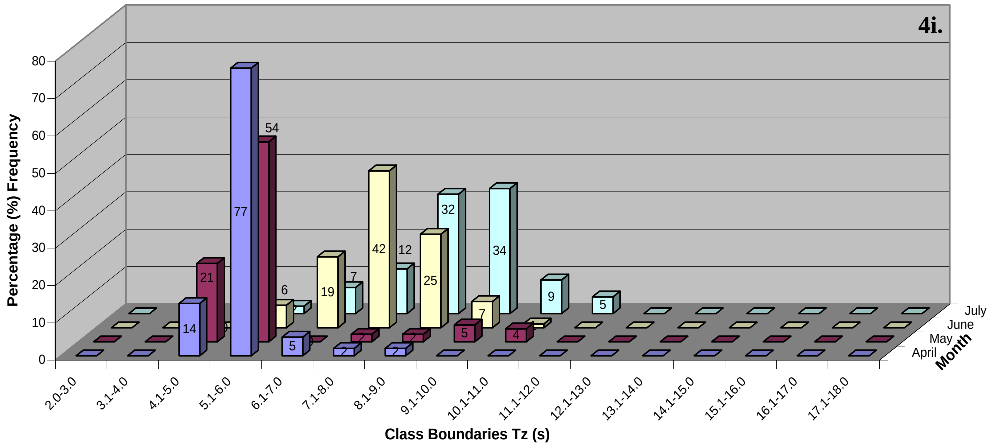

4e.
4f.
4g.
4h.
Percentage (%) Frequency
Class Boundaries Tz (s)
2.0-3.0
3.1-4.0
4.1-5.0
5.1-6.0
6.1-7.0
7.1-8.0
8.1-9.0
9.1-10.0
10.1-11.0
11.1-12.0
12.1-13.0
13.1-14.0
14.1-15.0
15.1-16.0
16.1-17.0
17.1-18.0

Fig. 4 Cont'd...



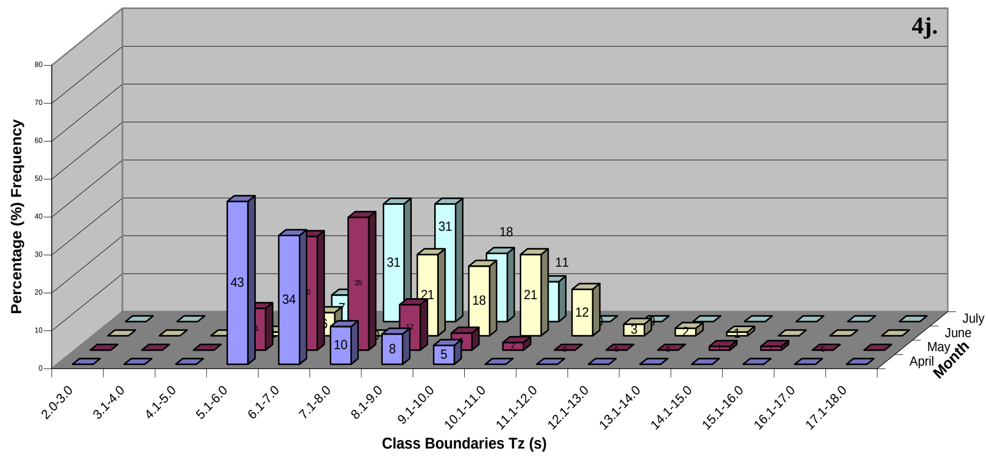


Fig. 4. Month wise frequency distribution of significant wave period (T_z); **a.** April 1985, **b.** May 1985, **c.** June 1985, **d.** July 1985, **e.** April 1986, **f.** May 1986, **g.** June 1986, **h.** July 1986, **i.** south-west monsoon 1985, **j.** south-west monsoon 1986.

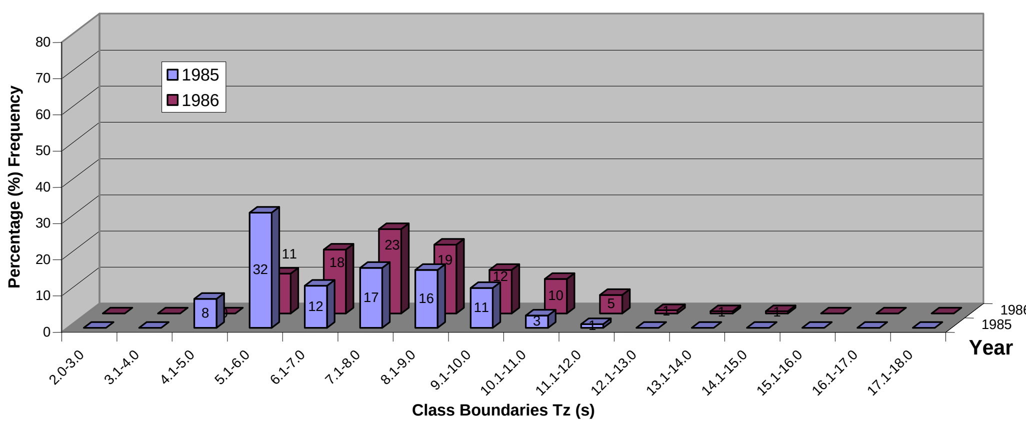
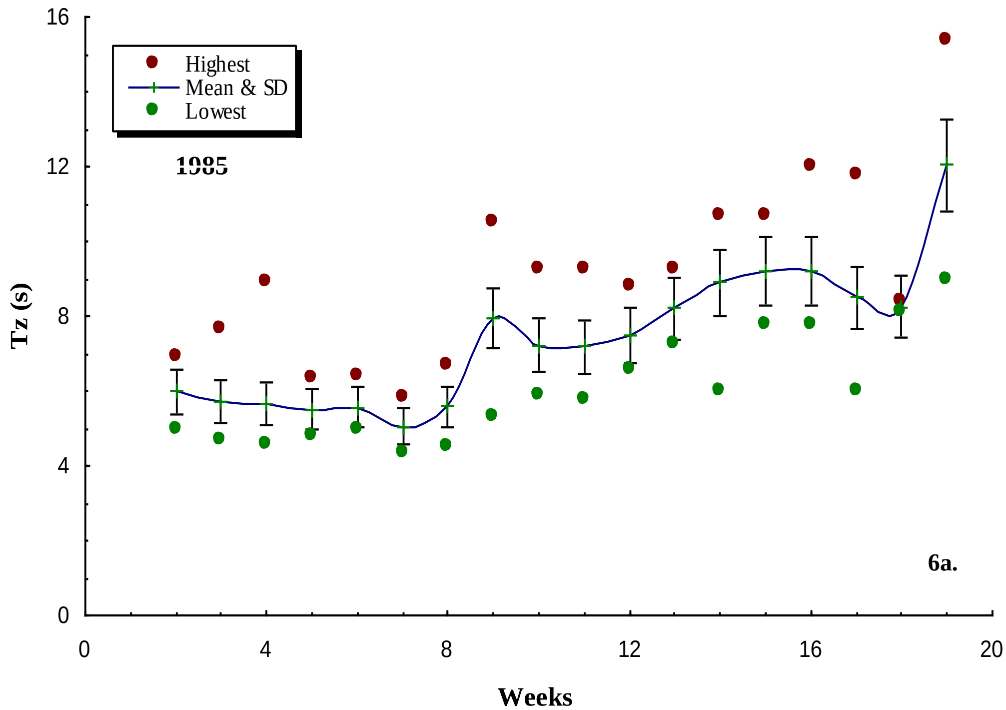


Fig. 5. Year wise frequency distribution of significant wave period (T_z) for the year 1985 & 1986.



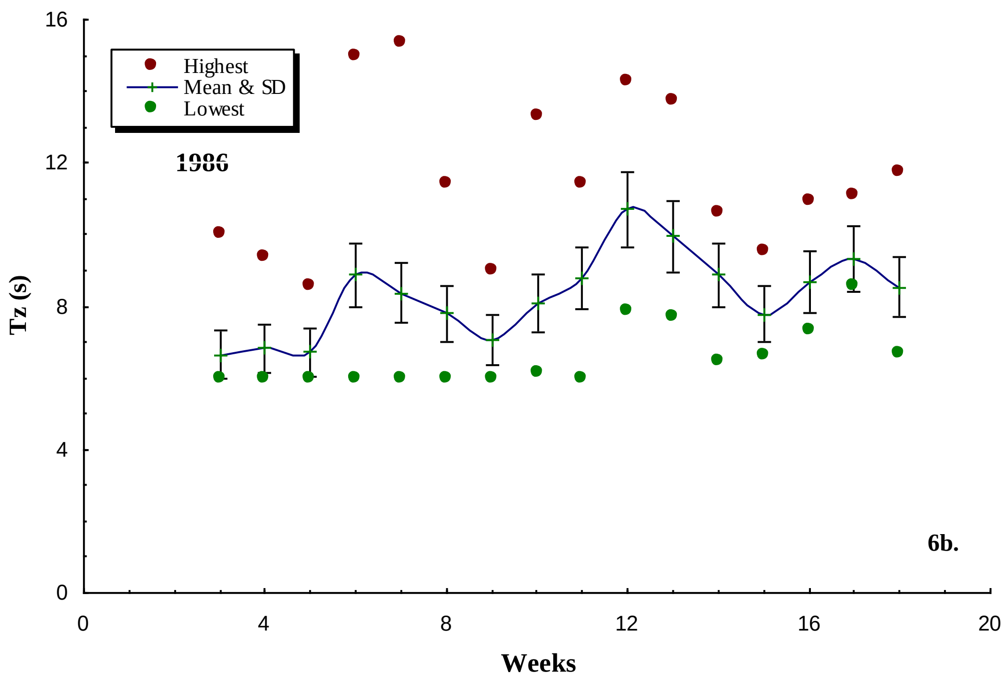


Fig.6. Weekly mean, SD, highest & lowest significant wave period (T_z), **a.** south-west monsoon 1985, **b.** south-west monsoon 1986.

The mean weekly off-shore significant wave period (T_z) during 1986 SW Monsoon with the SD of each week is shown in figure 7b. Weekly highest and lowest values are also shown in the same figure. The mean value of 6.65 s of T_z occurred during third week of April with an SD of 1.12 s. The highest and lowest T_z for the week were 10.0 s and 6.0 s. In the fourth week of April the mean value of T_z was 6.83 s with an SD of 1.27s. The highest and lowest values for the week were 9.38 s and 6.0 s. In the fifth week the mean T_z was 6.73 s with an SD of 0.89 s, the highest of 8.57 s and the lowest of 6.0 s.

The mean value of 8.87 s for T_z occurred during the first week of May with an SD of 2.7 s, highest of 15.0 s and lowest of 6.0 s. In the second week of May the mean T_z was 8.37 s with an SD of 3.09 s, highest of 15.38 s and the lowest of 6.0 s. In the third week the mean T_z was 7.81 s with an SD of 1.49 s, highest of 11.43 s and lowest of 6.0 s. In the fourth week of May the mean was 7.04 s with an SD of 0.85 s, highest of 9.02 s and the lowest of 6.0 s.

The mean T_z of 8.1 s occurred during the first week of June with an SD of 2.05 s, highest of 13.33 s and lowest of 6.12 s. In the second week the mean T_z was 8.78 s with an SD of 1.42 s, highest of 11.43 s and the lowest of 6.0 s. In the third week of June the mean T_z was 10.7 s with an SD of 1.78 s, highest of 14.28 s and lowest of 7.89 s. In the fourth week the mean T_z was 9.94 s with an SD of 1.51 s, highest of 13.75 s and lowest of 7.69 s.

The mean T_z of 8.88 s occurred during first week of July with an SD of 1.23 s, highest of 10.62 s and lowest of 6.45 s. In the second week the mean was 7.78 s with an SD of 0.85 s, highest of 9.52 s and lowest of 6.63 s. In the third week the mean T_z was 6.68 s with an SD of 1.27 s, highest of 10.94 s and the lowest of 7.32 s. In fourth week the mean T_z was 9.31 s with an SD of 0.77 s, highest of 11.11 s and lowest of 8.57 s. In the fifth week of July the mean T_z was 8.53 s with an SD of 1.58s, highest of 11.76 s and lowest of 6.67 s.

The highest T_z in the month of April was 10.0 s and the lowest was 6.0 s. In the month of May the highest was 15.38 s and the lowest was 6.0 s. In the month of June the highest T_z of 14.28 s and lowest of 6.0 s occurred. In July the highest T_z of 11.76 s and the lowest of 6.45 s were observed. The highest value of 15.38 s for T_z during the SW Monsoon of 1986 occurred in the second week of May and the lowest of 6.0s occurred in the third week of April with a mean of 8.37s and 6.73s respectively (Fig. 7b).

Shipping and naval or marine activities like off shore mineral and oil exploration, utilization of water and energy and construction of marine structures and harbours require accurate information on wave climatology. In any assessment of threats to the coastline waves must be taken into account. Sea level rise is given much importance, but in the last few decades, a rise in wave heights is a significant danger for the British Isles (Bacon and Carter, 1991). It is often necessary to make some estimate of the highest wave period, which is likely to occur in the life time of a coastal structure. Unfortunately, reliable wave data around the Pakistan coast is very meagre and limited. It would be of great value to carry out instrumental wave measurement programme spreading over the vast coastal zone for a number of years so that suitable predictions could be made. This study has been undertaken to present the wave-data for two years in a statistical and unified form so that useful predictions can be made for future reference and design applications and for scientists who need this information. The graphical comparison of T_z for the year 1985 and 1986 has revealed that the highest T_z may be expected in the month of June during southwest monsoon (SWM) in the coming years.

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