Wave Climate Assessment in the Coast of Merang – Energy and Mariculture Perspective

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Abstract

Ocean waves are a power-dense, predictable source of clean and sustainable energy that has not yet been exploited to any significant extent in Malaysia. The lack of suitable sheltered sites is forcing mariculture farmers to move to more exposed offshore locations in order to provide for continued growth in the industry. However, as farmers move to more exposed sites for on-growing, extreme wave climate conditions must be regarded as a normal environmental condition. The present work aims to evaluate the wave climate condition in Merang, which is traditionally considered as being more energetic. The study was based on data collected during the period of 2008 and 2010. From the analysis following features of the wave climate in the area of study was identified. The months November to January has the highest probability of occurrence of waves with significant wave heights greater than one meter. The frequency of occurrence of wave heights less than 0.5m occurred approximately equally in May, June, July and August. The wave mean periods greater than 5s were encountered in November, December and January. In general, the wave mean periods were greater than 3s through out the year. The dominant wave direction was from the northern sector accounted more than 64% and the southern sector percentage was around 20%. Therefore, potential wave renewable energy is mainly available during November to January. However, system for mariculture in this location should be designed to take into account these wave climate conditions. This analysis is a prerequisite for further investigations extended in time and area of coverage.

Keywords: Merang, Significant wave heights, Wave climate, Wave direction, Wave periods

1. Introduction

East coast of Peninsular Malaysia, facing the South China Sea, is subjected to a harsh wave climate. The lack of suitable sheltered sites is forcing mariculture farmers to move to more exposed offshore locations in order to provide for continued growth in the industry. However, as farmers move to more exposed sites for on-growing, extreme weather conditions must be regarded as a normal environmental condition. For appropriate fish cage system selection and sitting, sufficient wave data has to be available, as wave action on floating cage structures may create conditions where failures are likely. On the other hand, this wave energy has potential as renewable energy for the mariculture farms. This study attempts to survey its potentiality.

The development of renewable energy sources together with the expansion of those currently exploited is crucial to reducing the emissions of greenhouse gases as prescribed by the Kyoto protocol. Amongst renewable energy sources, ocean waves contain the highest energy density. This allows for substantial energy generation in relatively small areas from a virtually inexhaustible energy source. Wave energy presents a number of advantages with respect to other CO_2-free energy sources – high availability factor compare with other resources such as wind or solar energy, resource predictability, high power density, relatively high utilization factor and low environmental and visual impact [1]. It has been estimated that if less than 0.1% of the renewable energy available within the oceans could be converted into electricity, it would satisfy the present world demand for energy more than five times over. The majority of environmental impacts occur during the construction and installation phases, but once in operation wave energy converters (WEC) release no greenhouse gases and are unlikely to affect migratory fish patterns or coastal eco-systems [2]. A WEC can even have positive environmental effects, as the mooring lines that keep the WEC in place provide artificial reef habitat for sea life [3-4].

A research and development program on wave energy was established by the International Energy Agency in 1978, the program was lead by Ireland, Japan, Norway, Sweden, United Kingdom and USA [5]. In the last few decades, various locations have been investigated for the availability of wave power for energy conversion. Studies on wave power potential of UK, Denmark, Belgium, Portugal, Baltic Sea, USA, India, Argentina, Brazil, New Zealand, Ireland, Japan, Chile, Korea, Norway and Sweden and Australia can be found in the related literature.

Waves at different places have certain character and energy density. The amount of energy that can be created using wave technologies varies from day-to-day and site-to-site, depending on location and weather conditions. Nevertheless, wave energy can be accurately predicted within a period of a few days. In the basic studies as well as in the design stages of a WEC to ensure that it will convert the energy efficiently over a sufficient wave period range while accommodating the large distribution of powers, the knowledge of the statistical characteristics of the local wave climate is essential. Therefore, it is important to map the available energy to optimize the benefits from prospective developments. The potential for the wave energy extraction can be obtained from analysis of the wave climate.

Selection of a suitable site for mariculture venture determines investment, running cost and strongly influences the ultimate success of the resulting enterprise [6]. Particularly in the case of fish cage culture, most fish farm sites have been placed in relatively sheltered waters but there are a finite number of such suitable sites. A variety of pressures are now ensuring that the future of mariculture is likely to be further offshore, with the whole trend of the industry being towards larger units, supporting deeper and heavier nets in more exposed waters. Mariculture is also facing increasing numbers of objections from those in the tourism industry who regard fish farms as an offensive intrusion upon the best natural view, and the increase and rapid transmission of endemic diseases to adjoining areas has resulted in a general movement of production to further offshore. Moreover, it seems clear that near-shore sites with restricted depths and water transfer are leading to the need to monitor the sites on a regular basis, with associated increases in cost of production.

The possible environmental problems in offshore mariculture, wave action is of most concern. Knowledge of the wave action at a potential site will help the choice of a proper cage and mooring technology for the site, as well as estimating the risk of failure [7]. Both likely highest waves over a certain period and prevailing or average wave heights are significant measures in assessing the mariculture system structure. The challenges of sitting and operating mariculture systems in exposed sites fall into two major areas; storm survival and servicing or operating capabilities. Neither area has a substantive track record of experience on which to base decisions [8].

The wave energy potential has been reported for few countries around the world, reliable and yearlong wave data is still needed for Malaysia, especially east coast of Peninsular Malaysia. This study therefore addressing this need by investigating and evaluating the amount of ocean wave power at Merang, Terengganu state, facing South China Sea using wave activity data collected by this research. Further, this research focuses on extreme wave height estimations as this is a more general and straightforward indicator for sitting mariculture systems.

2. Ocean wave properties

Regular ocean waves are the sum of numerous smaller wave components. Each component wave has its own height, period, and direction of propagation. But when evaluating the incident energy in a complex sea state, there are many interacting waves, so there is not a single wave height and wave period.

To measure the incident energy of a complex sea state, two characteristic values are used: significant wave height, H_S (m), and energy period, T_e (s). Both of these values are independent of the direction of wave propagation.

In order to analyze the weeks, months and years variations of the wave height and wave power, the data are averaged to get the typical variation of wave properties in a period by

$$H_{averaged}, T_{averaged}(k) = \frac{1}{M}\sum_{i=1}^{M} H_i, T_i(i,k) \quad (1)$$

$$P_{averaged}(k) = \frac{1}{M}\sum_{i=1}^{M} P_i(i,k) \quad (2)$$

where M is the number of years of available data. The mean power at a station is estimated by calculating the mean of the averaged wave power, $P_{averaged}$. Based on this estimation, one can identifies the locations which are having more ocean wave renewable energy density and further, mariculture farming sites selection can be done with out much difficulty.

3. Study area and data

The area of interest is Merang, Terengganu state, facing South China Sea. The data set has been recorded from under water fixed platform where Acoustic Wave and Current (AWAC) meter was used. The Merang under water platform is situated about six kilometers east of the Merang coast in a water depth of approximately twenty meters. The data are recorded continuously and simultaneously at 1 Hz. The data are transmitted on a monthly basis and this now constitutes the largest, continuously recorded set of wave data on the Merang. This constituted data provides large sample of data covering a range of H_s, T_e and wave direction.

4. Results and Discussion

The measured data sources were considered for this analysis. The data measured during the period 2008 to 2010 at 2 hour intervals in the coastal environment close to Merang jetty. Significant wave height and mean wave periods of whole year are presented in Figure 1.

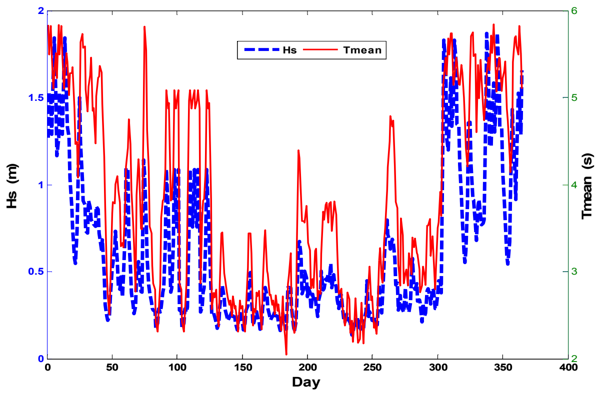

Figure 1: Significant wave height and mean wave periods of whole year

The ocean wave climate and the average wind velocity [9] have a quite pronounced cyclic evolution at Terengganu. The wave climates in the study area are characterized by significant wave height variations during the year. The annual average evolution of periods of calm sea, significant wave heights smaller than 0.2 m as well as of the alternating occurrence of smooth seas and rough seas are presented in Figure 2. From this results it is observed that the duration of the periods of calm is maximum in August (30% of the total time) and minimum in November, December and January (0%). Smooth seas occur more than 50% of the time in whole year and more than 90% of the time in February, March, April and October. Rough seas occur more than 40% in November, December and January and other months less than 5%. The ratio between smooth seas and rough seas being about 1.0 in January, 1.5 in November and 0.9 in December.

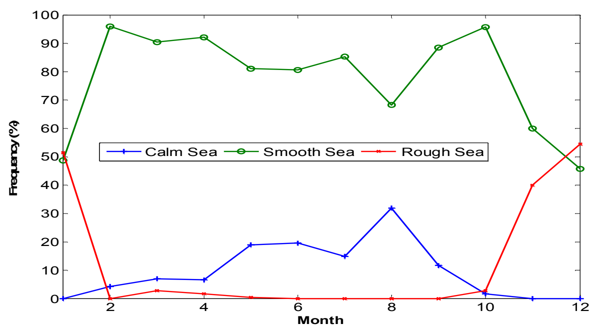

Figure 2: Annual average evolution (%) of periods of calm, smooth and rough seas

The principal wave directions distributions computed for each month and year (% of the time) are presented in Table 1. The waves were observed to propagate from the northern sector (41%). The highest average values of the wave parameters are encountered in November, December and January;(more than 1.2 m significant wave height and more than 5 s mean period) as illustrated in Figure 3.

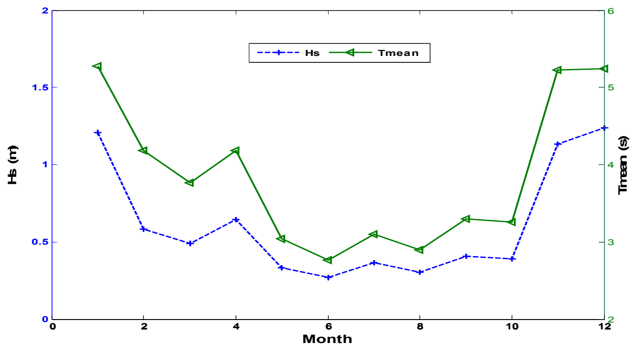

Figure 3: Monthly average values of the wave parameters (Hs and Tmean)

The results from the analyses are presented in Figures 4 - 7 and they include the classes of significant wave height (Figure 4), mean periods (Figure 5). The monthly maximums and average values of the wave heights and wave periods are shown in Figure 6 and 7, respectively.

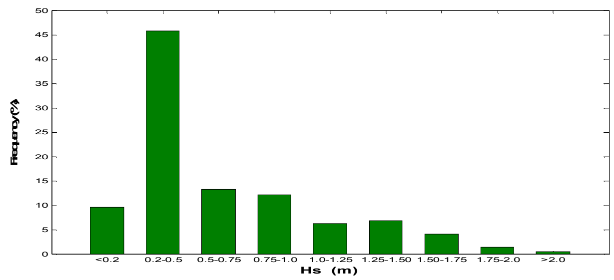

Figure 4: Classes of significant wave height for whole year

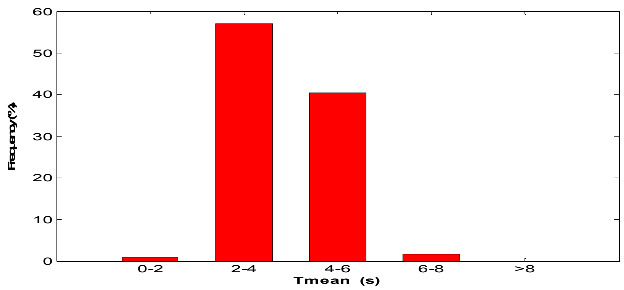

Figure 5: Classes of wave mean period for whole year

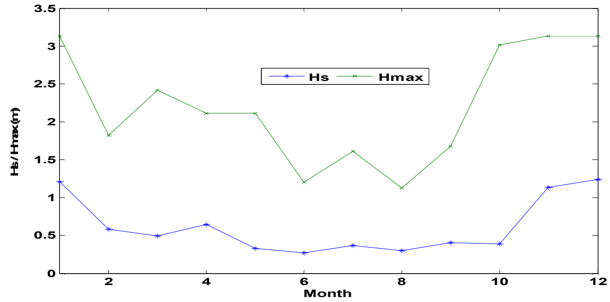

Figure 6: Monthly average values for the Hs and maximum wave height

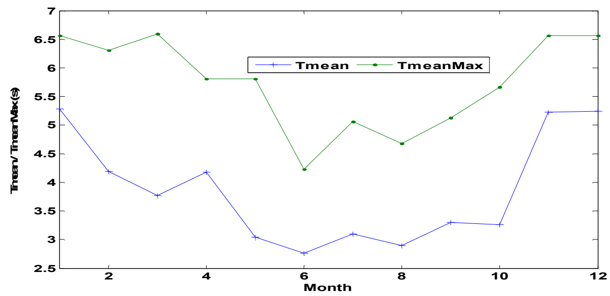

Figure 7: Monthly average values for the average and maximum wave mean periods

From the results, the following features of the wave climate in the study area can be identified. Much of the wave energy occurs during the northeast monsoon period. The northeast monsoon is considered the five-month period extending from November through March. The month of December has the highest probability of occurrence of significant wave heights greater than 2 m (2%), the possibility of this occurrence begins in November and lasts through January. Similarly, the month of December has the highest probability of occurrence of maximum wave heights greater than 2 m is 44.1% followed by January (41%) and November (33%). An identical evolution is seen for the wave heights in the classes 1-2 m, the highest frequency of occurrence is in December and represents 68.01% of the total of the month. The frequency of occurrence of wave heights greater than 1 m is greatest in December (70%), whereas no such waves occur in June to August. Waves with heights smaller than 1 m occur more than 29% throughout the year, with a minimum in December and a maximum (100%) in June to August. The maximum wave heights greater than 1 m is greatest in November (57%), whereas less than 1% waves occur in June. Maximum waves heights; smaller than 1 m occur less than 10% in November, December and January.

Regarding wave mean periods, values greater than 6 s were encountered in November to March with a minimum in March (1%) and a maximum in January (7%). The periods greater than 6s are characteristic of northeast monsoon only. The periods less than 2 s were encountered in May to September with a minimum in May (1%) and a maximum in July (4%). The wave periods 2-4 s occurred more than 40.6% in February to October with a minimum in April (41%) and a maximum in June (98%). The other class of wave mean periods (2-4 s) occurred more than 59.4% in November to April other than March with a minimum in April (59%) and a maximum in November (93%).

The dominant wave direction is from the northern sector (NW, N, and NE) with 64%. The southern sector (SE, S, SW), is accounted only 20%. Some general observations can be made from the analysis of the above case study. The first observation is that the locations of the energetic peak and the maximum significant wave height do not always coincide.

Further, the studies reveal that the annual average wave energy was 17.69 x10^6 Wh/m/year and the average wave power at 4040 W/m. It is observed that monthly averaged wave power varies between 150 W/m and 6490 W/m. In general, monthly mean wave power is higher in the start and end of the year.

Table 1: Wave frequencies (%) corresponding to the principal directions computed for each month

Dir	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
N	69.9	70.8	59.9	66.7	12.9	9.4	6.5	9.1	10.6	22.6	75.0	75.8	40.5
NE	24.5	14.6	19.6	26.7	12.9	13.3	9.1	18.5	13.3	11.0	19.2	18.8	16.8
E	0.5	0.3	3.2	0.0	13.2	14.7	14.5	25.0	14.2	2.4	0.6	0.5	7.5
SE	0.0	0.3	0.3	0.0	8.1	7.5	4.3	7.8	6.4	5.9	0.0	0.0	3.4
S	0.0	0.3	0.0	0.0	7.5	8.3	7.0	3.8	38.3	32.0	0.0	0.0	8.1
SW	0.0	0.9	1.1	0.0	20.7	20.6	20.4	9.7	13.1	18.3	0.0	0.0	8.8
W	0.0	2.1	3.0	0.3	17.2	18.1	28.5	14.0	3.3	5.6	0.0	0.0	7.7
NW	5.1	10.7	12.9	6.4	7.5	8.1	9.7	12.1	0.8	2.2	5.3	4.8	7.1

5. Conclusions

An analysis of the measured wave parameters in the study area was carried out using data measured. The months of November, December and January have the higher probability of occurrence of waves with significant wave heights greater than 1m. The frequency of occurrence of wave heights less than 0.5m occurred approximately equally in May, June, July and August. The wave mean periods greater than 5s were encountered in November, December and January. In general, the wave periods were greater than 3 s throughout the year. The total wave energy was found to be 17.69x10^6 Wh/m in an average year, whereas the average wave powers vary from 150 to 6490 W/m. The dominant wave direction from the northern sector accounted more than 64% and the southern sector percentage was around 20%.

The potential for wave energy extraction and site selection for mariculture can be determined from analysis of the wave climate. Further, system for mariculture in this location should be designed to take into account these wave climate conditions. This analysis is a prerequisite for further investigations extended in time and area of coverage. The results of the present study can be used with confidence for future mariculture and ocean wave energy related planning and design works in the study area and areas with similar climate conditions.

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