

WAVE-POWER POTENTIAL ALONG THE COAST OF THE PROVINCE OF BUENOS AIRES, ARGENTINA

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Abstract—The coast of the Province of Buenos Aires, Argentina, has been studied to determine the wave-power potential. Using wave data (4 yr) from accelerometers, pressure sensors (1 yr) and a visual observation program (10 yr), the wave-power density was calculated at five locations. The annual average increases southwards, ranging between 2.3 kW/m at Mar de Ajó and 7.5 kW/m at Puerto Quequén. Annual averages of maximum wave power give 69 and 61.3 kW/m for Punta Médanos and Puerto Quequén, respectively.

INTRODUCTION

The global ocean energy resources may make an important contribution to satisfy a projected demand of 3×10^{13} W for the next century. Many systems for extracting energy from the ocean have been designed and tested. Some of these have already been put in use for power generating purposes, while others are still at a development stage. As noted by Carmichael et al.,¹ few wave-energy conversion systems have been tested at sea. Analyses of devices may be found in Refs. 2–5.

THE WAVE-ENERGY RESOURCE

Wave power estimation for a particular site requires previous measurement of the wave climate. Very often, economical and operative difficulties are responsible for the lack of wave data from most of the world's coastlines and open waters. In many cases visual observations are used to provide the necessary information at a very low cost. Worldwide figures for wave-power density are presented by Salter,³ who has reproduced a map of the world with the estimates made by Tornkvist.

The southwest Atlantic coast is one of the regions in which the lack of wave data is more evident. This paper presents a set of wave data obtained through accelerometer buoys, pressure sensors, and visual observations taken along the coast of the Province of Buenos Aires, Argentina (Fig. 1), a densely populated area. Two goals are pursued in this work: to modify the scarcity of published wave data from this area, and to make a first analysis of them so that the possibilities of wave energy conversion might be considered.

SITE DESCRIPTION AND SOURCES OF WAVE DATA

The Province of Buenos Aires has an important continental shelf and different bathymetric features along the coastline. These include straight and almost parallel depth contours in the area of Mar de Ajó, sand ridges between Punta Médanos and Pinamar,⁶ and a few sites where

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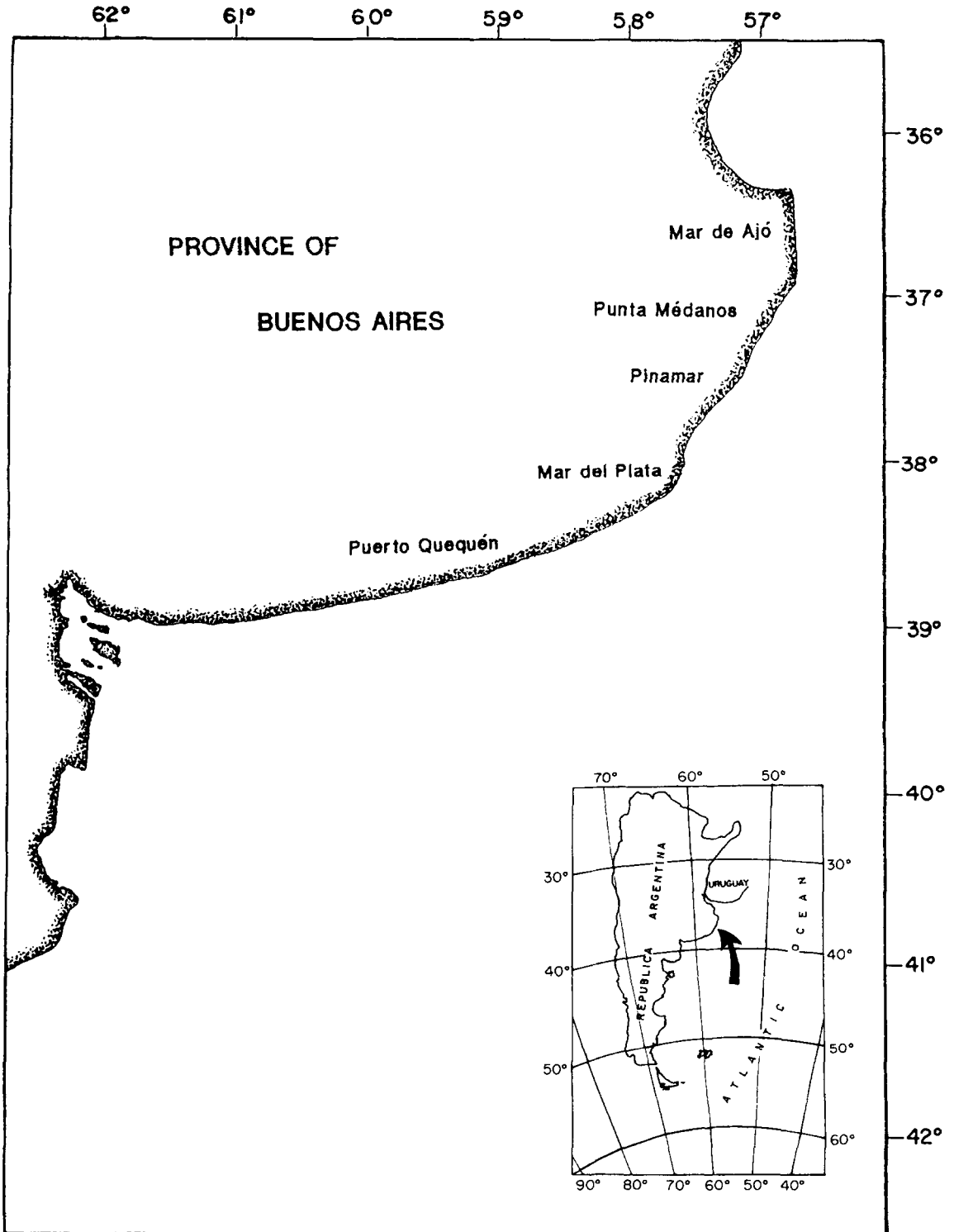


Fig. 1. Wave-measurement sites along the coast of the Province of Buenos Aires.

the depth is up to 20 m not far from the shoreline. Mar del Plata and Puerto Quequén have entrances open to the sea. The building of harbours and coastal defences, together with analyses of littoral sediment transport and longshore currents for future projects, have led to wave measurements along this coast (Fig. 1) by means of accelerometers (Punta Médanos⁷) and pressure sensors (Mar del Plata⁸ and Puerto Quequén⁹), as well as visual observations (Mar de

Aj6¹⁰ and Pinamar¹⁰). The analysis of the wave records was carried out by using a standard Tucker–Draper¹¹ method. The wave power was estimated from these data.

WAVE POWER

Although the use of non-linear theories is necessary for a more accurate description of some properties of ocean waves, especially those related to shoaling, the linear (or Airy) theory has proved to be adequate for the prediction of the basic features of waves. This theory states that the average power of a sinusoidal wave per unit crest width in deep water is

$$P = (\rho g^2 / 32\pi) H_0^2 T, \quad (1)$$

where ρ is the water density, g the acceleration due to gravity, H_0 the deep water wave height, and T the wave period. For a random sea, composed of a large number of linear (sinusoidal) waves of different heights and periods, Equation (1) becomes¹²

$$P = (\rho g^2 / 64\pi) H_s^2 T_z, \quad (2)$$

where H_s is the significant wave height and T_z the zero-crossing period. For the Province of Buenos Aires, wave data have been obtained at coastal locations for which deep-water conditions do not hold. The mooring depths were 12 m at Punta Médanos, 11 m at Mar del Plata and 7 m at Puerto Quequén. For the measured range of wave periods, these mooring depths give intermediate water depths conditions. Applying Airy's theory for intermediate water depths, Eq. (2) becomes

$$P = (\rho g^2 / 64\pi) H_s^2 T_z \{1 + [(2kd) / \sinh(2kd)]\} \tanh(kd), \quad (3)$$

where d is the water depth, $k = 2\pi/L$ is the wave number and L the wavelength. In this paper, $\rho = 1030 \text{ kg/m}^3$ and $g = 9.81 \text{ m/sec}^2$.

RESULTS AND DISCUSSION

Figures 2 and 3 show the distribution of monthly averages, maximum wave heights, and monthly average periods for the sites of Fig. 1. For Mar del Plata and Puerto Quequén, the records cover only 1 yr.^{8,9} Inspection of Figs. 2 and 3 shows a tendency for wave height but not the wave period to increase southwards. Annual averages of mean and maximum wave heights and of wave periods are shown in Table 1. Punta Médanos, despite its nearness to Mar de Aj6, exhibits an annual average wave height that is on the order of 70% higher than that of Mar de Aj6. The reason for this behaviour is that while Mar de Aj6 has straight and almost parallel depth contours, the bathymetric features of Punta Médanos are very complicated, with a set of sand ridges pointing to the SSE at an angle of 30° with respect to the shoreline.⁶ This type of bathymetry is responsible for shoaling and refraction that cause the focusing of wave energy.

Monthly distributions of average and maximum wave power per unit frontage have been calculated for these same sites and are illustrated in Figs. 4 and 5. Annual averages of mean and maximum wave power are summarized in Table 2. It is apparent that the mean wave power also increases southwards, ranging between 2.3 kW/m at Mar de Aj6 and 7.5 kW/m at Puerto Quequén. For the reasons explained above, Punta Médanos exhibits an average value of wave power that is almost 140% larger than that of Mar de Aj6. Annual averages of maximum wave power give values as high as 69 kW/m for Punta Médanos and 61.3 kW/m for Puerto Quequén.

The spectral method of Blackman and Tukey¹³ and the fast Fourier transform¹⁴ were applied to a 20-min long wave record from Punta Médanos to determine a characteristic wave height, H_c , and a peak period, T_p . The results are depicted in Fig. 6 and compared in Table 3 with

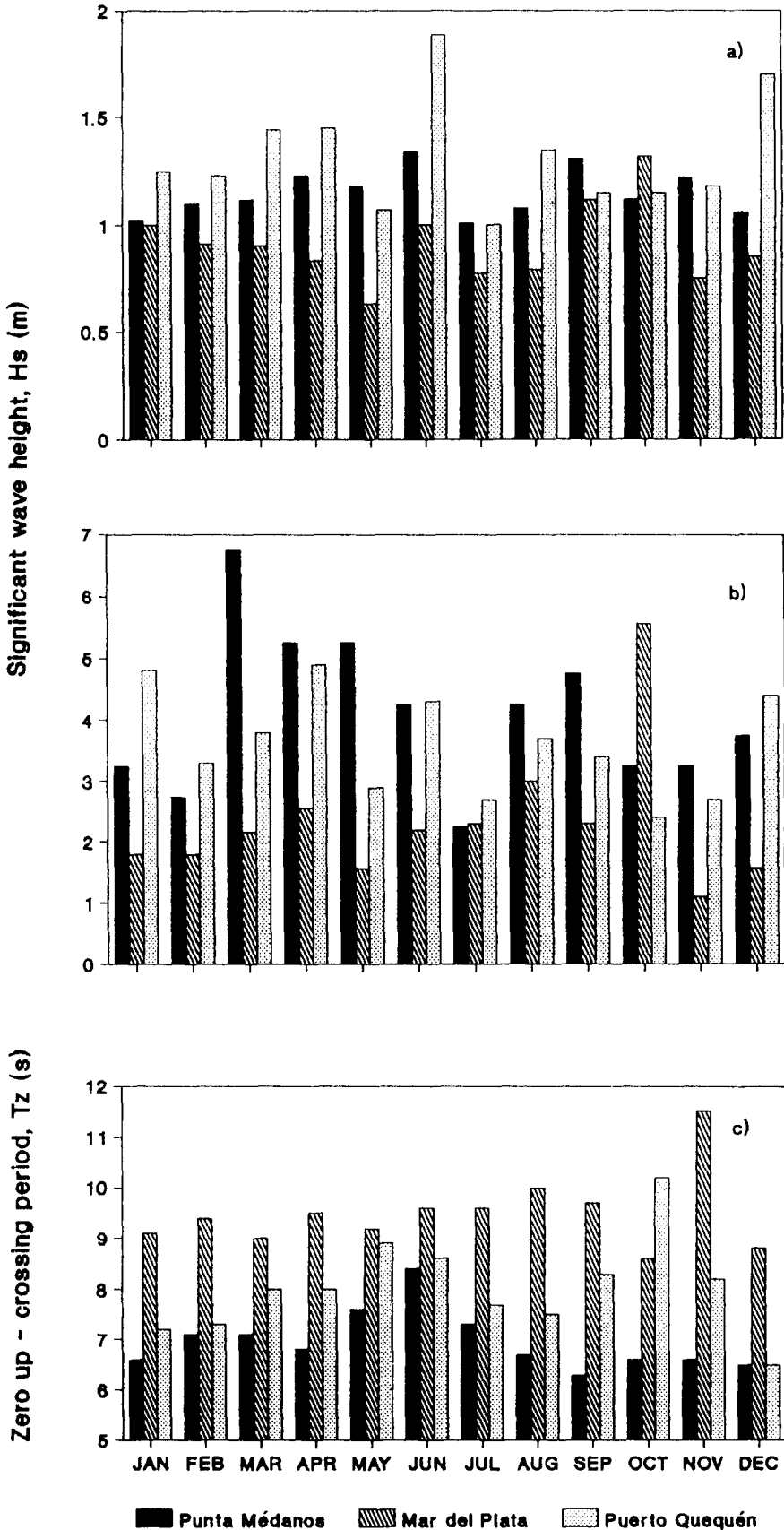


Fig. 2. Monthly distributions of average (a) and maximum (b) significant wave heights and average zero-crossing periods (c) for Punta Médanos, Mar del Plata and Puerto Quequén.

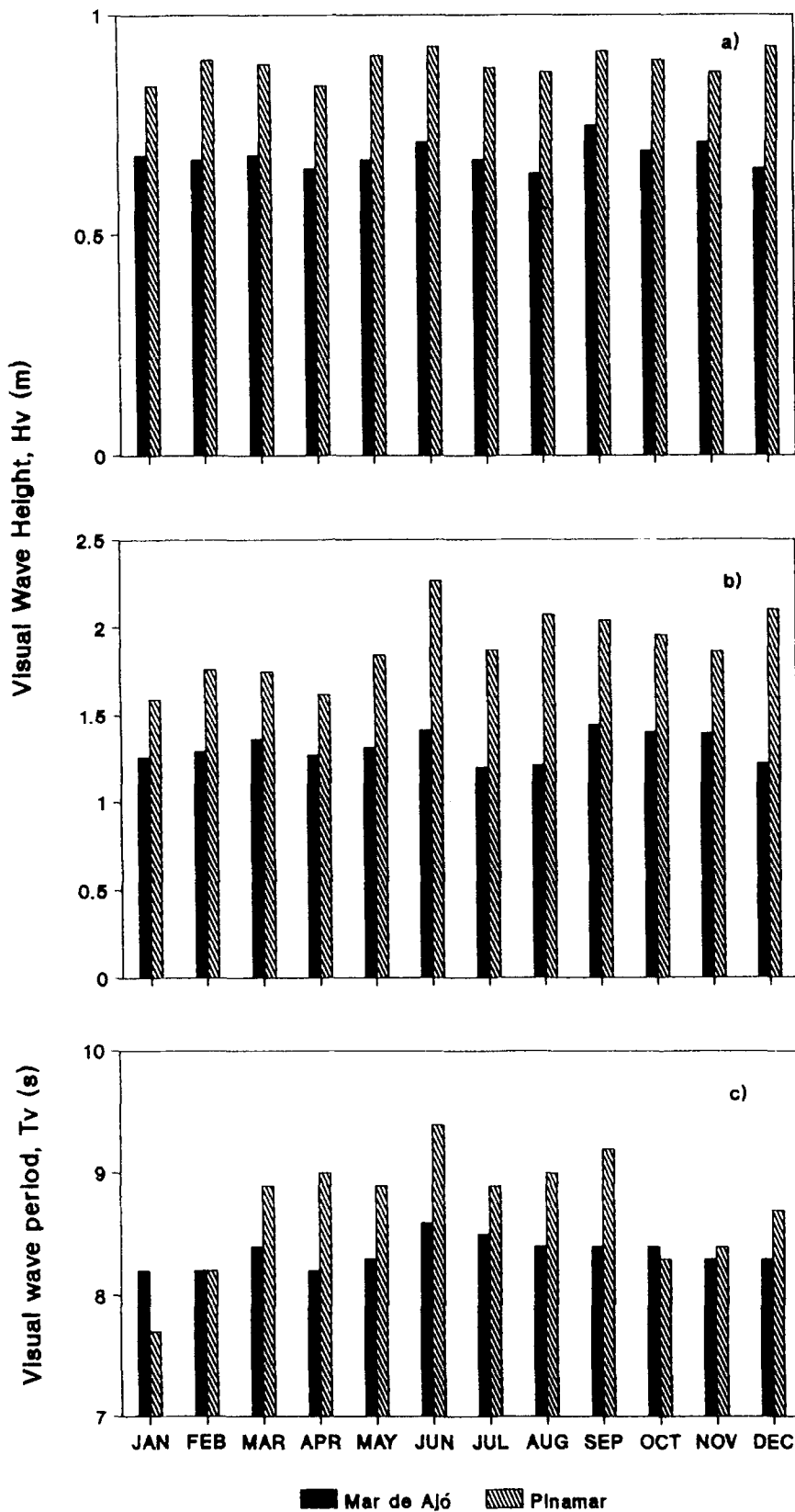


Fig. 3. Monthly distributions of average (a) and maximum (b) visual wave heights and average visual periods (c) for Mar de Ajó and Pinamar.

Table 1. Annual averages of mean and maximum wave heights and wave periods for the five locations.

Site	Wave height (m)		Period (sec)
	mean	maximum	
Mar de Ajó	0.88	1.31	8.4
Punta Médanos	1.15	4.10	7.0
Pinamar	0.89	1.90	8.7
Mar del Plata	0.91	2.30	9.6
Puerto Quequén	1.33	3.61	8.0

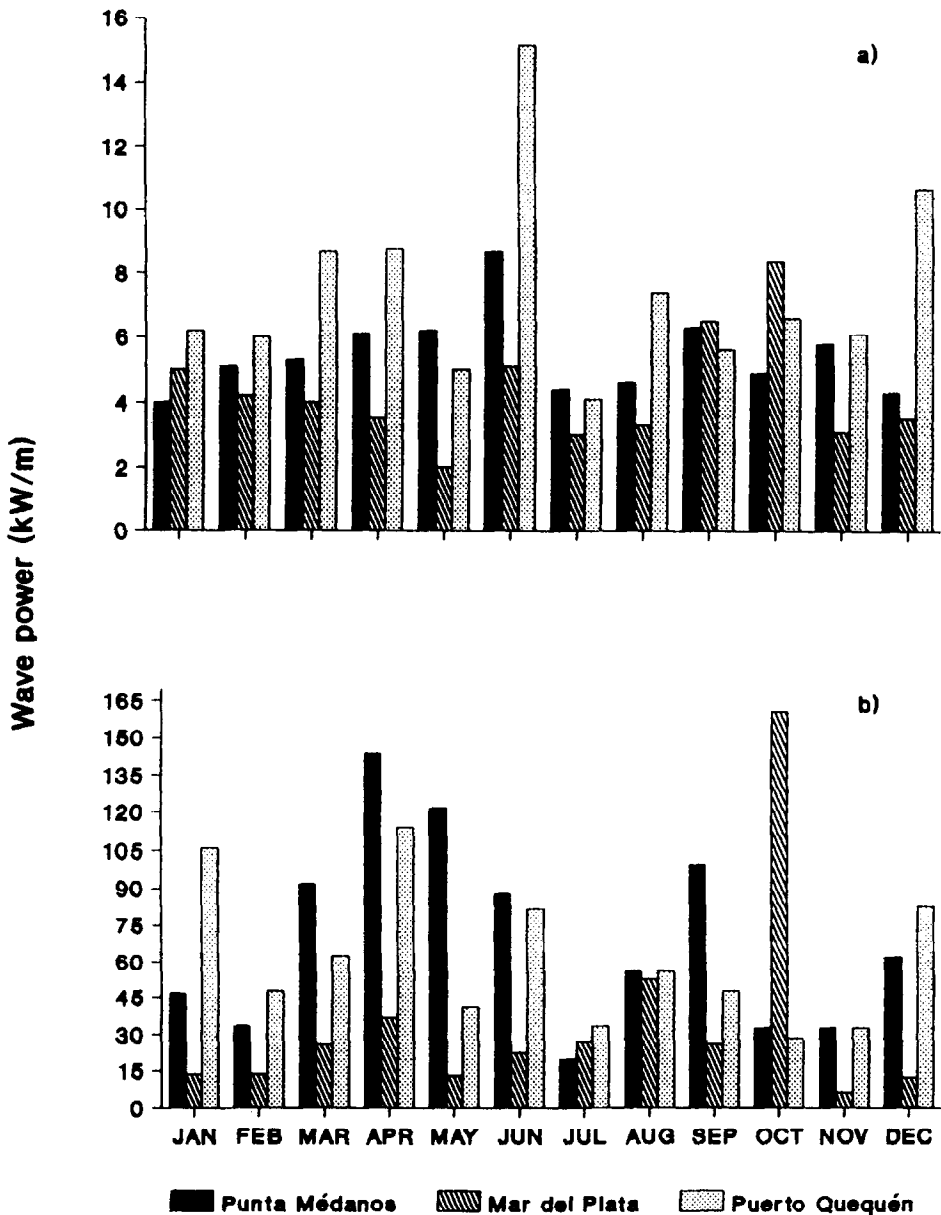


Fig. 4. Monthly distributions of average (a) and maximum (b) wave power for Punta Médanos, Mar del Plata and Puerto Quequén.

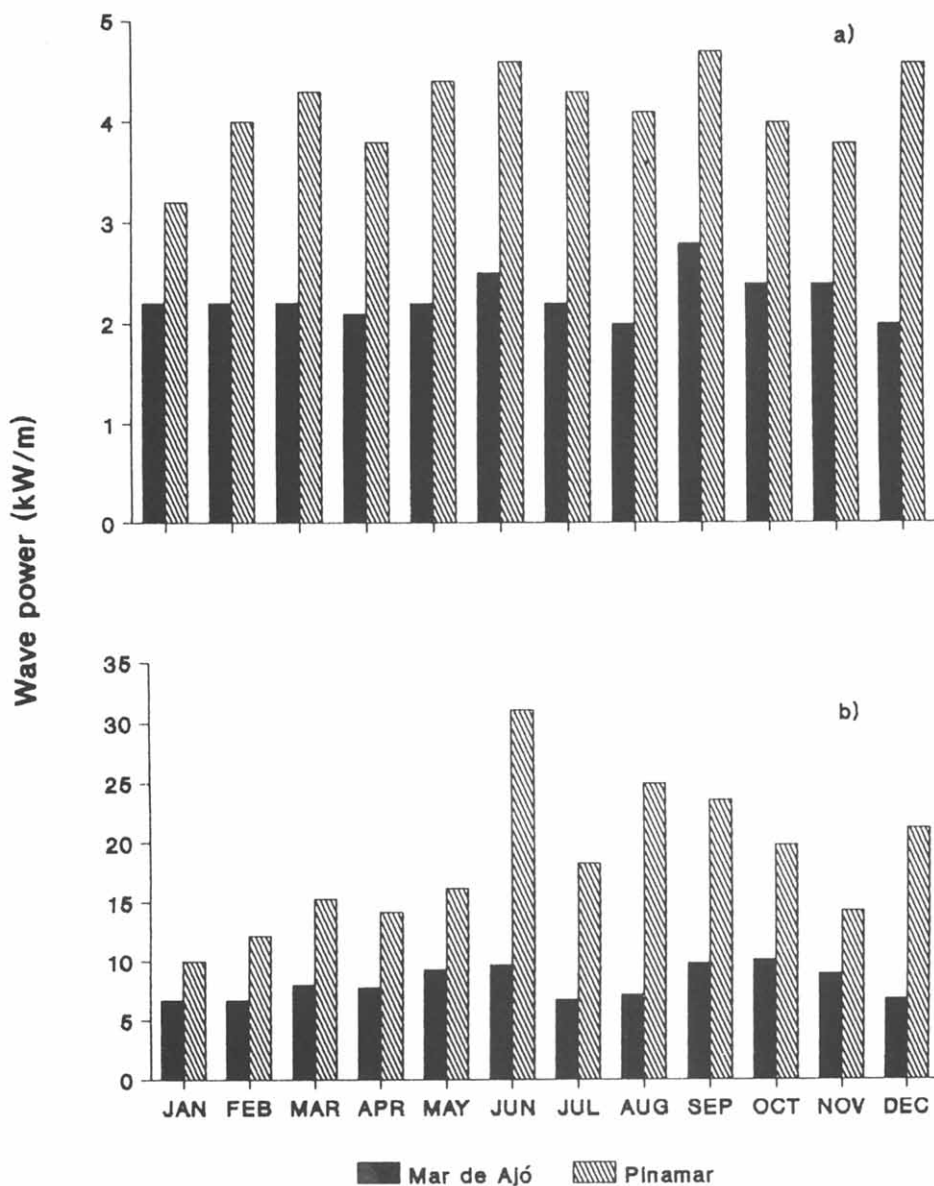


Fig. 5. Monthly distributions of average (a) and maximum (b) wave power for Mar de Ajó and Pinamar.

Table 2. Annual averages of mean and maximum wave powers for the five locations.

Site	Wave Power (kW/m)	
	mean	maximum
Mar de Ajó	2.3	8.2
Punta Médanos	5.5	69.0
Pinamar	4.2	18.5
Mar del Plata	4.3	34.2
Puerto Quequén	7.5	61.3

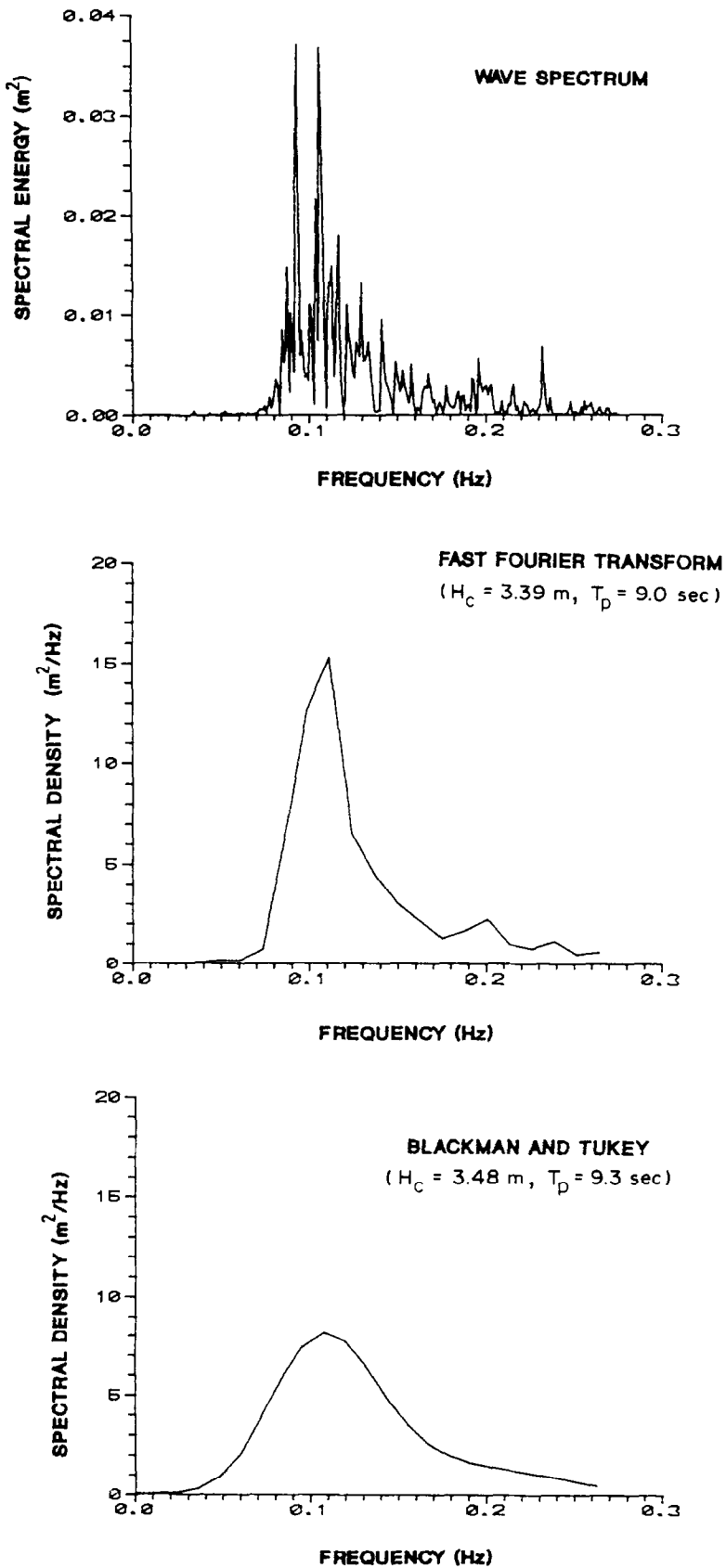


Fig. 6. Sample wave spectra from Punta Médanos. The upper spectrum was not smoothed.

Table 3. Comparison between the spectral method and zero-crossing wave statistics for a sample record from Punta Medanos.

Method	Hs (m)	Tz (sec)	Wave power (kW/m)
Blackman & Tukey ¹³	3.48	9.3	62.3
Fast-Fourier Transform ¹⁴	3.39	9.0	58.0
Tucker & Draper ¹¹	3.48	8.5	58.9

those for the same date and hour obtained through a Tucker-Draper¹¹ analysis. From these results, the corresponding values for the wave-power density were calculated. The agreement is good but, as Mansard¹⁵ has pointed out, the use of different expressions for calculating the wave power can yield estimates with variations up to 40%. For example, according to Mansard, zero-crossing wave statistics tend to underestimate the power by up to 18% and evaluation of the wave-power density should be performed using the spectral integral

$$P = (\rho g^2 / 4\pi) \int S(f) / f \, df \quad (4)$$

as a standard tool, where f is the wave frequency and $S(f)$ the variance density function of the wave record.

Punta Médanos and Puerto Quequén are the best places (see Table 2) for siting a wave-energy conversion project. A detailed further data-collection program is needed. Comparisons of the Province of Buenos Aires with other wave-power sites are included in

Table 4. Wave power estimates from different locations in the world.

Location	Annual Average Wave Power (kW/m)	Reference
OWS 'Juliett' North Atlantic	94.2	16
Famita Station North Sea	39.1	16
Norway's coast	11.9 - 38.3	16
Tofino, B.C. Western Head, N.S. Canadian coast	35.1 12.1	17
Sevenstones, SW of England	26.5	16
Province of Buenos Aires, Argentina	2.3 - 7.5	this work
Kerala Coast, SW of India	0.7 - 10.9	18
North Carolina, United States	5.0 - 6.0	4

Table 4. The coast of the Province of Buenos Aires is not as desirable as regions located on the North Atlantic shelf and the Pacific coast of Canada, but its wave energy resources may nevertheless be applied for limited purposes.

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