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RECREATION CLIMATE ASSESSMENT

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ABSTRACT

The study examines methods for assessing the atmospheric resource component of recreation environments. Beach use is selected as it is a highly weather sensitive recreational activity. The study area is King's Beach in Queensland, Australia. The nature of the relationship between beach climate and the enjoyment of recreational pursuits is taken to be a function of thermal, physical, and aesthetic components of the atmospheric environment. A body–atmosphere heat-budget model is used to integrate and isolate the thermal component of beach weather and enable identification of important non-thermal recreational resource attributes of the atmosphere. Beach-user sensory perception of on-site atmospheric conditions expressed verbally is used to assess the physical and aesthetic components of the atmospheric environment. The immediate thermal environment of the beach user is the main contributing factor to assessments of the desirability of on-site meteorological conditions, followed by the non-thermal effects of cloud and wind. Rainfall events of half-hour duration or longer have an overriding effect.

KEY WORDS Recreation climate Human thermal climate Human response to climate Beach climate

INTRODUCTION

Most of the research in recreation climatology appears to be motivated by the potential usefulness of climatological information within planning processes for tourism and recreation. For this reason, the research addresses the theme of recreation climate as an adjunct to a variety of decision-making processes, ranging from those related to such things as the development and location of appropriate recreational facilities, or determining the length of the recreation season during which a facility will operate, to those as specific as planning future activities involving personal decisions of when and where to go for a holiday.

There has also been interest in the indirect effects of climate. For example, Perry (1972) suggested that people leave swimming pools and golf courses on wet days and converge on nearby towns in search of amusement indoors. Therefore, depending on the weather sensitivity of the recreational activity, climatic information can help in the planning, scheduling, and promoting of alternative indoor entertainment facilities. Perry (1972) also describes the use of climatic information in publicity campaigns to condition tourists' expectations of climate at a certain location.

It is clear, however, that if climatic information is to be useful in decision making, it needs to be presented in a form appropriate to the problem. Recreationists respond to the integrated effects of the atmospheric environment rather than to climatic averages. It is generally accepted, therefore, that standard weather data or even secondary climatic variables are not always reliable indicators of the significance of atmospheric conditions. At any given air temperature, for example, the thermal conditions experienced will vary depending on the relative influence and often offsetting effect of wind, humidity, solar radiation, and level of a person's activity. Moreover, the design of a particular thermal assessment scheme will depend on the intended use as well as on the nature of the thermal climatic conditions to which it is to be applied. For example, schemes have been devised for groups of runners (de Freitas *et al.*, 1985), survival in climates of extreme cold (de Freitas and Symon, 1987), and for general purposes of human climate classification (Auliciems *et al.*, 1973; Auliciems and

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Kalma, 1979; de Freitas, 1979, 1987). The importance of this has been recognized in climate–recreation research (Terjung, 1968; Bauer, 1976; Reifsnyder, 1983), but so far no convincing case has been presented to identify optimal or preferred conditions for various outdoor recreational activities, nor for that matter, to show the sensitivity of recreation to atmospheric conditions generally.

Several writers have described recreation climate in terms of human response in preference to traditional taxonomic methods of portraying regional climates (Green, 1967; Davis, 1968; Maunder 1972; Murray, 1972; Findlay, 1973; Crowe *et al.*, 1973, 1977a, b; Crowe, 1976; Masterton *et al.*, 1976; Masterton and McNichol, 1981; Smith, 1985). In some cases, as in the work of Paul (1972), simple climatic indices, such as the Thom Discomfort Index and the Wind Chill Index, have been computed from climatological data and, in the case of Green (1967), generalized quantitative summations of weather variables arbitrarily weighted have been employed. Other researchers, such as Terjung (1968), Danilova (1974), Bauer (1976), and Yapp and MacDonald (1978), have used more sophisticated measures of recreation climate based on the body's thermal exchanges with the environment. More recently, Mieczkowski (1985) has devised a broadly based climatic index for evaluating world climates for tourism. However, meaning attached to these measures has been derived secondarily and interpreted without field investigation.

With the above in mind, the purpose of this research is to examine, by way of a case study, methods capable of giving information that can be used to appraise and rate recreational climates in terms of user sensitivity and satisfaction. Ideally, given the complexity of the problem of addressing the amenity role of climate, the research should concentrate initially on a well-defined human activity, preferably one that is clearly linked with amenity resource attributes of the atmospheric environment. These requirements are fulfilled by a variety of outdoor recreational activities, of which beach recreation appeared to be the most appropriate. There are several reasons for this. Firstly, beach recreation is an activity in which the human body is usually lightly clad and therefore directly exposed to atmospheric elements. Secondly, beach users are normally clustered in a relatively small area. Therefore, sample populations can be observed readily, and the compact area facilitates on-site monitoring of atmospheric and associated environmental variables representative of ambient conditions. A third reason is that, for the beach user, individual recreational aims or objectives of the occasion are similar. From a research standpoint these characteristics offer a relatively controlled situation. Fourthly, beach use is among the most popular of outdoor recreational activities in Australia and elsewhere, as measured by beach attendance figures. Thus, greater knowledge of the influence of climate on beach recreation is likely to be economically important to the coastal recreation industry.

Two broad categories of questions exist around which the investigation is built. Since the heat balance of the body is fundamental to assessments of human climates, the first category involves specification of the thermal environment.

(1) Given methods of body–environment energy budgeting, how are outdoor thermal conditions best quantified?

(2) How should thermal index values be interpreted?

The second category of questions centre on assessing the atmospheric resource generally in terms of recreation:

(a) What thermal atmospheric conditions are most preferred for beach recreation?

(b) To what extent is the level of beach-user satisfaction influenced by non-thermal atmospheric conditions?

(c) What are the relationships between atmospheric conditions and participant satisfaction?

CONCEPTUAL FRAMEWORK

The nature of the relationship between the atmospheric environment and the enjoyable pursuit of recreational activity may be seen to be a function of thermal, physical, and aesthetic on-site atmospheric conditions. A conceptual framework for this is shown schematically in Figure 1.

Treatment of the thermal characteristics of on-site conditions involves, firstly, integration of physical factors influencing the body–atmosphere thermal state. The method used must include both the attributes of those exposed and the functional attributes of the environment, as well as the complete range of atmospheric variables. Secondly, it is necessary to provide a rational index, with sound physiological bases, that

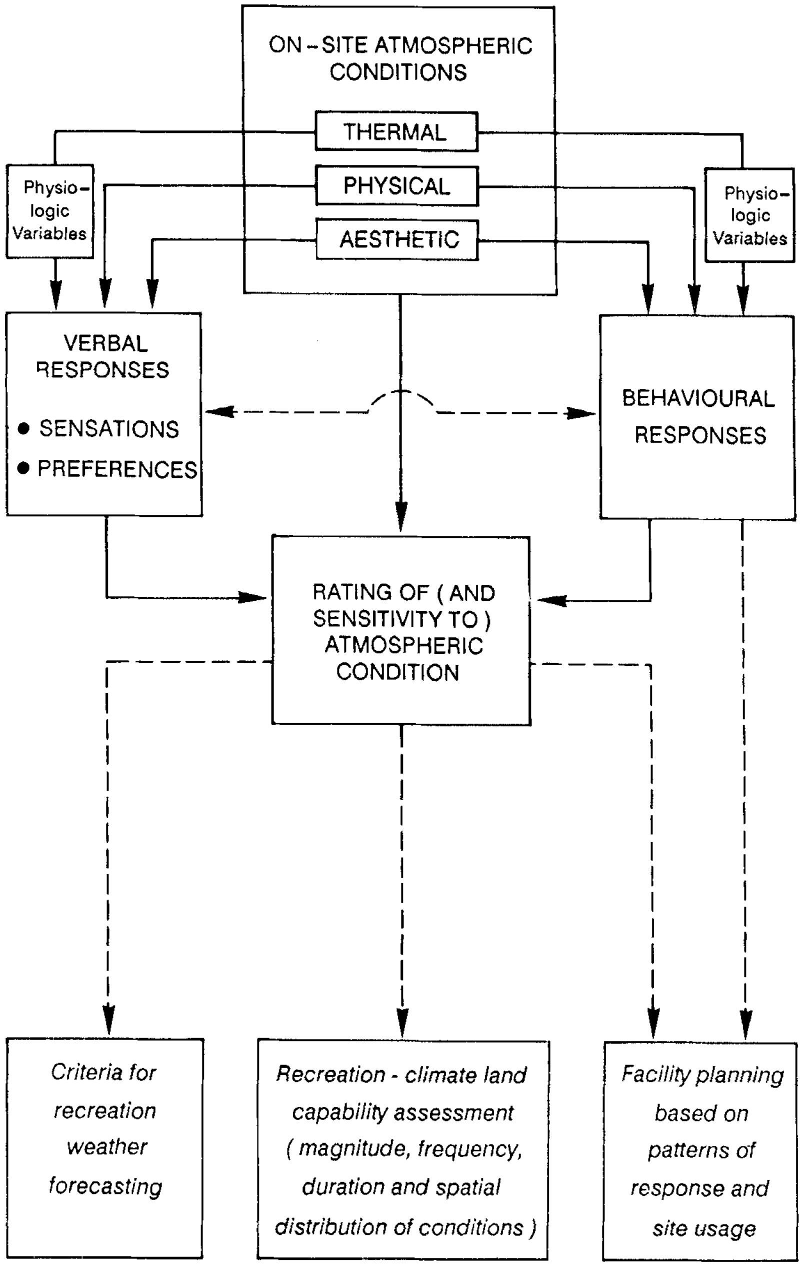

Figure 1. Conceptual framework for man–atmosphere relationships in a recreational setting

adequately describes the net thermal effect on the human body. Thirdly, relationships between the thermal state of the body and the condition of mind that expresses the thermal sensation associated with this state must be identified. Fourthly, it is necessary to provide a rating of the perceived thermal sensation and corresponding calorific index according to the level of satisfaction experienced. This means identifying subjective reaction classified on a favourable-to-unfavourable spectrum as a measure of desirability of conditions.

The 'physical' category shown in Figure 1 is identified in recognition of the existence of specific meteorological elements, such as rain and high wind, which directly or indirectly affect participant satisfaction other than in a thermal sense. The occurrence of high wind, for example, can have either a direct mechanical effect on the recreationist, causing inconvenience (personal belongings having to be secured or weighted down) or an indirect effect, such as blowing sand causing annoyance.

The 'aesthetic' aspects relate to the climatically controlled resource attributes of the recreation environment, which Crowe *et al.* (1973) have termed the atmospheric component of the 'aesthetic natural milieu'. Included within this category are 'weather' factors, such as visibility, sunshine, or cloud associated with the prevailing synoptic condition (for example, 'a nice, clear, sunny day').

To identify and describe the experience of on-site atmospheric conditions, two separate forms of user response are examined: firstly, sensory perception of the immediate atmospheric surrounds expressed verbally; secondly, behavioural responses that modify or enhance effects of the atmosphere (Figure 1). By employing, independently, separate indicators of the on-site experience, the reliability of each can be examined and interpreted by comparison and apparent threshold conditions verified. Assessment of behavioural responses is the subject of a subsequent study. Possible applications of the research shown in the lower portion of Figure 1 are considered in the 'Discussion' section.

STUDY AREA

The study area is King's Beach (26°48′S, 153°9′E), Caloundra, located approximately 90 km north of Brisbane, Australia. Caloundra has a permanent population of approximately 20,000 and is the largest town on the Sunshine Coast of Queensland. The Sunshine Coast lies within the most northerly sector of the subtropical high-pressure belt. From about April to September, the macro-scale drift of air is from the south-west over the Australian continent. This continental air is generally dry and stable. Characteristics of the period are low wind speeds and clear skies associated with large subtropical anticyclonic cells. From about October to March, moist unstable subtropical maritime air from the south-west Pacific flows from a general north-easterly direction and is the source of heavy rainfall. High solar inputs and advected heat from the north-east result in instability and warm surface temperatures. Sea-breezes are common throughout the year during the warmest hours of the day, but are strongest and most persistent during the high-sun months.

The climatological record (Table I) shows that average annual rainfall is 1569 mm, 61 per cent of which occurs during October to March. The lowest probability (< 45 per cent) of rainfall (more than 50 mm in any month) occurs during the period July–October. Mean maximum and minimum temperatures during July are 19·8 °C and 10·5 °C, respectively, and 28·0 °C and 21·4 °C in January. During the study period, sea temperature at King's Beach ranged from 27 °C in February (highest mean daily) to 19 °C in July (lowest mean daily).

METHOD

Assessing beach-user response

In the present context, there are several techniques available for obtaining beach-user-response information. Peterson and Neumann (1969) have presented and tested a conceptual model of preference processes of individual recreationists and the role of the visually perceived characteristics of the environment using photographs and semantic differentials as rating scales. Gaumnitz *et al.* (1973) have provided a complex methodology employing discrimination nets for examining the decision process by which recreational choices are generated. Adams (1971, 1973) has devised a 'theoretical approach' for examining the significance of weather for the recreationist and response consistency using probabilistic statements and pictorial displays of on-site weather.

Problems inherent in data gathered with the above methods stem from the difficulties in applying indirect methods of articulating environmental attributes in the context of user response, preferences, and perceptions. There is also the difficult problem of measuring perceptions. Since the measurement and interpretation of perceptions is concerned with the description of the environment as observed by individuals, emphasis must be placed on representing the environment in such a way that the effect is as objective or as real as possible.

Table I. Climatic data (1970–1974) for Caloundra Signal Station (Australian Bureau of Meteorology, 1975)

	Mean temperature (°C)		Mean relative humidity (percent)		Mean daily temperature (°C)		Rainfall (mm)		Mean No. of raindays
	0900 H	1500 H	0900 H	1500 H	Maximum	Minimum	Mean	Median	
January	25·8	26·5	81	76	28·0	21·4	186	147	11
February	24·6	25·6	86	82	27·2	20·8	217	159	13
March	24·4	25·7	78	74	26·9	19·8	222	194	14
April	21·3	23·6	74	69	25·2	16·9	149	133	11
May	18·5	21·5	62	60	22·8	14·6	150	127	10
June	15·4	19·1	65	60	20·4	12·0	102	75	7
July	14·7	18·5	61	55	19·8	10·5	89	69	8
August	16·6	19·9	70	59	21·4	12·3	58	49	7
September	19·6	21·1	61	58	22·7	14·0	57	52	6
October	22·4	23·0	65	63	25·2	16·8	90	71	8
November	23·4	23·8	72	73	26·0	18·2	101	72	9
December	25·1	25·6	82	78	27·1	20·2	148	110	9
Year	21·0	22·8	71	67	24·4	16·5	1569	1568	113

Many of the problems associated with tests relating to probabilistic statements or conditions, or the attributes of 'what if' questions, disappear when data is drawn from a naturally functioning system.

Questionnaire design and multidimensional scaling techniques have been used extensively in assessments of human thermal environments (Cabanac, 1971; Rohles, 1974; Humphreys, 1975; Nevins *et al.*, 1975; McIntyre, 1976). However, this research appears to have been conducted exclusively using so-called controlled groups of people, quite commonly children or university students in classrooms, or subjects located in climatic chambers. The reasons for this include ease of data collection where large samples are required, or the need to control environmental conditions. Clearly, data drawn from naturally functioning systems is more desirable so as to avoid errors in data associated with the artificial nature of experimental or laboratory conditions. In the current investigation, the beach provided a fixed, naturally bounded area for the implementation of sampling and monitoring procedures with the convenience of a controlled population, but with the qualities of a naturally functioning system where the data could be gathered easily and unobtrusively.

Whatever the nature of body–atmosphere heat exchange, the significance of the net thermal effect must be interpreted, preferably in a way that is both simple and easily understood. Verbal interpretation of thermal conditions depend on purpose but are assessed in terms of a person's reactions based on self-evaluation. These sensory responses are generally believed to offer a conceptual integration of the body's total response to applied stress. This view may be open to some misinterpretation since subjective evaluation of the thermal environment includes two main categories of perception, namely, thermal sensation and thermal preference. Identification of sensory states within the first category, thermal sensation, provide a verbal interpretation of thermal conditions of the body, and within the second category, a measure of the level of acceptability or degree of pleasantness associated with the sensed thermal state. The procedure, adopted here, involves registering the responses of subjects as recorded by a thermal sensation vote (TSN) on the seven-point American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) scale (Winslow *et al.*, 1937, 1938; Roberts, 1959; Rohles, 1974), as well as a comfort vote (TLK) on an interval scale (very unpleasant, unpleasant, indifferent, pleasant, very pleasant), shown in Table II.

Other on-site questionnaire data gathered included information on the level of satisfaction with prevailing conditions of humidity, wind, and cloud/sunshine. The grouped response categories are given in Table III.

Table II. Scales of thermal sensation (TSN) and pleasantness (TLK)

Description	Analysis code
Thermal sensation	
Very cold	−4
Cold	−3
Cool	−2
Slightly cool	−1
Neutral (i.e. neither warm nor cool)	0
Slightly warm	1
Warm	2
Hot	3
Very hot	4
Pleasantness	
Very pleasant	5
Pleasant	4
Indifferent (i.e. neither pleasant nor unpleasant)	3
Unpleasant	2
Very unpleasant	1

Table III. Response categories for prevailing conditions of humidity, wind (VVV), and sunshine/cloud (CLD)

Description	Analysis code
Humidity	
Much too humid	2
Too humid	1
Present condition just right	0
Too dry	−1
Much too dry	−2
Wind	
Much too windy	−2
Too windy	−1
Present condition just right	0
Wind too low	1
Wind much too low	2
Sunshine/Cloud	
Much too cloudy	−2
Too cloudy	−1
Present condition just right	0
Too sunny	1
Much too sunny	2

Subjects were also asked to rate the overall prevailing weather condition from the ranked continuum of descriptive categories shown in Table IV.

The above method was used in place of more elaborate procedures, such as those involving Likert and Guttman scales, which are more time consuming and cumbersome and therefore less easy to apply in a field study of this type. Furthermore, it is generally accepted that the reliability of unidimensional scales, such as these, tends to be good and that responses correlate well with those of Likert scales (Oppenheim, 1966), probably because conditions referred to are those based on personal observations of the respondent rather than on hypothetical situations. Open-ended or free-response methods might have been used, but the results would be difficult to systematize and quantify in a study of this type. Moreover, as it is necessary to classify the responses to open questions into discrete categories for analysis, much of the individuality of responses is lost and classification is open to researcher bias. There is also the risk that such open questions may draw a poor response from those who find it difficult to articulate their preferences.

The procedure used here is intended to provide a simple means of inferring preference from the way in which a subject grades the desirability or attractiveness of the atmospheric condition being experienced. Emphasis is placed on the ease with which questions could be administered by the interviewer and understood by the respondent.

As part of the on-site interview schedule, respondents were handed reference sheets giving a simple listing of the descriptive category scales shown in Tables II–IV. This procedure made it possible for the person being interviewed to scan the alternatives seen as a series of relative descriptive divisions and rapidly make a comparative judgment.

In addition to investigating the beach-user's perception of wind and cloud/sunshine conditions, the on-site interview schedule probed for reasons underlying the particular response. This was intended to provide information on the relative physical, thermal, or aesthetic influence of the variables. For example, whether or

Table IV. Response categories for overall weather rating (RAT)

Description	Analysis code
Very poor	1
Poor	2
Fairly poor	3
Just alright (i.e. neither good nor bad)	4
Fairly good	5
Good	6
Very good	7

not the dissatisfaction with prevailing wind conditions was a result of its uncomfortable cooling effect on the body or a result of sand particles being blown on to the body, clothing, and into the hair, or simply resulting from the annoyance of having to secure personal belongings against the force of the wind. As will be discussed later, this proved to be useful supplementary information since the apparent role of these influences can often be offsetting. For example, in excessively hot conditions, wind-blown sand adheres to the body, held by sweat on the skin surface, and may be considered to be less acceptable than suffering the increased heat load resulting from reduced convective losses in the absence of wind. Similarly for the dual role of sun/cloud conditions which may provide, on the one hand, aesthetically pleasing 'bright, clear sunny skies' and increased and often undesirable solar heat load on the other.

Field schedule

The atmospheric variables recorded on-site included solar radiation, longwave radiation, air temperature, vapour pressure, wind speed, cloud cover, cloud type, and sand surface temperature. Data were processed to provide hourly and daily averages. Details of the microclimatological instruments used, the monitoring schedule, the energy balance modelling procedure applied, and the rationale for the scheme are given by de Freitas (1985).

The data set used here comprises observations taken in the daylight hours of 24 weekdays during the period February 1975 to February 1976, giving a total of 179 sets of hourly environmental data for which there is corresponding interview data. There were at least 2 days of data for each month, except for January when two of three potentially full observation days were lost due to the occurrence of severe storms. Environmental and questionnaire data were compared at the times interviews were conducted. The range of values for atmospheric environmental conditions encountered during field observations are given in Table V.

Procedure

The present survey employed what Humphreys (1975) has called a transverse design, in which a large number of respondents are asked to make only one assessment of environmental phenomena, as opposed to the longitudinal design in which few respondents provide repeated assessments over a period of time. Using the latter approach, the consistency of individual responses usually appears to be high since there is a minimum scatter of points. In the transverse design, the results indicate the extent of variations among individuals, thus, data points appear more scattered but give good estimates for the population. Furthermore, because the atmospheric rating scales are made up of only a limited number of discrete categories, there is a large amount of overplotting of data points in graphs portraying large samples. In these circumstances, plots of averaged data (daily rather than hourly, for example) are preferable since averaged categorical response data is continuous and the number of data points much reduced in size.

Table V. Range of values encountered during field observations. S_{tu} is total incoming radiation for a horizontal surface; T_{sky} is mean radiant temperature of the sky; T_{gr}, T_m, and T_a are temperature of the ground surface, substrate, and air, respectively; rh is relative humidity, P_w is vapour pressure of air and V is wind speed

	S_{tu} ($W m^{-2}$)	T_{sky} (°C)	T_{gr} (°C)	T_m (°C)	T_a (°C)	rh (per cent)	P_w (mmHg)	V ($m s^{-1}$)
Maximum	1193	26	52	41	30·5	85	21·8	16
Minimum	0	−17	16	16	16·0	31	5·8	1

To examine associations among variables, two-dimensional regression analysis is used to estimate a series of polynomial regressions (Gaussian least-squares fit). The procedure is used as an exploratory analysis of data to provide clues on the nature of relationships, rather than as a rigorous statistical test of association, since problems can arise when categorical data are involved. In this approach, successive powers of the independent variable are inserted into the equation each serving to increase the correlation coefficient R. The fit of the equation to the data improves with additional polynomial terms; however, increases in the coefficient of determination R^2 may be inconsequential after a polynomial of a given degree is reached. To decide on this, the null hypothesis that the higher order polynomials are not significant is assessed, for each degree of polynomial, using the F-test procedure described by Nie *et al.* (1975, p. 372). By considering a maximum of five steps, the kth-order term after which an increase in $R^2 < 1$ was taken as the point at which no substantial improvement in fit occurs, at the 0·05 confidence level or better. Thus, the order of polynomial at this step was considered to adequately describe the best-fit curve. Both hourly data ($N = 179$) and mean daily data ($N = 24$) were used in all analyses.

RESULTS

Thermal conditions

Earlier work by de Freitas (1985) tested the adequacy of two body–atmosphere energy budget models (HEBIDEX and STEBIDEX) that integrated the multivariate thermal processes affecting the beach user and expressed the net effect in terms of a single heat-stress index. The relationship between thermal sensation (TSN) and HEBIDEX (HEB) is

$$\mathrm{TSN} = 0{\cdot}26 + (9 \times 10^{-3})\,\mathrm{HEB} - (2{\cdot}2 \times 10^{-6})\,\mathrm{HEB}^2 - (1{\cdot}4 \times 10^{-8})\,\mathrm{HEB}^3 \quad (1)$$

The correlation coefficient is high ($R = 0{\cdot}85$), where 73 per cent of the variation in thermal sensation is accounted for by HEBIDEX. The curve defined by Equation (1) based on detailed hourly data ($N = 179$) is given in Figure 2a. It shows that there is higher sensitivity in the zone of low thermal stress over that in the zone of high heat and cold stress. Interpretation of thermal indices in terms of thermal sensation category values are shown in Table VI derived from Equation (1).

Polynomial estimates of pleasantness votes (TLK) from thermal sensation votes (TSN) using the criteria described earlier are given by

$$\mathrm{TLK} = 3{\cdot}8 + 0{\cdot}672\,\mathrm{TSN} - 0{\cdot}181\,\mathrm{TSN}^2 - 0{\cdot}044\,\mathrm{TSN}^3 \quad (2)$$

The curve defined by Equation (2) based on mean daily data ($N = 24$) is shown in Figure 2b. R and R^2 are 0·84 and 71 per cent, respectively. It is clear from Figure 2b that the acceptability of thermal conditions is skewed towards the warm zone.

Solution of Equation (2) enables interpretation of thermal sensation (TSN) in terms of comfort and satisfaction (TLK). The optimal state of pleasantness occurs at +1·4 on the thermal sensation assessment

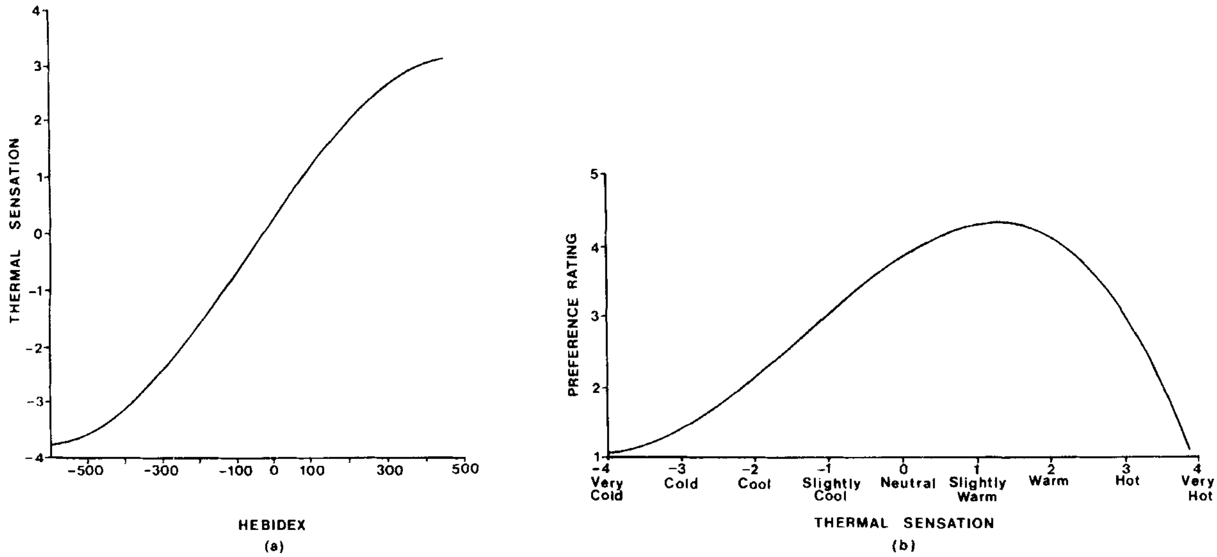

Figure 2. Variation of (a) thermal sensation (TSN) with HEBIDEX (HEB) and (b) thermal preference (TLK) with thermal sensation

Table VI. Interpretation of HEBIDEX values in terms of thermal sensation (TSN)

HEBIDEX	Thermal sensation
>530	Very hot
275 to 530	Hot
141 to 274	Warm
31 to 140	Slightly warm
−84 to 30	Indifferent
−185 to −85	Slightly cool
−314 to −186	Cool
−480 to −315	Cold
< −480	Very cold

scale; that is, at a point between 'slightly warm' and 'warm'. Applying this to Equations (1) and (2) for HEBIDEX and solving for TSN = 1·4, the optimal thermal state in terms of degree of pleasantness and satisfaction is HEBIDEX = 130. It is noteworthy that the preferred thermal state coincides with a condition of mild heat stress rather than with thermal neutrality.

The best-fit equation for estimates of overall weather rating (RAT) from HEBIDEX is given by

$$\mathrm{RAT} = 4{\cdot}8 + (6 \times 10^{-3})\,\mathrm{HEB} - (4{\cdot}2 \times 10^{-6})\,\mathrm{HEB}^2 - (9 \times 10^{-9})\,\mathrm{HEB}^3 \quad (3)$$

The coefficient of determination, R^2, is 62 per cent indicating that the contribution of the thermal component to the overall rating of recreation climate is large. The curve defined by Equation (3) using daily data ($N = 24$) is given in Figure 3a, which suggests that ratings level off at HEBIDEX values greater than 275 and then decrease if the curve is projected to the right. This relationship is substantiated in Figure 3b, showing overall weather rating as a function of thermal sensation (TSN) based on mean daily data, where

$$\mathrm{RAT} = 4{\cdot}8 + 0{\cdot}418\,\mathrm{TSN} - 0{\cdot}166\,\mathrm{TSN}^2 \quad (4)$$

where R^2 is 52 per cent ($N = 24$). On average, conditions interpreted as slightly warm–warm are associated with the highest weather rating.

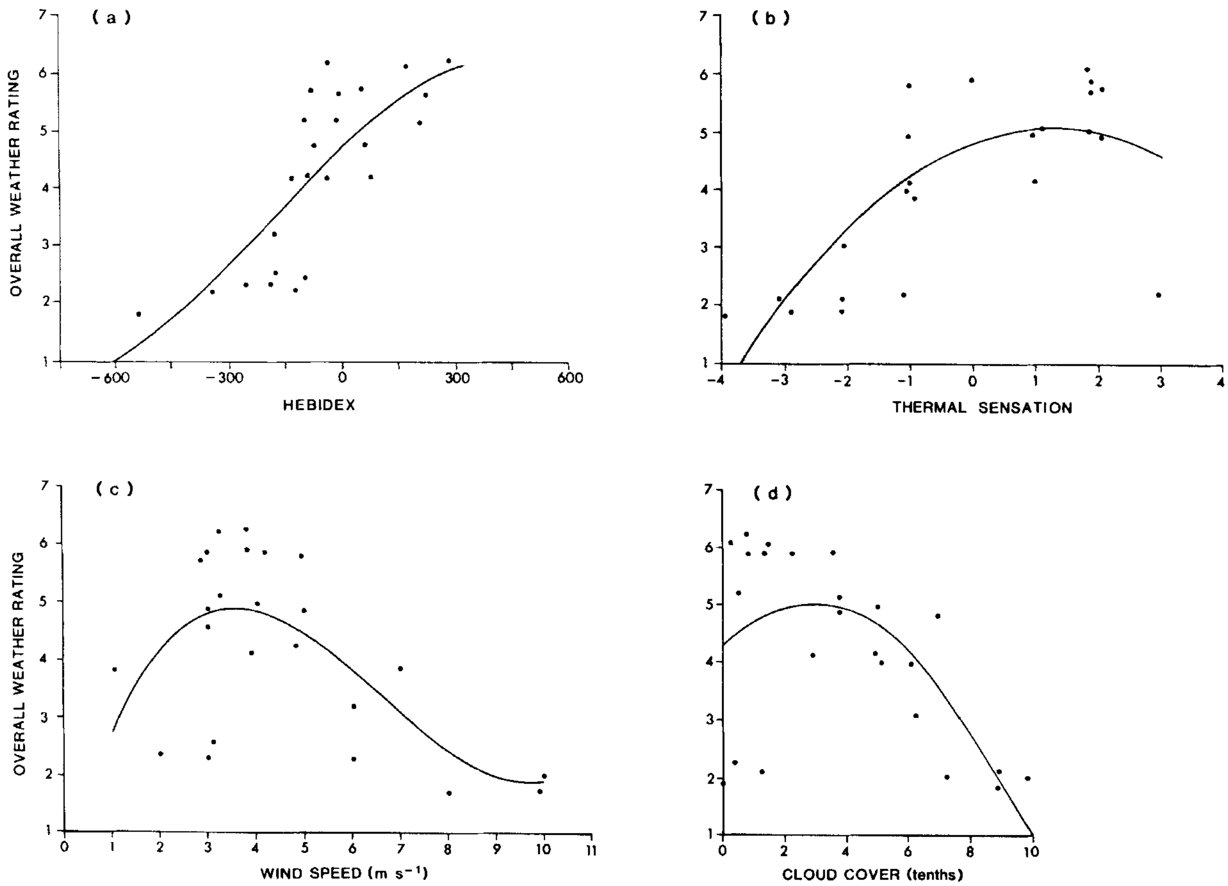

Figure 3. Variation of overall weather rating (RAT) with (a) HEBIDEX, (b) thermal sensation (TSN), (c) wind speed (VVV) and (d) cloud cover (CLD) using mean daily data ($N=24$)

Non-thermal components

The non-thermal components of the atmosphere likely to affect the level of satisfaction with on-site weather are wind and sun/cloud conditions, and the occurrence of precipitation. As previously discussed, the aim here is to identify the role of wind as a mechanical or 'physical' agent, and that of sun/cloud as an aesthetic variable since their thermal effects are included in the HEBIDEX model.

Unlike cloud-cover data, precipitation has to be treated essentially as binary data (occurrence/non-occurrence). In most cases the occurrence of even light rain resulted in ratings dropping to the lowest levels (1 and 2). Heavy rain usually resulted in immediate evacuation of the beach, terminating the interview schedule. A chi-square test showed that all lowest order ratings (levels 1 and 2) were associated statistically (significant at the 0·01 level) with rainfall events of half-hour duration or longer. The effect of brief, infrequent, light showers on levels of satisfaction was less clear. Although ratings dropped markedly and remained low for a short period following the shower, its net effect on mean daily ratings was small, and inconsequential when only a brief isolated shower occurred during the observation day.

The best relationship between mean daily ratings (RAT) and wind speed (VVV) is given by a third-order polynomial:

$$\mathrm{RAT}=0{\cdot}4+2{\cdot}847\,\mathrm{VVV}-0{\cdot}542\,\mathrm{VVV}^2+0{\cdot}027\,\mathrm{VVV}^3 \tag{5}$$

giving a R coefficient of 0·60 and R^2 of 36 per cent. This is based on mean daily data ($N=24$), although analysis using hourly data gives very similar results. The curve defined by Equation (5) in Figure 3c shows that ratings peak at level 5 at winds speeds between 3 and 4 m s^{-1}. The results suggest, therefore, that although light winds appear to be desirable attributes of beach weather, high winds detract from the enjoyment of the occasion. This was examined further.

Questionnaire data on wind conditions processed as annoyance/non-annoyance responses showed that a statistically significant difference exists between low weather ratings (levels 1–3) in association with winds of 6 m s^{-1} or more, and high ratings (levels 4–7) accompanied by winds of less than that velocity (chi-square test significant at the 0·01 level). The main contributing factor was blowing sand, with 81 per cent of the respondents giving this as the reason for annoyance and the remaining 19 per cent citing the direct mechanical effect (personal belongings having to be secured or weighted down) as the reason. The 6 m s^{-1} threshold corresponds with on-site analysis of sand movement which showed that saltation of sand grains (average grain size 0·21–0·25 mm) begins at a wind speed of 5·6 m s^{-1}.

The relationship between cloud cover (CLD) and weather rating are shown in Figure 3d, the curve being defined by

$$\mathrm{RAT} = 4{\cdot}5 + 9{\cdot}72\,\mathrm{CLD} - 25{\cdot}697\,\mathrm{CLD}^2 + 13{\cdot}2162\,\mathrm{CLD}^3 \tag{6}$$

for which $R = 0{\cdot}62$ and $R^2 = 38$ per cent. This is based on mean daily data ($N = 24$), but analysis using hourly data produced almost identical results. Although rating levels increase steadily with decreasing cloud cover, they peak at cloud amounts of approximately two- or three-tenths cover (Figure 3d). Part of the explanation for this may lie in the aesthetic appeal of a few scattered clouds in an otherwise cloud-free sky. However, in hot conditions, it seems that they are perceived as having a special thermal role. During clear-sky conditions, when HEBIDEX > 380, 66 per cent of all respondents indicated that scattered or 'periodic' cloud would be desirable to reduce direct solar radiation and relieve heat strain.

General response characteristics

To explore relationships between weather preferences and the relative roles of atmospheric variables, groups of variables were screened using a multiple step-wise regression procedure, as described by Draper and Smith (1966). The statistical method has been used in a similar context by Lund (1971), White (1974), and de Freitas (1975). Based on the form of underlying interactions suggested by the earlier polynomial models, bivariate relationships were restated in a linear form by transforming the original variables. The F level for inclusion or deletion of predictor variables was set at 0·01, with tolerance levels of inclusion set at 0·8. In the present context, the tolerance of a variable being considered for inclusion is the variance of this variable not explained by the variables already in the equation. A tolerance of 0·8 implies that a variable may be entered if the proportion of its variance not explained by other variables exceeds 80 per cent.

Subgroup (a) in Table VII identifies the HEBIDEX, cloud amount (CLD), and wind speed (VVV) as being the main environmental elements contributing to overall rating assessments. It is clear that wind contributes

Table VII. Summary results of stepwise regression showing relationship of overall weather rating (RAT) with: (a) HEBIDEX (HEB), cloud amount (CLD), and wind speed (VVV): and (b) thermal sensation (TSN), cloud amount, and wind speed

Dependent variable	Independent variable	Multiple regression	Increase in R^2	Simple R	Standard error	B coefficient
(a) RAT	HEB	0·66	0·444	0·66	1·432	0·004
	CLD	0·74	0·107	−0·46	1·289	−1·681
	VVV	0·75	0·013	−0·44	1·273	−0·109
(constant)						5·534
(b) RAT	TSN	0·75	0·570	0·75	1·258	0·607
	CLD	0·84	0·144	−0·46	1·028	−1·958
	VVV	0·85	0·008	−0·44	1·014	−0·087
(constant)						5·457

only marginally to an increase in the explained variance in weather rating. However, the inclusion of wind speed and cloud amount in the statistical model suggests that their contribution to weather rating is related, not to the thermal component (supposedly accounted for by the HEBIDEX), but to the aesthetic quality of on-site weather in the case of CLD, and to the so-called 'physical' element in the case of VVV. The absence of precipitation (PRE) from the results shown in Table VIIa is not surprising. Apart from the fact that heavy, continuous rainfall often terminated the observation day as described earlier, other reasons relate to the binary nature of the data on the one hand (treated as a dummy, presence–absence variable), and the relatively rare occurrence of precipitation on the other.

Part b of Table VII shows the output for a special case, where HEBIDEX was extracted from the environmental variables grouping and TSN inserted in its place. Where TSN is the sole integrated gauge of thermal conditions, the R coefficient is considerably larger at both the first and last stage of the model; as much as 10 points greater than that for HEBIDEX. This provides overwhelming evidence of both the adequacy of the ASHRAE scale and the large contribution of the thermal-atmospheric component to overall weather rating.

DISCUSSION

Possible benefits from research in the field of coastal-climate recreation studies centre on the economic importance of climate in recreation–tourism planning, in general, and the popularity and importance of beach recreation in particular. Mercer (1972, p. 123) has pointed out that for Australia '"The beach" manifestly is *the* national image', and suggested that beaches are by far the main focus of both active and passive recreational activities engaged in by Australia's large urban population. In response to growing recreational and leisure demands, beaches have assumed an enormous importance and are regarded now as valuable resource assets. In Australia, the dominant function of the coast continues to be recreational, and investments in beaches and related functions have been considerable.

This increasingly heavy use of the coast has presented recreational planners with several problems. One of these, as Yapp and MacDonald (1978) have pointed out, is the intense seasonal peaking of beach use in Australia during January and February. Yet they have assembled evidence that suggests that optimal atmospheric conditions of beach use occur in other months and, generally, that the period of peak demand is not justified by seasonal climatic conditions. It is believed that the difference between atmospheric conditions during peak usage and those during which more favourable conditions exist is of sufficient magnitude to encourage, with advertising and promotion, a more even distribution of beach usage. However, to implement this requires a better knowledge of beach recreation climate so that its relative attractiveness can be promoted.

On general economic grounds, provision of alternative coastal recreational opportunities by local governments and investors to supplement beach recreation when weather conditions are unfavourable are more likely to occur if the periods of high usage were extended or became more frequent. Such spreading of usage might follow both from better knowledge of preferred climatic conditions, especially thermal, and improved methods of presenting meteorological information to the public.

While this study is confined to specification of the attributes of the atmospheric environment and interpretation of the significance of these for the recreationist, a design for application could be drawn up based on frequency and duration assessments of significant synoptic meteorological conditions producing a measure of the climatic capability of an area to support a particular recreational activity or recreational land use. Meteorological and climatic data could then be incorporated into an outdoor recreation capability system of land classification. From an economic point of view, Rense (1974) has argued that with knowledge of this sort, planners and investors could evaluate proposed recreational development in the light of the influence of weather factors. This could be extended to the point of assessing the consequences of site modification or the desirability of microclimatic modifications as provided by wind breaks, shading structures, and the like.

CONCLUSION

The HEBIDEX model is used to integrate the effect on the body of thermal environmental as well as physiological variables and to produce a unitary index that can be used to derive the levels of thermal sensation and comfort experienced by recreationists. Also, it provides a method for isolating the thermal component of beach weather enabling identification of important non-thermal recreational resource attributes of the atmospheric environment.

The results show that optimum thermal conditions appear to be located in the zone of vasomotor regulation against heat, subjectively interpreted as warm, rather than precisely at the point of minimum stress or thermal neutrality. Sensitivity to thermal conditions appears to be greatest in the zone of moderate thermal stress.

The immediate thermal environment of the beach user is the main contributing factor to assessments of the overall desirability of on-site meteorological conditions, followed by cloud cover and wind. Rainfall events of half-hour duration or longer have an overriding effect on the perceived level of attractiveness of atmospheric conditions, resulting in ratings dropping to their lowest levels. Cloud cover/sunshine is the main aesthetic variable. High wind at speeds in excess of $6\,\mathrm{m\,s^{-1}}$ has an important direct physical effect on the beachgoer as well as an indirect effect stemming from the annoyance caused by blowing sand. Generally, ideal atmospheric conditions are those producing a HEBIDEX of 130 in the presence of scattered cloud (0·3 cover) and with wind speeds of less than $6\,\mathrm{m\,s^{-1}}$.

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