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Spatial and temporal analysis of beach tourism using webcam and aerial photographs

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Abstract

Tourism in northern Germany is focussed on summer season and concentrated along the coast. Large parts of the coast are subject to erosion and natural sandy beaches, which are required for bathing tourism, are rare. The beaches are or might become a limiting resource for further growth in tourism. Therefore, detailed knowledge about the spatial and temporal demands and behaviour of vistors at the beach are required. A new automatic method is presented to quantify the density of visitors on the beach. With a webcam the daily, weekly and seasonal course of visitors was observed. Linked to arial photographs, the data allowed the calculation of the beach area, which was available for every visitor at any time.
The results are shown exemplary for Warnemünde. In Warnemünde the new pier causes the exceptional situation of sand accumulation and a steady broadening of the beach. Despite that, the visitors are concentrated in a narrow strip close to the water, where sand quality is best. The average area available for every visitor in this strip during summer was only between 7.7 and 11.9 m² per person. The beach near the dunes is reserved for roofed wicker beach chairs, which cause a lower density of visitors. In this part, every visitor occupied an area between 28 and 62 m² per person. In Warnemünde the beach is not really a limiting resource, but it is likely that many visitors are not pleased and avoid the beach during the peak hours. Further, the analyses show that an integrated management concept for the coastal infrastructure, dunes, beaches and coastal waters is required.

1 Introduction

Along the southern Baltic Sea coast, in the Federal State of Mecklenburg-Vorpommern, Germany, tourism always played an important role as an economic factor. After the German reunification, the number of tourist beds as well as the number of overnight stays dropped dramatically. During the last decade the structure of the tourist industry changed and a steady increase in guest numbers is recorded, again. Nowadays, the number of tourist beds again exceed 160.000 (2002) with nearly 25 Mio. overnight stays. Tourism in northern Germany is focussed on the summer season and concentrated along the coast. Large parts of the coast are subject to erosion and natural sandy beaches, which are a pre-requisite for bathing tourism, are rare. Most tourist resorts take artificial measures to preserve and extent the beaches as well as to improve their quality. The qualitative and quantitative demands of tourists concerning the beach have increased. With ongoing increase in tourist density the beach quality and quantity becomes a limiting resource for tourism development along the German Baltic coast. A management and sustainable development strategy for beaches, dunes, and the infrastructure is required. This requires detailed knowledge about the spatial and temporal utilisation of the coast and the behaviour of visitors. Further information about the carrying capacity of the beaches is needed.

To supply background information a detailed study was carried out during the summer season 2002 (Kammler 2003). For detailed beach observation, a new automatic method was developed to quantify the density of visitors on the beach. With a webcam the daily, weekly and seasonal course of visitors

was observed. Linked to arial photographs, the data allowed the calculation of the beach area, which was available for every visitor at any time.

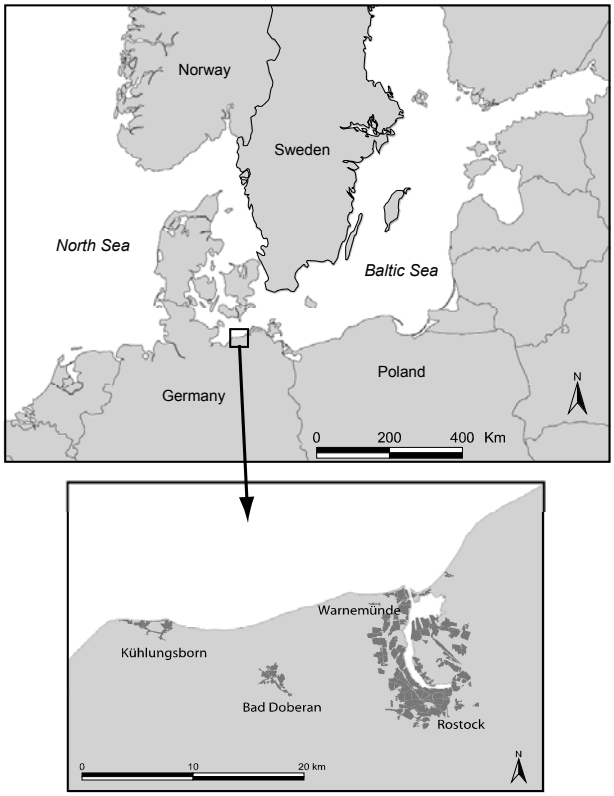

Figure 1: Location of the study area

2 Methods

Two distinct methods of data collection were used to study beach tourism and its intensity at the German Baltic Sea Coast. A webcam located at the upper floor of the Baltic Sea Research Institute Warnemünde, Germany was taking continuously pictures from a beach area of about 15,000 m². The beach area was defined as the stretch of sand between the bottom of cliffs or sand dunes and the water line. These webcam images were used to gain information about the temporal variation of the intensity of beach tourism during five month of monitoring. Aerial photographs were used to investigate the different intensities of tourism along the surveyed beach (pictures were taken from a plane). So, not only temporal but also spatial variations of beach tourism were analysed.

It was possible to monitor beach tourism over a long period of time by using a webcam and to gain information about daily and seasonal fluctuation of beach tourists. From May until the middle of September 2002, the webcam took one picture every half an hour each day from 6 a.m. to 11 p.m. (e.g. Fig. 2.). Due to the high number of images and with regard to their spatial resolution it was necessary to analyse the data automatically. It was assumed that the items on the beach were either people or sand. With this assumption it was possible to analyse the images´ different pixel characteristics. Brightness is one of the image characteristics that is measurable for every single pixel and varying with a changing number of people at the beach. But before the images were analysed, the relevant area was determined. Only the sandy beach areas were important and therefore they had to be cut out from the images (Fig. 2.). Static objects like beach chairs or lifeguard houses were not taken into account and therefore masked out (white areas in Fig. 2.).

Figure 2: Example of a webcam image and the relevant beach area for the automatical survey (the white areas were masked out).

For image processing the software Matlab by The MathWorks was used. After the RGB-webcam images were changed into 8-byte greyscale images, it was possible to analyse each image´s greyscale histogram.

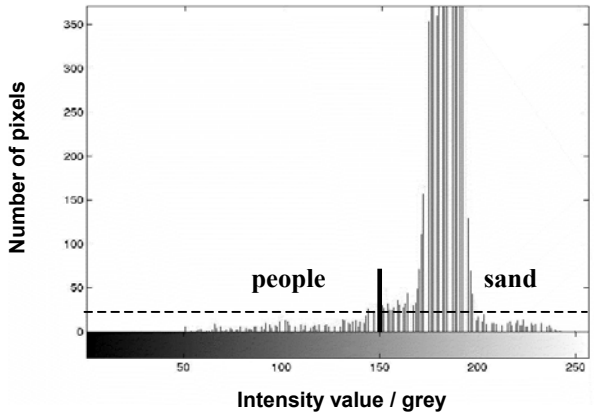

Figure 3: Greyscale histogram of an analysed webcam image

On a histogram (Fig. 3.) the x-axis shows the possible grey tones and the y-axis shows the number of the pixels of each grey tone presented in an image. On Fig. 3. the frequent, lighter grey tones represent beach sand, because sand is the predominant component of the beach. People are represented by darker intensity values (grey tones) and therefore at the lower grey tones near the coordinate origin. On the histogram of Fig. 3. the transition line between people and sand lies approximately at grey tone 150 (vertical line).

Because of different light and weather conditions sand changes its grey tone and therefore the border between sand and people varies. For example, sand has a darker colour in the evening so that the transition line then is at a lower grey tone. This is why the transition between people and sand has to be determined for every image separately. A strong increase in the number of pixels per grey tone indicates the beginning of the grey tone interval representing the beach sand. The beginning of this increase is indicated by the numbers of pixels regularly reaching 20 (horizontal line on Fig. 3.). If

three neighbouring grey tones have more than 20 pixels each, the border between sand and people is determined. Three grey tones were needed to avoid the influence of runaways and to find the border's appropriate position.

After counting the dark pixels that represent the people (left of the border) one can compare the different webcam images and the intensity of beach tourism for every time the camera took pictures. 91 days of monitoring were compared and studied. Some images couldn´t be analysed because of bad weather conditions or technical problems.

In order to validate the used method additional countings of people were carried out. The people on the surveyed beach were counted at different times in order to quantify them.

Aerial photographs, taken on a Sunday with extremely intensive beach tourism, helped to complete the information about the temporal variations of beach tourism with spatial information. Because the area of the coast which was studied was very rast and had changing infrastructure and natural settings, the aerial photographs gave essential information about intensively and extensively used beach areas. More than 140 photos were taken from a motor glider with a digital camera. Since they weren´t orthographic, they couldn´t help to measure the size of the available beach area, but they helped to count the number of people between the resorts Warnemünde and Kühlungsborn.

For the spatial distribution analysis, the beaches were divided into beach strips, that could be found easily in maps. Marine buildings like breakwaters, piers or other clear-cut points marked these borders. In order to compare the different beach areas, the proportion between beach area and people (m² / person) was measured. The beach area was determined with the help of digital maps (LVermA M-V 2001), beach measurements (StAUN Rostock 2002 & 2000) and orthographic aerial photographs (Kataster-, Vermessungs- und Liegenschaftsamt Rostock 2002).

3 Results

After analysing 91 days of beach monitoring with the webcam, it was possible to show the daily variations of the intensity of beach tourism and to show how they depend on different characteristics. The influence of weather conditions, seasonal changes and weekly changes were predominately analysed.

The diagrams on Fig. 4. show results of the webcam monitoring. Each diagram shows the number of pixels at different times of the day. The number of pixels (y-axis) representing the darker pixels of the webcam images were classified as people. The monitoring days were classified according to different characteristics in order to find out how important e.g. the weather is. Therefore, five different diagrams are shown on Fig. 4. The proportion between pixels and people couldn´t be determined exactly so that we at this point of time assume that it is linear. As you see on all figures the features of the graphs look in a similar way. Every day, beach tourism reaches its maximum at around 3:30 p.m. Lots of people arrive between 9 and 11 a.m. and after 8 p.m. the beach is almost empty (see Fig. 4.).

By adding all pixels representing people of one monitoring day it is possible to compare the different days and their intensity of beach tourism. The monitoring days were classified after season, month, workday or weekend and weather conditions. Fig. 4.a shows that there were more people at the beach in the peak season (July and August) at any time of day than during early or post season. Since more than twice as much pixels were classified as people during that time. The most intensively beach tourism was during August followed by September that had extraordinary good weather conditions followed by July (see Fig. 4.b). The monitoring data also showed that the beach occupation differs between weekends and workdays, but this difference (30 %) isn´t that obvious (see Fig. 4.c). A very important factor for beach tourism is the weather. The intensity of beach tourism changes a lot with changing weather conditions (see Fig. 4.d). Season and weather conditions were the most influencing characteristics. Combining these two characteristics (see Fig. 4.e) it becomes obvious that beach tourism is even more reliant on very good weather than in peak season. To sum it up the results confirm what had been expected and therefore they support the monitoring method with a webcam as

reliable. The validity of webcam monitoring showed that the proportion between pixel and people isn´t linear. Relatively small groups were represented with a lot of pixels in comparison to larger groups of people where the number of pixels increases less than proportionally ("unterproportional?"). Reasons for this are the sloping webcam view and consequently with an increasing number of people an also increasing occlusion of people.

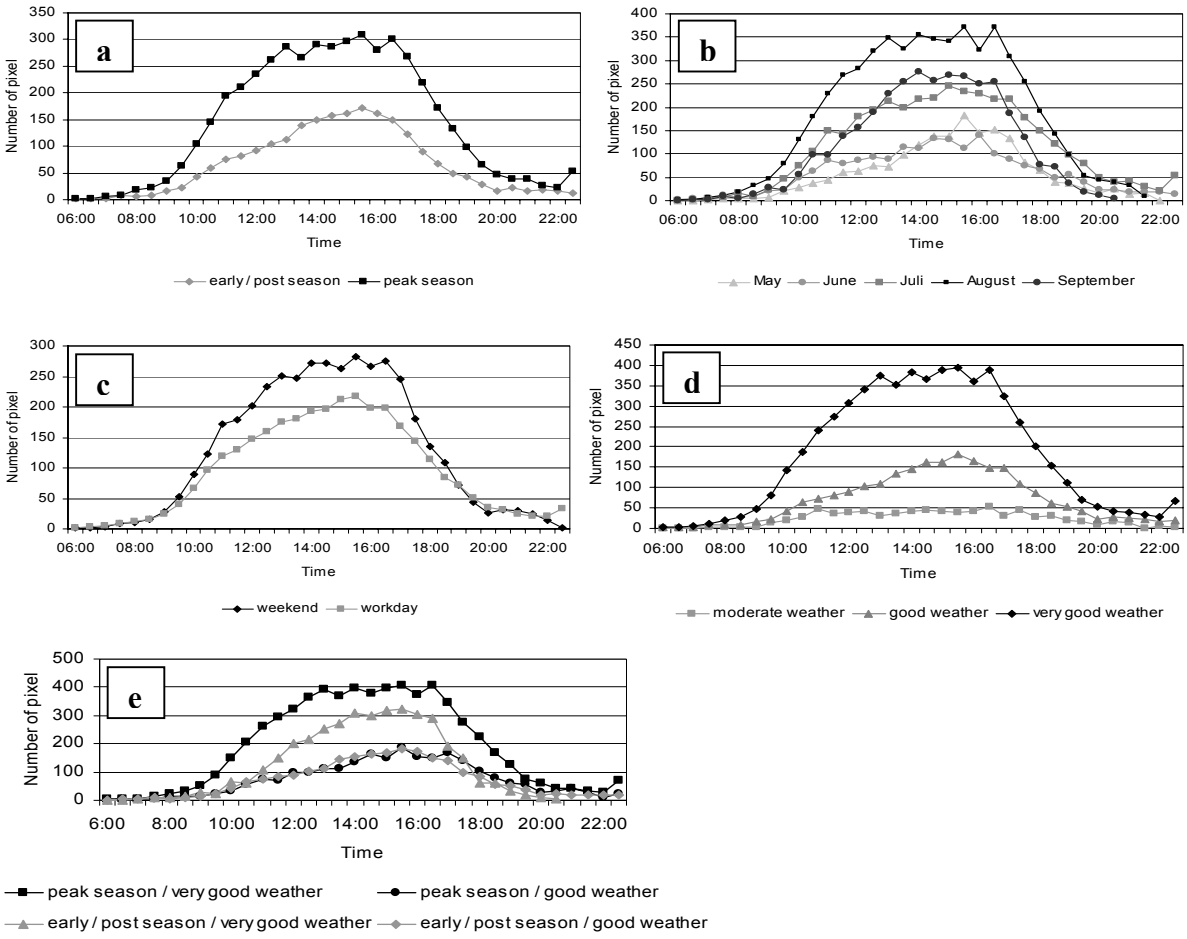

Figure 4: Results of webcam monitoring – Day course of beach occupation at days with different characteristics (a: seasonal variations, b: monthly variations, c: week course, d: weather conditions, e: seasonal variations combined with weather conditions)

The spatial distribution of people showed that the occupation density isn´t homogeneous along the surveyed coast. Different characteristics like infrastructure e.g. parking lots and other facilities, beach accesses and sand quality determine the occupation intensity. This forms a coast with a mosaic of intensive and extensive beach tourism. Occupation values at peak hours vary from less than 10 to > 150 m² available beach area / person. It isn´t surprising that beach tourism in the popular resorts Warnemünde and Kühlungsborn is intensive but there where also beaches that show a high occupation value which had almost no infrastructure.

Figure 5 shows the measured occupation values for Warnemünde with a beach of 2.5 km length. Along the beach of Warnemünde the occupation values also vary, because of infrastructure, beach width or sand quality.

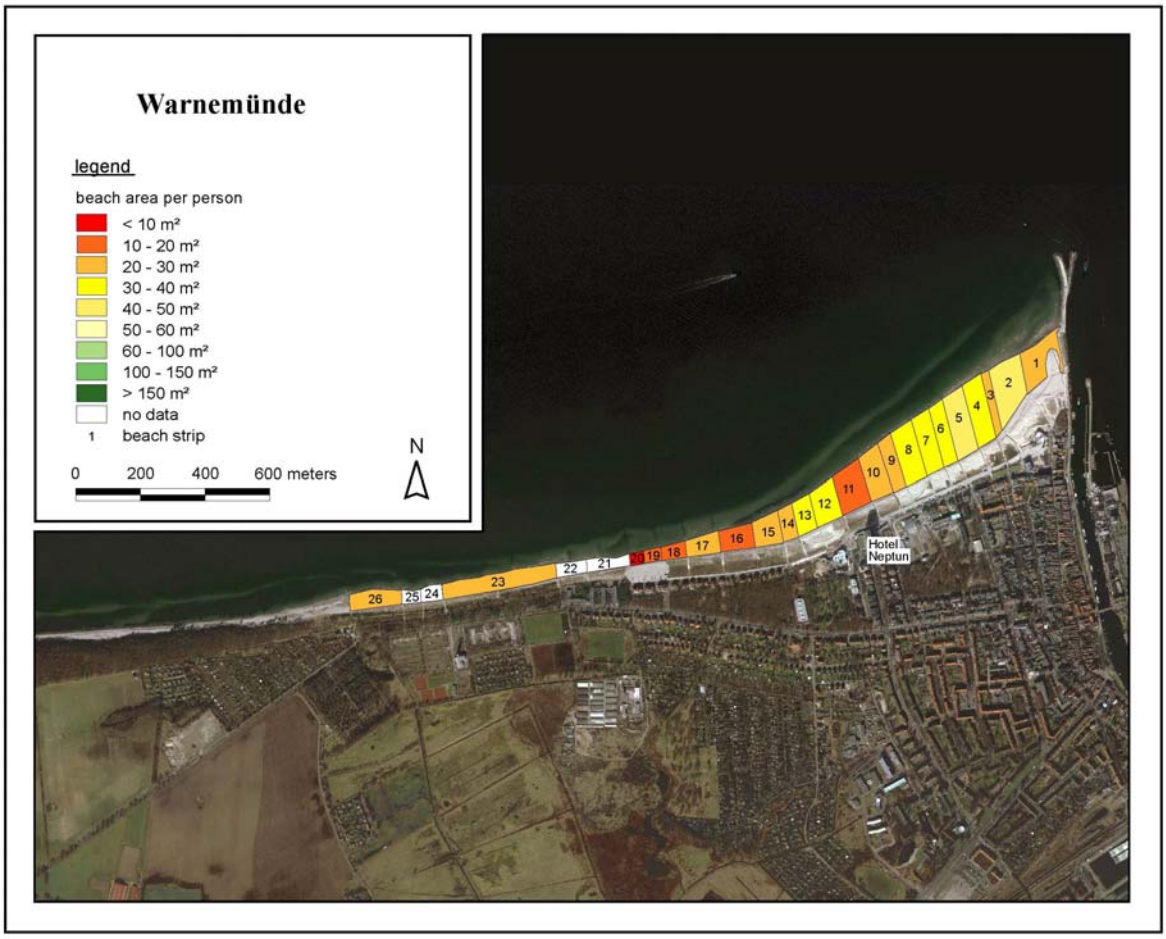

Figure 5: Beach area per person at the beach of Warnemünde (aerial photograph: Kataster-, Vermessungs- und Liegenschaftsamt Rostock 2002).

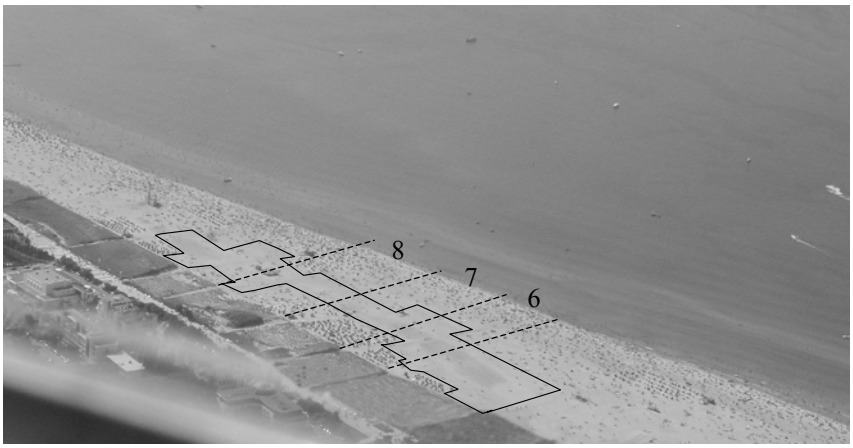

Figure 6: Overview of Warnemünde beach.

Up to here it has only been analysed when and where most of the people are at the beaches between Warnemünde and Kühlungsborn. But especially in Warnemünde, where the beach is partly 180 m wide or more, it is obvious that the occupation intensity also changes with distance to the water. Fig. 6. shows an overview of the beach of Warnemünde where the framed area marks the most extensively

used beach parts. Detailed photographs were taken from Hotel Neptun (Fig. 5.) that offered a good overview of the beach. The results of a detailed analysis of the occupation value within a beach strip can be seen on Fig. 7. The plot is not a true to scale top view of the beach strips shown in Fig. 6. The available beach area changes a lot between water line and dune, where a large number of beach chairs is located. The most extensively used areas are the central beach areas. In beach strip eight for example 80% of the people use 12 % of the beach area. That shows the different priorities people have. A reason for people to use the beach area close to the dunes could be that they think of the area near the waterline as being too crowded.

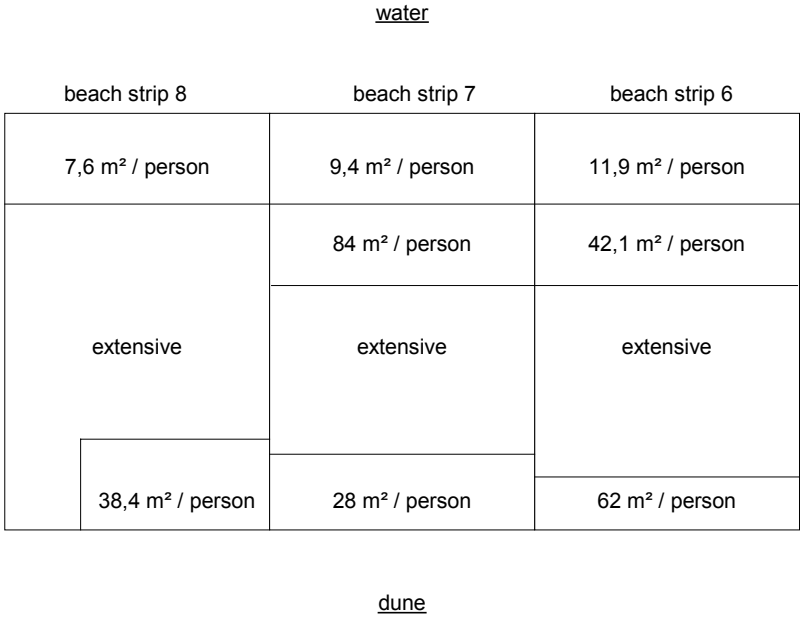

Figure 7: Detailed top view of the beach area per person at the beach of Warnemünde

4 Discussion

The permanent observation of a beach with a webcam is an efficient method to get a spatial and temporal picture of visitor density and behaviour. Beach utilisation is depending on season, day, time and weather, is highly variable and hard to predict. Therefore, traditional manual counting methods carried out only on several days per season yield an incomplete picture. The webcam overcomes these problems and is relatively cheap but still requires technical improvements. A higher resolution of the pictures would be valuable, the sloped view of the camera complicates the analysis and disturbances by objects at the beach (umbrellas, roofed wicker beach chairs, wind shelters) cause uncertainty. Details are given in Kammler (2003). However, the linkage of aerial photographs, webcam observations and traditional counting methods (for calibration purposes) form a successful strategy for beach observations.

Acknoledgements

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