COASTAL FLOOD RISKS AND SEASONAL TOURISM

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Abstract
Since coastal tourism is one of the fastest growing sectors of tourism industry, coastal areas have become increasingly vulnerable in case of flooding. Yet, coastal tourism is a seasonal phenomenon, with variations according to climate, holiday seasons and seasonal traditions. Despite its relevance in environmental issues, the effects of seasonal tourism have only scarcely been studied in coastal flood risk management. In this study, GIS and detailed tourist census data are used to analyze the temporal effects of seasonal tourism on flood risks at the Belgian coast. Different time settings are considered as well as tourist behaviour with respect to storm situations. The results of this study give new insights in the effects of seasonal tourism on coastal flood risks which may be useful in the context of early warning systems.

Keywords: coastal floods, casualty risks, seasonal tourism and GIS

1 INTRODUCTION

Coastal tourism is widely regarded as one of the fastest growing areas of the world's tourism industry (Hall 2001). All over the world, coastal areas are developing rapidly and are attracting more and more tourists each year. The harmful impacts of coastal tourism on coastal environments have been discussed in depth in the academic literature (e.g. Bellan and Bellan-Santini 2001; Burak et al. 2004). The growth of the coastal tourism industry also generates new challenges regarding climate change, sea level rise and flood risks: the more tourists in a coastal area, the higher the adverse consequences of a coastal flood. Moreover, several authors have suggested that tourists are more vulnerable than locals in disaster situations, because they are less independent and less familiar with local hazards and the resources that can be relied on to avoid risk (Burby and Wagner 1996). Nonetheless, the effects of tourism have only scarcely been studied in coastal flood risk management. Traditional studies generally use fixed population data in their estimates of casualty numbers, but rarely account for effects of population dynamics such as tourism (Lentz 2006).

This paper aims to answer at least two research questions. The first question concerns the behaviour of residential tourists in storm surge conditions. Are tourists inclined to continue their holiday plans or are they frightened by the potentially adverse effects of storms? Questionnaire data are applied to address this issue. The second research question deals with the potential effects of tourism dynamics on coastal flood risks. How can we measure these effects and how should we interpret these? Using a GIS model endorsed by the Flemish government (Deckers et al. 2010), casualty calculations are performed with tourist census data as input. The touristic Belgian coast is selected as study area.

2 BACKGROUND

Within the quantification of risks to people, results are generally expressed by individual risk and/or societal risk. Individual risk refers to the probability that an average, unprotected person is killed at a certain location, whereas the societal risk refers to the probability that a number of people of a given population is killed due to one event (Jonkman et al. 2003). While the former approach is common practice in technical hazards (e.g., the dispersion of toxic gasses, fire, nuclear waste, etc.), the latter is more apposite to natural hazards such as floods and earthquakes. The estimation of the societal risk generally includes three phases (Jonkman 2007):

1. The assessment of physical effects associated with the hazard, including the dispersion of the effects and the extent of the exposed area;
2. The determination of the number of people in the exposed area;

3. The estimation of the mortality and casualty number amongst the exposed population.

While phase 1 and phase 3 are strongly linked to engineering models, phase 2 is principally a spatio-temporal problem. The main focus in this phase is to find out who is exposed to a hazard, considering population dynamics. In literature, a distinction is often made between the concepts of registered population, people at risk and exposed population (Lentz and Rackwitz 2004). The registered population N_{POP} are those people that are registered in the municipal. All individuals present in an exposed area are indicated as people at risk, often denoted as N_{PAR}. The actually exposed population N_{EXP} refers to all individuals that are exposed to the physical effects of the disaster.

Jonkman (2007) has argued that in large-scale applications with high population numbers, N_{PAR} can safely be approximated by the registered population in the area N_{POP}. In many cases, however, it might be essential to consider population dynamics to avoid crude over- or underestimations of the flood impact. The number of people at risk might, for example, be considerably smaller than the registered population when a part of this population is working outside the exposed area. Conversely, N_{PAR} might be larger when large numbers of tourists visit the area regularly. The effect of time on N_{PAR} is realized at three different levels (Lentz 2006): time of day (i.e. working, sleeping, leisure times), day of the week (working/weekend day) and season.

While fluctuations at the level of daytime have been studied in prior risk assessment studies (e.g. Ahola et al. 2007), the effects of tourism fluctuations which primarily occur at the level of day of the week and seasons have garnered less attention. Therefore, the present study will explicitly focus on the effects of seasonal and day-to-day variations in tourist dynamics on coastal flood risk assessment. We will use N_{RT} to denote the time dependent number of residential tourists on the Flemish coast. Assuming N_{POP} constant over the timescales considered, the population at risk N_{PAR} can then be formulated by:

$$N_{PAR}(t) = N_{POP(c)} + N_{RT}(t) \qquad (1)$$

In this study, we will seek to account for this adjusted, time-varying number of people at risk.

3 STUDY AREA

The Belgian coast is located along the Southern Bight of the North Sea and measures 65 kilometres. It is characterized by sandy beaches, dune areas and hard defence structures such as groynes and sea walls. Due to the limited length of the coastline and the increasing population pressure, most of the coastal zone has become urbanized and half of the coastal dunes has disappeared (Charlier and Demeyer 1995). Figure 1 depicts the location of the ten coastal municipalities included in this study. Approximately 0.2 million people (2% of the Belgian population) live in this area. The mean population density amounts to more than 500 inhabitants per km², but in several statistical sectors[1], population density runs up to thousands of people per km². The city of Oostende is with ca. 65 000 inhabitants the largest population centre on the Belgian coast, followed by Knokke-Heist (ca. 32 000 inhabitants) and Koksijde (ca. 20 000 inhabitants). The entire coastal area is attractive to many human activities, such as recreation, fishery, shipping, agriculture, trade, etc. Particularly the recreational attractiveness causes an increase in population with approximately 0.3 million residential tourists during summer (Lebbe et al. 2008).

According to the outcomes of the on-going Flemish project Integrated Master Plan for Flanders Future Coastal Safety (Mertens et al. 2008), today about one third of the Belgian coast can be considered vulnerable to a coastal flood. Most vulnerable are the city centre of Oostende and the coastal villages of Raversijde, Mariakerke and Wenduine (cf. Figure 1 for their location). The Integrated Master Plan seeks solutions to cope with future coastal floods, considering climate change impacts until 2050. The project aims at protecting the coast against floods with a recurrence period of 1000 years. Among the measures that are explored, beach nourishment and dike enforcements (e.g. building storm walls) are considered the most effective defence structures for the Belgian coast.

While coastal floods can be caused by various factors, such as windstorms, seismic activity (tsunami) and tidal waves, coastal flood risk management in Belgium is primarily focused on one plausible causer: windstorms.

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[1] Statistical sectors are arbitrary areas used to aggregate socio-economic statistics. The origin of these sectors lies in the early 70s, when the National Institute of Statistics (NIS, Belgium) was looking for a small territorial entity as a basis for socio-economic data. Sectors were chosen with equal morphologic and social characteristics. In this way, densely populated areas were split up in many small sectors, while sectors in rural – less populated – areas generally larger.

Northwesterly storms are particularly hazardous for the Belgian coast, since they push up the North Sea water toward the coastal areas. The situation becomes disastrous if these storms coincide with spring tide, which was the case in 1953. In the low-land areas, windstorms occur mostly from October to April. However, even in the summer half of the year, storms remain possible. Summer storms usually last less long and are less intense than winter storms, though some summer storms have shown their hazardous impacts on coastal areas as well (Lozano et al. 2004).

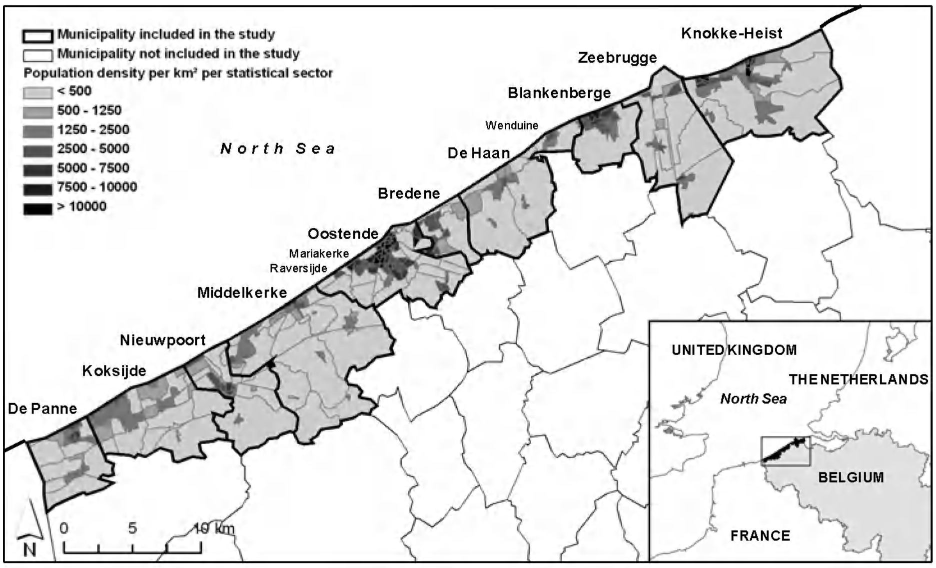

Figure 1 Location of study area

The high degree of urbanization and tourism activities makes the Belgian coast extremely vulnerable to coastal flooding. It is therefore an intriguing area to study the relation between tourism dynamics and coastal flood risks.

4 DATA

4.1 Location and occupancy of second residences

Within the framework of the Belgian coastal Action Plan (2005-2009), the West Flanders Economic Agency (WES) has held a large-scale survey with regard to the use and occupancy of second residences on the Belgian coast. About 5100 inland and foreign home-owners were queried, representative towards country, region, municipality and time of the year. In their study, WES defined second residences as private dwellings with recreational purposes which are included in the direct taxes. The owners of these second residences are not registered in the municipal and pay second residence taxes. Second residences represent about three-quarter of both the accommodation capacity and the total number of nights on the Belgian coast. The remaining quarter, which comprises accommodation in "open air" (such as camp sites, holiday domains, etc.), hotels and other (e.g. accommodation for specific audience such as the elderly) is not considered in the WES survey (Gunst et al. 2008). The number of second residences on the Belgian coast is higher than in any other Flemish municipality. In 2007, 82700 second residences were registered in ten coastal municipalities. The highest concentrations of second residences are found in the statistical sectors bordering the coastline. About 70% of the second residences is located at a distance of less than 300 m from the coast.

From the WES survey, three raw data sets are used in this study: (i) the number of second residences per statistical sector, (ii) the daily occupancy of second residences (June 2007 – May 2008) for the entire coast and (iii) the average number of persons per second residence (per municipality). From these data sets, the number of residential tourists N_{RT} is estimated per statistical sector for a given timescale (cf. Section 6.1). Combining the number of second residences per statistical sector with the average number of persons per second residence, an estimated maximum of residential tourists ($N_{RT(MAX)}$) can be defined. Figure 2 depicts the ratio of $N_{RT(MAX)}$ to the number of people at risk (N_{PAR}) per statistical sector. The map highlights those sectors where high percentages of tourists reside relative to the number of registered people. A significant part of the sectors adjacent to the coastline is touristy, but several sectors in the hinterland show high ratios as well. In section 6.3, we will examine how these findings turn out with respect to flooding.

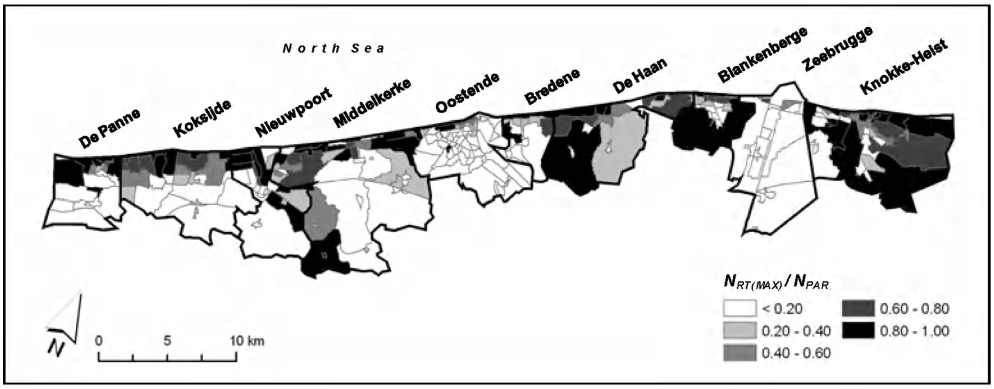

Figure 2 Ratio between the number of residential tourists (assuming all second residences are occupied, $N_{RT(MAX)}$) and the number of people at risk (N_{PAR})

4.2 Tourist behaviour in stormy weather

Questionnaire data is used to gain insight in the behaviour of tourists in stormy weather conditions on the Belgian coast. During two weekends in the autumn of 2008 (no holiday period), a survey was organized on the Belgian coast, in which the public perception was measured with respect to coastal flood risks and defence structures (Kellens and De Maeyer 2009). In addition to these perception measurements, residential tourists were asked to express their degree of agreement for six items regarding two storm scenarios (Table 1). In the first scenario (A), the respondent is assumed to have booked a holiday week on the Belgian coast. However, a couple of days before his/her holidays, the respondent hears about a major storm approaching the coast in the next days. The second storm scenario (B) has exactly the same meteorological conditions, but the respondent is now assumed to stay already on the coast at the time the storm is forecasted. Table 1 lists the six items for storm scenario A and B. All items were measured on a 3 point-scale: no agreement, agreement and no opinion.

Table 1 Items for storm scenarios A and B (see text for meaning of A and B)

Storm scenario	**Item number**	**Item**
A	1	*I decide to go to the sea.*
A	2	*I decide to delay my depart and see how the forecasting evolves.*
A	3	*I cancel my trip to the sea immediately.*
B	1	*I leave the coastal area immediately and go back home.*
B	2	*I wait for the storm sand see how it turns out.*
B	3	*Stormy weather can cause spectacular pictures. I stay on the coast to watch the storm.*

4.3 Flood model

This study uses the results of a flood model that is currently in use in the framework of the Belgian BELSPO project CLIMAR, which proposes adaptation techniques specific to the Belgian coast with regard to climate change and sea level rise. Two time horizons are studied in this context: 2040 and 2100. For both time horizons, WCS (worst case scenario) flood models flood models have been implemented for corresponding changes in hydrodynamic boundary conditions. Since uncertainty levels are increasing enormously with prediction horizons, the model closest to the present is chosen. WCS 2040 is based on a maximum storm surge level of 8.71m TAW and a significant wave height of 8.77 m (Reyns et al. 2010). According to the model, this "super storm" will cause dozens of dike breaches along the Belgian coast. Figure 3 shows the flood extents and water depths which are to be expected in the coastal region. The floods are mainly situated in two regions: Middelkerke/Oostende and Blankenberge/De Haan (Wenduine). Particularly in the low-lying city centre of Oostende, record water depths are estimated of ca. 4.9 m. Elsewhere, water depths vary between 0.2 m and 1.5 m. The lines in the flood areas represent roads. The rectangular dark area south of Blankenberge is a very low-lying polder, originated from peat exploitation. Given the current climate change models, the estimated return period of this extreme flood scenario is about 7000 years by 2040.

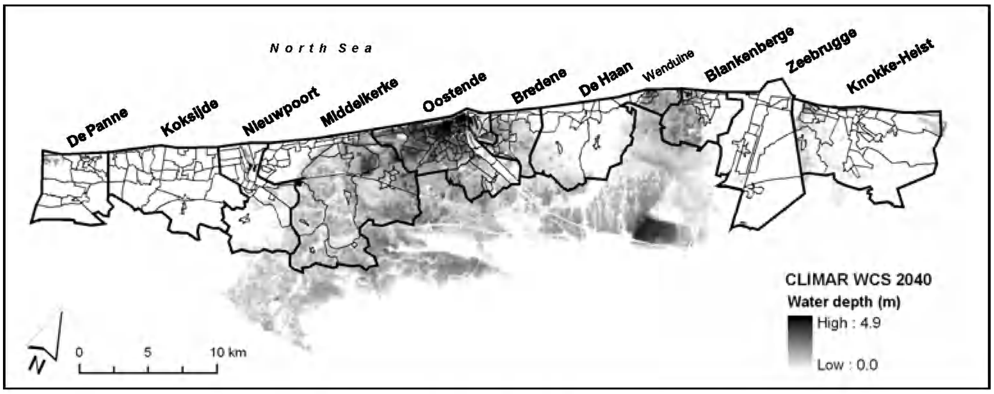

Figure 3 Flood extents and water depths according to the CLIMAR WCS 2040 flood model

5 METHOD

5.1 Study design

The WES survey data comprises estimated daily tourist numbers at the Belgian coast between June 2007 and May 2008. The 366 observations recorded within this period are aggregated into a number of categories, allowing us to work with meaningful scenarios. Eight separated scenarios are defined as follows: weekdays, weekend days, no holidays, holidays, spring days, summer days, autumn days and winter days. Based on these separated scenarios, 16 combinations are possible.

5.2 GIS model

Since 2007, the Flemish government is using a GIS tool for the support of its flood risk management, called LATIS. The tool is developed by Ghent University and Flanders Hydraulics Research and functions as a shell around the raster based IDRISI software (Clark Labs). Based on the Flemish flood risk methodology (see Vanneuville et al. 2006 for a comprehensive discussion), LATIS allows the user to perform risk computations for both economic losses and casualties. Critical mortality parameters in the present methodology are water depth, rise velocity and flow velocity. The number of casualties is determined as a percentage of the number of inhabitants (N_{POP}). It grows exponentially with water depth and linearly with rise velocity and flow velocity (Deckers et al. 2010). In the present study, LATIS is used to calculate the casualties among the registered population (denoted as C_{POP}) and the casualties among the residential tourists (C_{RT}). The total number of casualties C_{TOT} is defined as the sum of C_{POP} and C_{RT}.

6 RESULTS

6.1 Seasonal tourism on the Belgian coast

Based on the data sets from WES, the mean occupancy of second residences was determined for 16 time scenarios. Figure 4 depicts this occupancy numbers for each scenario with the corresponding number of residential tourists N_{RT}.

Summer is obviously the most attractive season of the Belgian coast. It does not matter if it is weekday or weekend, holiday or not, the mean occupancy is always higher compared to the respective scenarios in spring, autumn or winter. On average, there are more second residences occupied during weekends than on weekdays, regardless of whether or not weekdays fall within a holiday period. As expected, the difference between the occupancy on weekdays and weekends is smaller during holidays than outside holidays. Furthermore, the mean occupancy of second residences is more or less similar in autumn and winter.

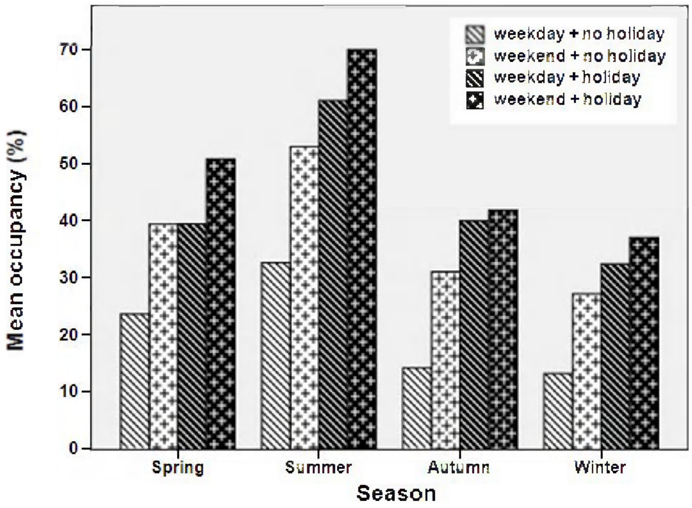

Figure 4 Mean occupancy of second residences and mean tourist number on the Belgian coast for various scenarios

Employing a Scheffé post-hoc test, significant differences were found between the mean tourist number in spring and summer ($p < .001$), but not between autumn and winter ($p = 1$). Regardless of the season, the mean tourist number on weekdays or weekends differs significantly ($t = -7.32$, df = 364, $p < .001$, two-tailed), as well as on holidays or non-holidays ($t = -18{,}86$, df = 184.28, $p < .001$, two-tailed). An unplanned comparison on the combined scenarios revealed significant differences in mean tourist number between the combination "weekday + no holiday" and "weekend + holiday" ($p < 0.001$). However, no significant differences were observed between "weekday + holiday" and "weekend + holiday" ($p = .11$).

Summarized, coastal tourism fluctuations differ significantly between the summer half year and the winter half year, as well as on the level of day of week. Holidays play an unmistakably important role in occupancy of second residences. With these outcomes, we have found evidence for the significance of the factor time within N_{RT} (cf. Section 2).

6.2 Tourism behaviour

The overall response rate of the perception questionnaire (cf. Section 4.2) was approximately 20%. The respondents were asked to answer the six items listed in Table 1. Table 2 presents the results of the questionnaire. As for scenario A, where the respondent is supposed to set off for a trip to the sea when weather forecasts predict major storms, we found that 58% of the respondents will continue their holiday plans. Only 22% will cancel their trip immediately and over 45% will postpone their departure. In scenario B, where the respondent is supposed to stay at the coast at the moment the storm is forecasted, similar results are reported. About one third of the respondents will leave the coastal area immediately. The remaining part agrees to wait for the storm and see how it turns out. Noticeably, almost half of the respondents answers that they would stay on the coast, just to watch the storm.

Table 2 Questionnaire results on tourist behaviour in stormy weather

	No agreement		**Agreement**		**No opinion**	
	Number	**%**	**Number**	**%**	**Number**	**%**
A1 *(going to the sea)*	73	41.7%	101	57.7%	1	0.6%
A2 *(delay depart)*	91	52.0%	79	45.1%	5	2.9%
A3 *(cancel trip)*	127	72.6%	41	22.3%	9	5.1%
B1 *(leave coastal area)*	117	66.9%	57	32.6%	1	0.6%
B2 *(await storm)*	52	29.7%	118	67.4%	5	2.9%
B3 *(storm watching)*	92	52.6%	78	44.6%	5	2.9%

The results of this questionnaire show that about two third of the respondents are rather persistent in their holiday plans, particularly if they are already on the coast at the moment the storm is announced (scenario B). The effects in terms of casualties are presented in the next section.

6.3 Casualty calculations

The results of the LATIS computations are presented geographically in two figures. Figure 5 depicts the number of casualties per m^2 among the registered population (C_{POP}). Figure 6 represents the number of casualties per m^2 among the residential tourists on the assumption that all second residences are occupied ($C_{RT(MAX)}$). In order to see the raw effects of the tourist numbers, the outcomes of the behavioural study (cf. Section 6.2) are not implemented in the calculations.

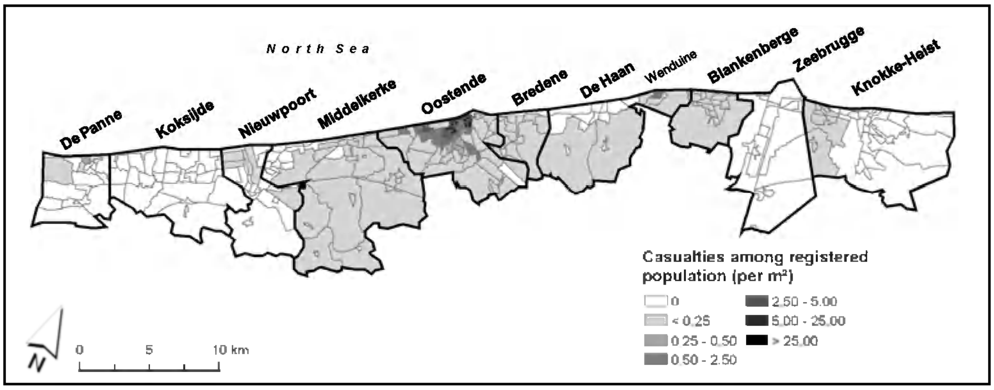

Figure 5 Casualties among registered population (C_{POP}, flood model: CLIMAR WCS 2040)

As for C_{POP} (Figure 5), it is clear that impact of the CLIMAR flood model is marked in the city of Oostende. Close to the coastline, several sectors indicate estimations of more than 25 casualties per km^2 among the registered population. Other noticeable impacts are observed in Wenduine, a small town near Blankenberge.

A slightly different image is obtained for the computations of $C_{RT(MAX)}$ (Figure 6). Compared to C_{POP}, C_{RT} is more pronounced in those sectors bordering the coastline. Marked impacts of the CLIMAR flood model are particularly observed in Oostende, Wenduine and De Panne. In Oostende, several sectors adjacent to the coastline indicate densities of more than 25 casualties per km^2. The centres of De Panne and Wenduine, both very close to the coastline, represent areas with densities over one and six casualties per km^2 respectively.

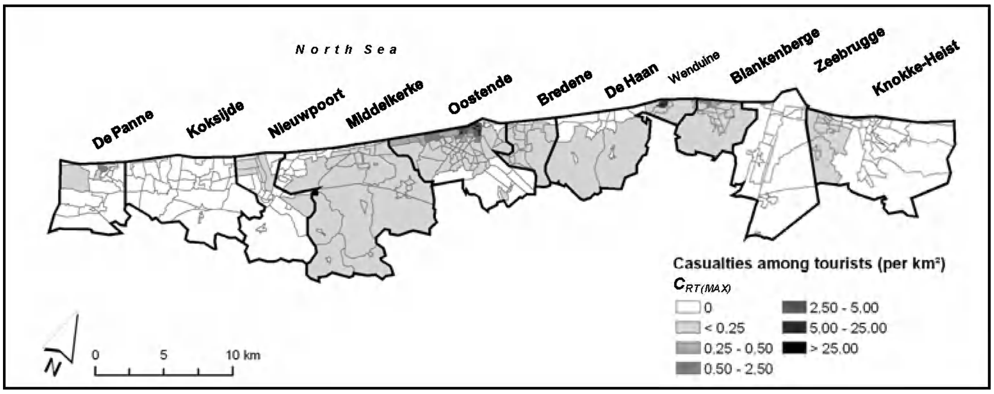

Figure 6 Casualties among tourists ($C_{RT(MAX)}$, flood model: CLIMAR WCS 2040)

Table 3 presents for each municipality the absolute numbers of the registered population (N_{POP}), the casualties among the registered population (C_{POP}), the maximum number of residential tourists ($N_{RT(MAX)}$) and the casualties among these tourists ($C_{RT(MAX)}$). Further, absolute numbers are presented for a summer and winter scenario. For both scenarios, the mean occupancy of the second residences was used (56.1% for summer; 21.4% for winter). We recall that the number of people at risk N_{PAR} equals the sum of N_{POP} and N_{RT} and that the total number of casualties C_{TOT} for both scenarios is defined as the sum of C_{POP} and C_{RT}.

On summer days there are over 0.4 million people at risk in the ten coastal municipalities. More than half of them are residential tourists. In winter, tourists weigh less heavily on the total number. Then there are on average nearly 0.3 million people at risk, of whom 30% are residential tourists. The percentages in the N_{RT} column of Table 3 represent the portion of residential tourists (N_{RT}) against the total number of people at risk. Regarding tourism, the most vulnerable municipalities are Middelkerke (N_{RT}/N_{PAR} = 71.5%), Koksijde (N_{RT}/N_{PAR} = 67.8%) and Nieuwpoort (N_{RT}/N_{PAR} = 67.3%). Least vulnerable are Bredene (N_{RT}/N_{PAR} = 19.9%) and Zeebrugge (N_{RT}/N_{PAR} = 15.7%). Figure 2 shows the spatial variations for a geographical output of the N_{RT}/N_{PAR} ratio at the level of the statistical sector.

For three municipalities - Nieuwpoort, Zeebrugge and Koksijde - few or no casualties are estimated. The WCS 2040 flood extents are negligible in these municipalities (cf. Figure 3). We ignore them in the remainder. The vast majority of casualties falls in Oostende (ca. 98%), followed by De Haan, Blankenberge and De Panne. The percentages in the C_{RT} column of Table 3 represent the impact of casualties among the residential tourists (C_{RT}) compared to the total number of victims for that scenario (C_{TOT}). We observe that the impact of C_{RT} is highest in the municipalities Blankenberge, De Haan and De Panne. In the summer scenario, 60.6% to 74.1% of the casualties are residential tourists. This percentage is lower in the winter scenario, but still more than 50% for De Haan and De Panne. The marked outcomes for De Haan are mainly due to the losses in Wenduine. In the municipalities Bredene, Knokke-Heist and Middelkerke, the impact of residential tourism on the total number of casualties is rather limited. The percentage of C_{RT} in the city of Oostende amounts to 36.3% in summer and 17.9% in the winter. These values are lower than in Blankenberge, De Haan and De Panne, but they represent hundreds of casualties.

Table 3 Summary of casualty computations for each municipality

					Summer				Winter			
Municipality	N_{POP}	C_{POP}	$N_{RT(MAX)}$	$C_{RT(MAX)}$	N_{RT}	N_{PAR}	C_{RT}	C_{TOT}	N_{RT}	N_{PAR}	C_{RT}	C_{TOT}
Blankenberge	17386	4.83	29322	13.23	16450	33836	7.42	12.26	6275	23661	2.83	7.66
					48.6%		*60.6%*		*26.5%*		*36.9%*	
Bredene	12633	3.90	5602	0.25	3143	15776	0.14	4.04	1199	13832	0.05	3.95
					19.9%		*3.4%*		*8.7%*		*1.3%*	
De Haan	11126	11.35	35058	57.85	19668	30794	32.46	43.81	7502	18628	12.38	23.73
					63.9%		*74.1%*		*40.3%*		*52.2%*	
De Panne	9870	2.42	31149	14.50	17475	27345	8.13	10.55	6666	16536	3.10	5.52
					63.9%		*77.1%*		*40.3%*		*56.2%*	
Knokke-Heist	32394	3.57	92414	1.59	51844	84238	0.89	4.47	19777	52171	0.34	3.91
					61.5%		*20.0%*		*37.9%*		*8.7%*	
Koksijde	20052	0.00	75419	0.00	42310	62362	0.00	0.00	16140	36192	0.00	0.00
					67.8%		--		*44.6%*		--	
Middelkerke	16503	3.04	73775	1.89	41388	57891	1.06	4.10	15788	32291	0.40	3.44
					71.5%		*25.9%*		*48.9%*		*11.7%*	
Nieuwpoort	10244	0.01	37562	0.06	21073	31317	0.03	0.04	8038	18282	0.01	0.02
					67.3%		*85.9%*		*44.0%*		*70.0%*	
Oostende	65688	1906.04	28887	1939.45	16206	81894	1088.03	2994.07	6182	71870	415.04	2321.08
					19.8%		*36.3%*		*8.6%*		*17.9%*	
Zeebrugge	9168	0.00	3047	0.00	1709	10877	0.00	0.00	652	9820	0.00	0.00
					15.7%		--		*6.6%*		--	
Total	205064	1935.16	412237	2028.82	231265	436329	1138.17	3073.33	88219	293283	434.17	2369.33
					53.0%		*37.0%*		*30.1%*		*18.3%*	

7 CONCLUSION

In this paper, we have substantiated the inclusion of residential coastal tourism and its dynamics in societal flood risk, which is determined by the number of people at risk and the number of casualties expected in case of flooding. A case study was conducted on the Belgian coast, a densely populated area characterized by a large tourism industry and a high vulnerability toward coastal flooding. A worst case flood scenario was employed to analyze the effects of coastal tourism on casualty computations. Two questions were addressed in this study: are tourists inclined to continue their holiday plans or are they frightened by the potentially adverse effects of storms? How do tourism dynamics affect coastal flood risks? This section provides answers and discussion points to both questions.

Concerning the first question, the outcomes of the questionnaire on tourism behaviour suggest that residential tourists are rather persistent in their holiday plans, irrespective of storm forecasting. Moreover, several tourists indicate that they would go to the sea just to watch the storm surge, an outcome which supports previous studies on "storm watching" behaviour . Based on the results of the questionnaire, we believe that a significant part of the residential tourists – about two third – will be present at the coastline in case a flood occurs. The second question was addressed in two steps. Firstly, tourism dynamics were mapped out through a set of time-scaled scenarios based on day-to-day variations (weekday, weekend day or holiday) and seasonal fluctuations. Raw data reflected the occupancy rate of second residences (private dwellings with recreational purposes), from which the number of residential tourists (N_{RT}) could be determined. Significant differences were observed between the summer half year and the winter half year, as well as on the level of day of week and holidays. Secondly, the number of people at risk and the number of casualties in case of a flooding were determined. It was shown that the number of people at risk (N_{PAR}) in the summer is twice as large than if only the registered population N_{POP} is taken. In winter, N_{PAR} is almost 30% more than if only N_{POP} is used. Casualty calculations were conducted for a worst case scenario (in which all second residences are supposed occupied) and two time-scaled scenarios (mean tourist number on a summer and a winter day). Employing a worst case flood scenario (CLIMAR WCS 2040), marked outcomes were particularly observed in flooded sectors having a high N_{RT}/N_{PAR} ratio. This is mostly the case in those sectors adjacent to the coastline, which are also most vulnerable to flooding. The casualty calculations indicate that considering tourism dynamics can produce a significant impact, which can also vary significantly in time.

The outcomes of this study have clearly foregrounded the implications of accounting for coastal tourism dynamics for flood risk calculations. However, the question remains to what extent the increased insights that can be obtained by the incorporation of tourism dynamics justifies the extra data requirements and computational efforts? If the flood prone area is as touristy as the Belgian coast, it may certainly be justified. Although effects may differ between coastal areas, we believe that flood risk management should always verify possible tourism effects. Moreover, the study of tourism dynamics should not be restricted to coastal flood risks. Since mountainous areas are also attractive to tourists, considering tourism dynamics in mountain flash floods could be important as well. Outcomes of such research may be helpful to set up and improve early warning systems, which depend not only on the forecasting system but also on the knowledge on human behavior (Plate 2007). Taken together, we hope that our study will stimulate a more careful consideration of the implications of tourism dynamics in risk management and early warning systems.

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