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General health and residential proximity to the coast in Belgium: Results from a cross-sectional health survey

Alexander Hooyberg[a,*], Henk Roose[b], James Grellier[c], Lewis R. Elliott[c], Britt Lonneville[a], Mathew P. White[c], Nathalie Michels[d], Stefaan De Henauw[d], Michiel Vandegehuchte[a], Gert Everaert[a]

[a] Flanders Marine Institute (VLIZ), Ostend, Belgium
[b] Department of Sociology, Ghent University (UGent), Ghent, Belgium
[c] European Centre for Environment and Human Health (ECEHH), University of Exeter Medical School, University of Exeter, Truro, United Kingdom
[d] Department of Public Health and Primary Care, Ghent University (UGent), Ghent, Belgium

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ABSTRACT

The health risks of coastal areas have long been researched, but the potential benefits for health are only recently being explored. The present study compared the general health of Belgian citizens a) according to the EU's definition of coastal (< 50 km) vs. inland (> 50 km), and b) between eight more refined categories of residential proximity to the coast (< 5 km to > 250 km). Data was drawn from the Belgian Health Interview Survey (n = 60,939) and investigated using linear regression models and mediation analyses on several hypothesized mechanisms. Results indicated that populations living < 5 km of the coast reported better general health than populations living at > 50–100 km. Four commonly hypothesized mechanisms were considered but no indirect associations were found: scores for mental health, physical activity levels and social contacts were not higher at 0–5 km from the coast, and air pollution (PM_{10} concentrations) was lower at 0–5 km from the coast but not statistically associated with better health. Results are controlled for typical variables such as age, sex, income, neighbourhood levels of green and freshwater blue space, etc. The spatial urban-rural-nature mosaic at the Belgian coast and alternative explanations are discussed. The positive associations between the ocean and human health observed in this study encourage policy makers to manage coastal areas sustainably to maintain associated public health benefits into the future.

1. Introduction

Coastal regions are defined in the EU as within 50 km of the coast, and account for 40% of the European land area and population (Eurostat, 2013). Public health research related to the marine ecosystem has traditionally focused on reducing impacts by natural hazards and risks, and on improving human health by the maximal exploitation of goods and services such as seafood and novel pharmaceuticals (European Marine Board, 2013). It has long been acknowledged that exposure to marine and coastal environments may also improve health (Charlier and Chaineux, 2009). Systematic research into such benefits within the last decade has begun to discover the diverse role of coastal environments as an accessible public health resource (Cracknell, 2019; Gascon et al., 2017). While most literature has focused on exposure to the sea or beach specifically, the coast in general (including both urban and natural areas) also provides health benefits (Gascon et al., 2017). Coasts are often diverse and consist of a mosaic of urban towns, cities and harbours interspersed by rural and more natural beaches and dunes. Early work in England and Ireland suggested that populations living in proximity to the coast in general reported better general health and well-being compared to those living inland (Brereton et al., 2008; Wheeler et al., 2012; White et al., 2013a).

This study investigates the link between general health and residential proximity to the coast, and additionally aims to identify the mechanisms underlying that relationship. Four likely mechanisms have been proposed to explain the health benefits from living in proximity to the coast, which are similar to those discussed for the relationships between health and residential green space exposure (e.g. to parks and

* Corresponding author. Flanders Marine Institute (VLIZ), InnovOcean site - Wandelaarkaai 7, 8400, Ostend, Belgium.
E-mail addresses: alexander.hooyberg@vliz.be (A. Hooyberg), henk.roose@ugent.be (H. Roose), j.grellier@exeter.ac.uk (J. Grellier), l.r.elliott@exeter.ac.uk (L.R. Elliott), britt.lonneville@vliz.be (B. Lonneville), mathew.white@exeter.ac.uk (M.P. White), nathalie.michels@ugent.be (N. Michels), stefaan.dehenauw@ugent.be (S. De Henauw), michiel.vandegehuchte@vliz.be (M. Vandegehuchte), gert.everaert@vliz.be (G. Everaert).

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forests) (Gascon et al., 2017, 2015; Kabisch et al., 2015; Lahart et al., 2019; Maas et al., 2009, 2006; Markevych et al., 2017; Nieuwenhuijsen et al., 2017; Van Aart et al., 2018; Völker and Kistemann, 2015; White et al., 2016b). First, characteristics of coastal environments may divert attention from everyday routines and demands, consequently restoring those psychological resources that facilitate the reduction of stress and support positive mental health (Elliott et al., 2019; Garrett et al., 2019a; Kaplan and Kaplan, 1989; White et al., 2010, 2013b, 2013a). Psychological benefits, such as reduced depression, can even be obtained from having a view of water from the residence (Dempsey et al., 2018; Garrett et al., 2019b; Nutsford et al., 2016; Peng and Yamashita, 2016), or by looking at marine wildlife (Cracknell et al., 2017, 2016; 2018; White et al., 2017). Second, coastal environments may support health by promoting walking and other physical activities (Elliott et al., 2018, 2015; Kerr et al., 2014). As such, a person is more likely to attain healthy levels of overall physical activity (Bauman et al., 1999; Pasanen et al., 2019; White et al., 2014). Increased coastal physical activity can manifest in for example less childhood obesity (Wood et al., 2016) and slower decline in muscular strength among older adults (de Keijzer et al., 2019). Third, the positive social ambience in coastal environments may improve health by reinforcing positive interactions between individuals (Bell et al., 2015; Dzhambov et al., 2018; Hartig et al., 2014). Qualitative research, for instance, has demonstrated that children enjoyed family interactions most when visiting the beach compared to other (semi-) natural environments (Ashbullby et al., 2013). Finally, the relative absence of traffic and industry at sea compared to on land may result in distinct physiochemical characteristics in proximity to the coast, such as reduced air pollution. People have been using the health-enhancing properties of coastal air since the nineteenth century (Charlier and Chaineux, 2009; Pirlet, 2016; Verkest, 1898). However, much less researched to date are the public health benefits that can be obtained from reduced air pollution in coastal environments (e.g. Prüss-Ustün et al., 2016; Davidson et al., 2005; Lu et al., 2015; Pope and Dockery, 2006; Pope, 2002).

Despite the growing amount of health promoting effects described in literature, evidence which links general health with residential proximity to the coast is still mixed and originates from only a couple of countries such as the United Kingdom (Gascon et al., 2017). Moreover, studies which link this relationship with each of the four hypothesized mechanisms are scarce. So, the question remains if the described benefits and mechanisms can accumulate to a measurable increase in the general health of coastal populations across Europe. Therefore, this paper addresses these knowledge gaps with a twofold aim. First, this study explores whether positive relationships between general health and residential proximity to the coast exist in Belgium. Since no comparable research has been carried out in Belgium, we addressed the health-residential proximity relationship at two different spatial scales: one comparison is based on the EU definition of ‘coastal’ (< 50 km vs. > 50 km) and is contrasted against a more nuanced delineation (i.e. 0-5 km, > 5–20 km, > 20–50 km, > 50–100 km, > 100–150 km, > 150–200 km, > 200–250 km and > 250 km), similar to that used in previous research (Wheeler et al., 2012; White et al., 2013a). The second aim explores if any of the four hypothesized mechanisms account for the association between residential proximity to the coast and the general health of Belgian citizens. The mediation effects of specifically mental health, physical activity, social interactions and air pollution are tackled.

2. Materials and methods

2.1. Data

2.1.1. Health interview survey

Repeat cross-sectional survey data from the Belgian Health Interview Survey (HIS, N = 60,939, obtained through Sciensano in accordance with privacy regulations) were used to test both hypotheses. The HIS is a large national survey that collects data on demography (e.g. residence location, education and employment), health and well-being (e.g. perceived general health, long term diseases and limitations, pain, mental health and indices of quality of life) and other issues related to health behaviour and lifestyle, the use of health care and social services, physical activities, and social contacts. It has been administered in 1997 (n = 10,786), 2001 (n = 12,770), 2004 (n = 13,831), 2008 (n = 11,938) and 2013 (n = 11,614) through written and oral questionnaires (still ongoing), using a stratified and multistage-clustered design. Respondents were stratified at the province level, and clustered at the municipality level and household level. Each year, a minimum of 3500 participants from the Flemish and Walloon regions, and 3000 participants from the Brussels region, were randomly selected based on their social number. The potential presence of a participation bias was acknowledged, and overcome by weighting each sampled individual based on age, sex, and household size to be representative of the population in the province of residence.

2.1.2. General health

The outcome variable in this study concerns self-reported general health. This was derived from the question: “*How is your health state in general?*” Five possible answers ranged from ‘*very bad*’ (scored 1) to ‘*very good*’ (scored 5). This single item is one that is among the three variables forming the Minimum European Health Module, which was designed to allow comparable calculations of health expectancies across Europe (Robine et al., 2003), and is the same one as used in the European Health Interview Survey. General health was assessed in all waves throughout the study period (i.e. 1997, 2001, 2004, 2008, and 2013) and only administered to respondents aged 15 years and older.

2.1.3. Residential proximity to the coast

Residential proximity to the coast has been associated with a variety of health outcomes, such as physical activity, mental and general health (Pasanen et al., 2019; White et al., 2014, 2013a). Residential proximity to the coast in this study was calculated as the distance travelled using the fastest driving route from the geographical centre of the residential municipality to the nearest point at the Belgian coast (extended up to Breskens in The Netherlands, marking the boundary with the Western Scheldt estuary, Fig. 1). To do so, the OpenStreetMap road network (OpenStreetMap contributors, 2018) and Eurostat coastline data (Nomenclature of Territorial Units for Statistics (NUTS), 2013) were combined in QuantumGIS 3.2.2 to generate a dataset of coastal destination points. Afterwards, the distance corresponding with the fastest driving route from the municipality centres to these points were calculated using the ArcGIS Pro 2.2.0 Network Analyst extension. Fig. 1 illustrates the modelled origins, destinations, and fastest travel routes between them. On this map, it is clearly visible that most of the fastest travel routes involve the same highways through the country. In contrast with Euclidean distances as were used in previous studies (Brereton et al., 2008; Wheeler et al., 2012; White et al., 2013a), it is assumed that these fastest travel routes are a good reflection of the real travel behaviour of Belgian citizens. Fig. 1 also illustrates that the GIS model predicts only a few accessible routes when nearing the Belgian coast. It should be emphasized that Belgian citizens are likely to deviate from these routes when nearing the coast to reach more remote areas along the coastline, such as dunes, smaller coastal towns, parking lots, etc. This geographical nuance near the Belgian coast has to be taken into account when interpreting Fig. 1 and the results.

Residential proximity to the coast was then categorized in two ways. The first approach was based on the simple EU Nomenclature of territorial units for statistics (NUTS) definition NUTS3 (European Commission, 2003). This compared the general health of Belgian residents living in ‘inland’ areas (i.e. > 50 km = *ref*) to the general health of people living in ‘coastal’ areas (i.e. < 50 km). The second approach was more nuanced, where the general health of residents was compared between eight populations living at finer gradation of coastal

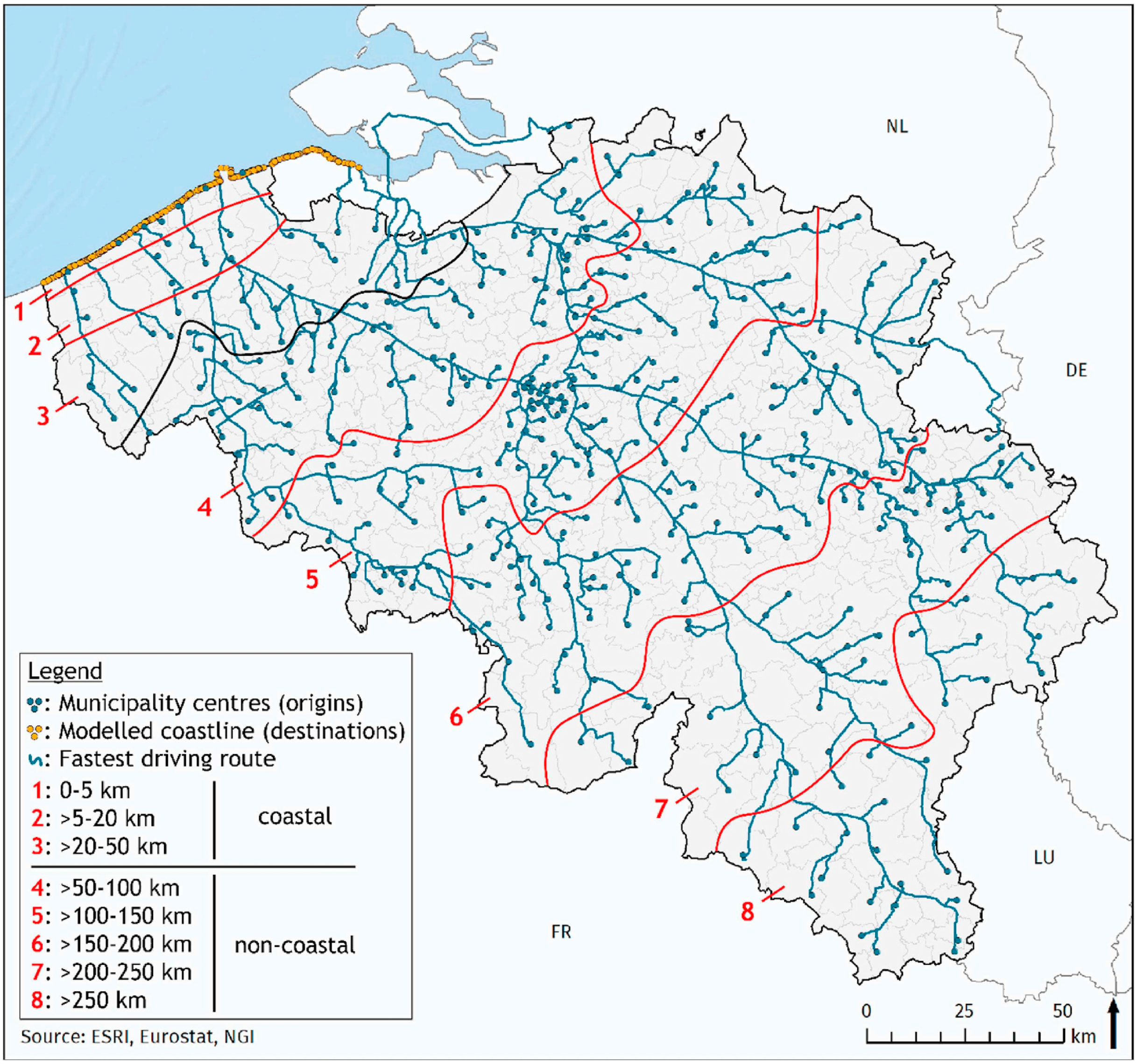

Fig. 1. Map of Belgium showing the geographical centres of all sampled municipalities (blue dots, legend) in any wave (1997, 2001, 2004, 2008 and 2013) throughout the study period, and the corresponding fastest driving route (blue lines, legend) to the nearest point at the coast (orange dots, legend). The corresponding distances are categorized as coastal or inland (black line, legend) by the EU NUTS3 definition, or in eight nuanced populations with different residential proximity to the coast (red lines and numbers, legend). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

proximity, i.e. at 0–5 km, > 5–20 km, > 20–50 km, > 50–100 km = *ref*, > 100–150 km, > 150–200 km, > 200–250 km and > 250 km (maximum fastest driving distance is 309.73 km). See Fig. 1 for a graphical representation. The specific categories (and reference categories) have been used and adjusted from similar research in England (Wheeler et al., 2012; White et al., 2013a). In England, Wheeler et al. (2012) made a differentiation between 0-1 km, > 1–5 km, > 5–20 km, > 20–50 km and > 50 km (*ref*) from the coast, while White et al. (2013a) distinguished 0–5 km, > 5–50 km (*ref*) and > 50 km from the coast. The eight categories in this study as such allow comparison with this previous body of work, adjusted for the different geography of Belgium. The reference category in the second approach was defined at > 50–100 km because (1) this group makes the results most comparable to previous research in England, (2) this group is among the groups that contain the most amount of data, and (3) this group is among the groups that are most representative for the entire country, and does not contain the rather 'remote' populations at the coast or in the Ardennes areas or disproportionally densely populated areas in and around the capital Brussels.

2.1.4. Covariates

Factors that can covary with general health and residential proximity to the coast were also included in all analyses. Based on expert knowledge and knowledge from literature (Dormann et al., 2013; Wheeler et al., 2012; White et al., 2013a), twelve potential confounding factors were selected *a priori*. The first set of potential confounders originated from the HIS survey itself: age (< 20 year, 21–45 year = *ref*, 46–65 year, > 65 year), sex (male = *ref*, female), having a chronic disease (yes, no = *ref*, no answer), BMI (normal weight = *ref*, underweight, obesity class I, obesity class II, obesity class III), employment status (employed = *ref*, unemployed), income (quintile 1, quintile 2, quintile 3, quintile 4, quintile 5 = *ref*, no answer), smoking status (non-smoker = *ref*, occasional smoker, daily smoker, no answer) and level of urbanization (urban = *ref*, sub-urban, rural). The year (1997, 2001, 2004 = *ref*, 2008, 2013) and season (winter = *ref*, spring, summer, fall) were also included as potential covariates.

The distinct geographical landscape of Belgium, with for example more forested areas in the southeast (far from the coast), was also considered in the analyses, because an emerging literature is showing that green space or blue space in the neighbourhood can influence self-reported general health (Dzhambov et al., 2018; Gascon et al., 2017; Maas et al., 2006). Accordingly, environmental information from Statbel (2019) was used to complement the first set of covariates with the amount of green space and freshwater blue space in the municipality. The green space ratio (0–10%, > 10–20%, > 20–30% = *ref*, …, > 80–90%, > 90–100%) was calculated as the percentage of green outdoor surface area selected from a list of land uses as defined in the municipality cadastre, i.e. grasslands, gardens and parks, forests, savage grounds/disused areas, recreational areas and areas for sports (built areas, roads and agricultural land were not included). Similarly, the freshwater blue space ratio (0–0.25% = *ref*, > 0.25–0.5%, > 0.5–0.75%, …, > 1.75–2%, > 2%) was derived from the amount of cadastrated freshwater surface in the municipality, including rivers, lakes, ponds, canals, etc. (not the sea).

A prerequisite to act as covariate is that the abovementioned variables change with proximity to the coast. Sex and season were similar across the study area, and were consequently excluded from further analysis (Fig. S3). A description of all variables considered in this study is available in Table S1.

2.1.5. Hypothesized mechanisms

The hypothesized mechanistic effects of mental health, physical activity, social interactions, and air pollution were also investigated. Mental health was investigated by consulting the General Health Questionnaire (GHQ-12) score, which was also embedded in the HIS, and which measures psychological distress (Goldberg, 1972). This score is calculated on the basis of twelve questions related to for example being able to concentrate, feelings of worry, self-confidence and happiness. Answers were '*More so than usual*', '*Same as usual*', '*Less than usual*', or '*Much less than usual*'. Each answer was coded with a value of 0 (no mental distress) or 1 (mental distress) and summed to an overall (reversed) score of mental health, ranging from 0 (worst mental health) to 12 (best mental health).

Mean health-enhancing energy expenditure linked to physical activity per week was used as a proxy for the level of physical activity, and was also queried through the HIS. This score is based on the International Physical Activity Questionnaire (IPAQ, Craig et al., 2003) and uses energy requirements defined in METs (multiples of the resting metabolic rate) in combination with the time that is spent walking (3.3 METs), performing moderate intensity activities (4.0 METs, e.g. cycling) and vigorous intensity activities (8.0 METs, e.g. running), to calculate a final score in METs per minute (per week).

The quality of social interactions was operationalized by asking participants to rate their appreciation of social interactions as '*really satisfying*' (scored 3), '*rather satisfying*' (scored 2), '*rather unsatisfying*' (scored 1) or '*really unsatisfying*' (scored 0), henceforth referred to as 'social appreciation'. Numerical scores were used during the data analyses.

Finally, air pollution levels were assessed using data from the Belgian Interregional Environment Agency (CELINE, 2019) on the annual mean PM_{10} concentration (μg/m^3) per municipality. These means per municipality are obtained from interpolated concentrations that are based on several measurement stations all over Belgium. The annual mean PM_{10} concentrations per municipality are considered to be representative for how much each participant was exposed to air pollution in and around his/her residence. Particulate matter correlates well with other anthropogenic air pollutants such as SO_2 and O_3 in Belgian households (Stranger et al., 2009).

2.2. Analyses

The first aim of this study tackled general health in relation to residential proximity to the coast by formulating linear regression models in R (R Core Team, 2018). General health was treated as a numerical scale, as was also done in White et al. (2013a), and because it makes little difference whether analyses assume a linear or ordinal structure for such kinds of measures with limited scores (Ferrer-i-Carbonell and Frijters, 2004). During modelling, the survey design in terms of weights, stratification and clustering was taken into account using the R package 'survey' (Lumley, 2017, 2004). The association between health outcomes and residential proximity to the coast was evaluated by two models, one using the EU NUTS3 definition of 'coastal', and one using eight categories of residential proximity to the coast. In both models, residential proximity to the coast was the main predictor. Then, covariates were added one after the other using a forward selection procedure, in which the covariate that resulted in the highest reduction in Akaike Information Criterion (AIC, lower values indicate a better balance between model fit and model complexity; Zuur et al., 2009) was added next. As such, only variables which explained sufficient information were included. Models were based on respondent data for which no missing values were present for all the variables in the model. Described model coefficients represent the predicted deviation in the response (i.e. general health) for a category level change from the reference level in the specific predictor, given that all other predictors are held constant. A significance level of 5% was adopted using p-value estimation.

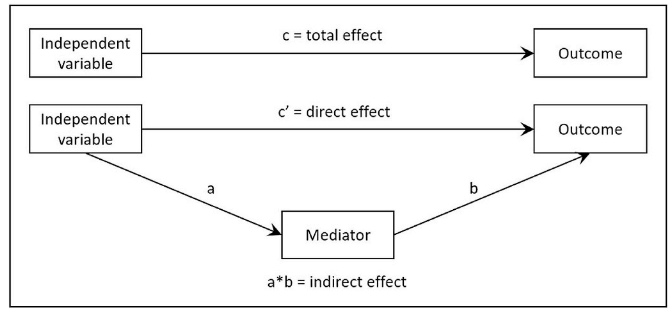

Fig. 2. Conceptual diagram of the total effect (c), direct effect (c') and indirect effect (a*b) calculation. Each arrow represents a linear regression model with predictor of interest at the base of the arrow and outcome at the arrowhead. The letters a, b, c, and c' indicate regression coefficients and represent either the slope (in the case of a continuous predictor) or difference (in the case of a categorical predictor) in the response.

The second aim of this study was to explore the mediating effect of the hypothesized mechanisms, i.e. mental health, physical activity, social appreciation and air pollution. The hypothesized mechanisms are primarily relevant for dwellers relatively close to the coast, so these analyses contrasted only the population living at 0–5 km compared all populations living beyond 5 km from the coast. Mediation effects were quantified by formulating several linear regression models to calculate the total effect, direct effects and indirect effects (Preacher, 2015). These models controlled for the same covariates and used the same forward selection procedure based on the highest reduction in AIC as in the first part of this study. Then, as endorsed by MacKinnon et al. (2004) and Preacher (2015), sample distributions of total, direct and indirect effects were generated by bootstrapping with 16,000 random subsamples of the data. In a final stage, percentile 95% confidence intervals were calculated from these distributions to assess deviation from zero and significance. Fig. 2 demonstrates the conceptual diagram underlying these mediation models. Indirect effects were used to determine if mediation occurred or not, and the values for path *a* and path *b* were used to explain the nature of the mechanistic relationship.

3. Results

3.1. General health - residential proximity to the coast

Self-reported general health was not associated with residential proximity to the coast for Belgian citizens when comparing coastal vs. inland areas. Populations living within 50 km from the coast reported similar general health as those living beyond 50 km from the coast (B = 0.043, 95% CI = -0.022 – 0.108) (Table 1). In contrast, the more nuanced analysis with eight categories of residential proximity to the coast revealed that self-reported general health was positively

Table 1
Results of the linear regression analyses from two models testing the relation between general health and residential proximity to the coast. A first model compared the general health of inland and coastal populations using the 50 km boundary from the EU NUTS3 definition (column 'Coastal vs. Inland'), another model compared the general health among eight categories of proximity to the coast (column 'Eight categories'). Coefficients for the covariates are also reported. Significance codes for p-values: *: < 0.05, **: < 0.01, ***: < 0.001.

	General health		
	B (95% CI)		n
	Coastal vs. Inland	Eight categories	
Intercept	2.346 (2.297, 2.394) ***	2.341 (2.289, 2.393) ***	23,624
Residential proximity to the coast			
Inland (> 50 km) (ref)	–	–	22,211
Coastal (< 50 km)	0.043 (-0.022, 0.108)	–	1413
Residential proximity to the coast			
> 250 km	–	0.018 (-0.020, 0.055)	2074
200–250 km	–	0.010 (-0.032, 0.051)	2419
150–200 km	–	-0.001 (-0.040, 0.039)	5014
100–150 km	–	0.016 (-0.018, 0.050)	8153
50–100 km (ref)	–	–	4551
20–50 km	–	0.065 (-0.006, 0.136)	841
5–20 km	–	-0.055 (-0.122, 0.012)	304
0–5 km	–	0.131 (0.003, 0.259) *	268
Age			
0–20 year	0.110 (0.003, 0.216) *	0.109 (0.002, 0.215) *	223
21–45 year (ref)	–	–	9492
46–65 year	-0.147 (-0.177, -0.118) ***	-0.148 (-0.177, -0.119) ***	8057
> 65 year	-0.268 (-0.320, -0.217) ***	-0.269 (-0.320, -0.218) ***	5852
Having a chronic disease			
No (ref)	–	–	16,080
Yes	-0.778 (−0.816, −0.741) ***	-0.777 (-0.815, -0.740) ***	7221
No answer	-0.443 (-0.548, -0.338) ***	-0.444 (-0.549, -0.340) ***	323
BMI			
Normal weight (ref)	–	–	11,595
Underweight	-0.164 (-0.237, -0.090) ***	-0.161 (-0.236, -0.086) ***	711
Pre-obesity	-0.069 (-0.096, -0.042) ***	-0.069 (-0.096, -0.042) ***	8054
Obesity class I	-0.175 (-0.220, -0.131) ***	-0.176 (-0.220, -0.132) ***	2481
Obesity class II	-0.312 (-0.390, -0.234) ***	-0.313 (-0.390, -0.235) ***	573
Obesity class II	-0.348 (-0.484, -0.211) ***	-0.345 (-0.481, -0.209) ***	210
Having a paid job			
Yes (ref)	–	–	11,997
No	-0.178 (-0.212, -0.144) ***	-0.179 (-0.213, -0.145) ***	11,237
No answer	-0.148 (-0.237, -0.058) **	-0.147 (-0.234, -0.060) **	390
Income			
Quintile 1	-0.181 (-0.222, -0.140) ***	-0.180 (-0.221, -0.138) ***	3890
Quintile 2	-0.189 (-0.229, -0.148) ***	-0.186 (-0.226, -0.146) ***	3821
Quintile 3	-0.117 (-0.157, -0.078) ***	-0.116 (-0.155, -0.077) ***	4024
Quintile 4	-0.065 (-0.102, -0.027) ***	-0.063 (-0.100, -0.026) ***	3976
Quintile 5 (ref)	–	–	4439
No answer	-0.054 (-0.102, -0.006) *	-0.054 (-0.101, -0.006) *	3474
Smoking status			
Non-smoker (ref)	–	–	16,013
Occasional smoker	-0.094 (-0.151, -0.038) **	-0.094 (-0.150, -0.038) **	1141
Daily smoker	-0.147 (-0.173, -0.121) ***	-0.147 (-0.173, -0.121) ***	5744
No answer	-0.032 (-0.095, 0.031)	-0.032 (-0.095, 0.031)	726
Year			
1997	–	–	0
2001	-0.023 (-0.056, 0.009)	-0.024 (-0.055, 0.007)	7459
2004 (ref)	–	–	7474
2008	0.032 (-0.009, 0.072)	0.030 (-0.011, 0.070)	6116
2013	0.017 (-0.027, 0.060)	0.016 (-0.027, 0.058)	2575
Number of observations	23,624	23,624	
R^2	0.328	0.328	
AIC	10,568	10,567	

Abbreviations: B = unstandardized model coefficients, CI = Confidence Interval, n = number of observations associated with each coefficient, ref = reference category, R^2 = ratio explained/unexplained variation, AIC = Akaike Information Criterion.

associated with residential proximity to the coast. Specifically, populations living within 5 km from the coast reported better general health compared to populations living between 50 and 100 km from the coast (B = 0.13, 95% CI = 0.003 – 0.26). Other populations in Belgium who lived further than 5 km from the coast reported similar general health (Table 1).

In both categorical approaches, results were standardized for 7 covariates, which varied with proximity to the coast, i.e. age, having a chronic disease, BMI, employment status, income, smoking status and year (Fig. S4). Unfortunately, each of these variables contained some missing values, and the inclusion of these variables resulted in a substantial data-reduction from 60,939 records to 23,624 records for the modelled health-proximity to the coast relationship. The data-reduction per variable can be consulted in the Supplementary files (Table S1). The reduction of data in the models was irrespective of age, gender ratio, having a chronic disease, BMI, employment, income, smoking ratio, urbanization ratio, and neighbourhood green space and blue space (Fig. S3, Table S2). Note that the urbanization level, green space ratio and blue space ratio were not included in both models, due to insufficient contribution to AIC.

3.2. Mediation by hypothesized mechanisms

Mediation analyses using bootstrapped confidence intervals could not reveal that any of the hypothesized mechanisms included in this study accounted for the relationship between general health and

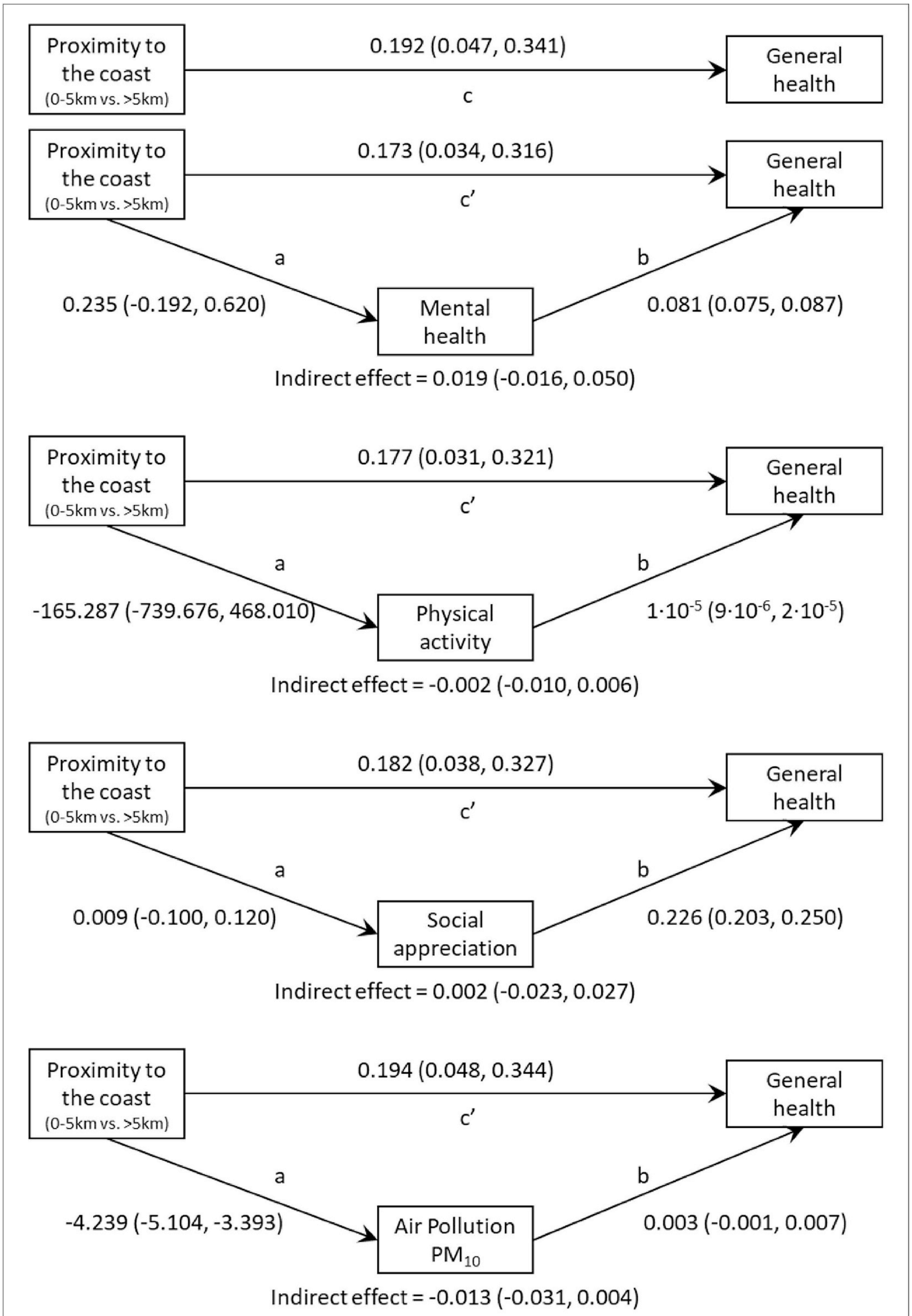

Fig. 3. Results of the indirect effect (a*b), direct effect (c') and total effect (c) calculation from the mediation analyses. Each arrow represents a linear regression model with predictor at the base of the arrow and outcome at the arrowhead. The letters a, b, c, and c' indicate regression coefficients and represent either the slope (in the case of a continuous predictor, so for b) or difference (in the case of a categorical predictor, so for a, c and c') in the response.

residential proximity to the coast (Fig. 3). More specifically, scores for the mental health, physical activity and social appreciation were similar when comparing populations living within 5 km and beyond 5 km from the coast (Fig. 3). For example, scores for mental health (GHQ-12) were scaled continuously from 0 to 12, and were on average 0.235 points (a, 95% CI = -0.192 – 0.620, i.e. not significant) higher in the 0–5 km group compared to the reference at > 5 km from the coast (similar interpretation for physical activity and social appreciation). Hence, no significant indirect effects related to these three factors were observed (Fig. 3). Nevertheless, general health was positively associated with better mental health, higher levels of physical activity and better social appreciation (Fig. 3). For example, when mental health was regressed against general health and bootstrapped multiple times, the mean slope coefficient was 0.081 (b, 95% CI = 0.075 – 0.087]). This positive and significant slope indicates that higher values of mental health were associated with higher values for general health (similarly for physical activity and social appreciation, Fig. 3).

The results for air pollution were different. There was significantly less air pollution within 5 km from the coast compared to all municipalities beyond 5 km from the coast (a = -4.239, 95% CI = -5.104 – -3.393], units in $\mu g/m^3$). However, no significant impact of air pollution on the self-reported general health could be detected (b = 0.003, 95% CI = -0.001 – 0.007). This resulted in the absence of mediation by air pollution (Fig. 3).

Results on these mediation pathways were standardized for the same 7 covariates as in the analysis for the health-proximity to the coast relationship. There was an additional data-reduction during the mediation analyses down to 15,418 records, since incomplete data on the four hypothesized mechanisms (i.e. mental health, physical activity, social appreciation and air pollution) also had to be included in the models.

4. Discussion

This study provides evidence that living at the coast is positively associated with general health in Belgium. Using data from the Belgian Health Interview Survey, this study found that people residing at less than 5 km from the Belgian coast report better health compared to citizens from further inland. These results are analogous to the results from a cross sectional study from England. More specifically, Wheeler et al. (2012) reported increased self-reported 'good' health in urban areas at 0–5 km from the coast compared to inland urban areas (> 50 km). A subsequent analysis on longitudinal data from the same individuals over time, found that people's health tended to be slightly better in years when they lived nearer the coast (0–5 km) when contrasted to those living further inland (> 5–50 km, White et al., 2013a). Thus, this study strengthens the current evidence that living nearer the coast is associated with better health, by revealing new evidence in the different national context of Belgium.

Scientists have been proposing several mechanisms to explain why people living near the coast report better health and wellbeing. This study assessed the four most commonly hypothesized mechanisms to explain better health in coastal areas, i.e. less stress and better mental health (Dempsey et al., 2018; Garrett et al., 2019b; Nutsford et al., 2016), more physical activity (Elliott et al., 2018, 2015; White et al., 2014), better appreciation of social interactions (Bell et al., 2015; Dzhambov et al., 2018) and better environmental quality such as less air pollution (Ashbullby et al., 2013; Bell et al., 2015; Davidson et al., 2005; Dempsey et al., 2018; Elliott et al., 2018; Kerr et al., 2014; Pasanen et al., 2019; Pope and Dockery, 2006; Prüss-Ustün et al., 2017; White et al., 2013b). However, this study found no evidence that any of the above-stated mechanisms accounted for the relationship between health and residential proximity to the coast for Belgian citizens. No such indirect effects were observed because the scores for mental health, physical activity and social appreciation were similar for people living within and beyond 5 km from the coast. This contrasts with the findings from literature from other countries (Ashbullby et al., 2013; Bell et al., 2015; Dempsey et al., 2018; Elliott et al., 2018; Kerr et al., 2014; Pasanen et al., 2019; White et al., 2013b). It is argued that the unexpected absence of any mediation effects in this study may be the result of the spatial heterogeneous character of the Belgian coast. The abovementioned cited literature mostly focused on the effects of exposure to beaches or seeing the seawater per se (e.g. Ashbullby et al., 2013; Dempsey et al., 2018). However, the Belgian coast displays a mosaic pattern of urban, rural, and natural areas, similar as other coastlines in Europe. As such, the health benefits from the sea per se can become obscured by being exposed to other types of environments. In Belgium for example, sandy beaches co-occur next to dunes, agricultural land and nature parks, which are hypothesized to have positive impacts on the mental health, physical activity and social interactions. In contrast, coastal towns, cities and harbours are hypothesized to have negative impacts on these mechanisms. It remains to be investigated how exposure to a combination of such different coastal environments on a small spatial scale can impact the mental health and the physical and social activities performed around the residence, and how such processes may have resulted in the observed better overall health at the Belgian coast.

Regarding air pollution, this study found lower PM_{10} concentrations within 5 km from the coast compared to the average concentrations in other parts of Belgium. Very few modern studies compared levels of air pollution between coastal and inland areas, but our results for example resemble the lower PM_{10} concentrations found in coastal zones of California compared to inland areas of California (Kim et al., 2000). The results of this study are also consistent with the well-established historical belief that coastal air is healthier than inland air (Charlier and Chaineux, 2009; Pirlet, 2016; Verkest, 1898). Indeed, already since the mid-nineteenth century, the air in coastal areas was advertised to be health promoting by the still-famous Flemish writer, Hendrik Conscience (1861), for example. He wrote "the sea air is healthy and gives strength to ill persons" (translated from the original Dutch version) and his statements are known to have reached a wide public all over Belgium. Although this study did not provide evidence that reduced air pollution was responsible for the better health of Belgian coastal residents, it is generally accepted that polluted air negatively impacts public health by a range of adverse health outcomes, such as increased prevalence of cardiopulmonary conditions and subsequent mortality (Pope and Dockery, 2006; Pope, 2002). An important nuance that has to be made here is that the absence of land is not the only factor which can influence the air quality in coastal areas. Marine traffic (e.g. in harbours) and harmful algal blooms can for example also impact the healthiness of the air with measurable differences in coastal areas (Fleming et al., 2011; Van Acker et al., 2020; Viana et al., 2014).

None of the hypothesized mechanisms were shown to account for the health benefits at the Belgian coast. Systematic reviews also suggests that mechanistic relations between health and natural environments are entangled and yet unclear (Dzhambov et al., 2018; Gascon et al., 2017). It is also likely that several mechanisms interact and have additive and/or synergistic effects on overall health. Therefore, we argue that a more thorough investigation of these hypothesized mechanisms is needed to unravel which mixture of factors is actually driving better health in coastal populations, while taking into account the heterogeneity of coastal areas. We encourage that recent related studies investigated the health inequalities among populations with different socio-economic indices (Boyd et al., 2018; Clitherow et al., 2019). However, the observed better general health in coastal areas in this study persisted even after standardising for a whole range of socio-economic, demographic and lifestyle factors. Therefore, we argue that also relatively unexplored plausible pathways should be considered as well, for example (1) the potential presence of biogenic compounds in coastal sea spray which can inhibit molecular pathways that are linked to cancer and high levels of cholesterol (Asselman et al., 2019); and (2) the consumption of seafood, for example as promoted by the numerous coastal town restaurants, which may impact health in multiple ways (McManus et al., 2011). Furthermore, scientists still don't know how to isolate the amount of health benefits that are derived from the sea per se. To unravel these marine influences from other factors which can influence health, future research should try to encompass all environmental exposures, i.e. those that complement the universal genomic differences between individuals ('exposome', Miller, 2014; Vrijheid, 2014; Wild, 2012). If one wants to incorporate this exposome paradigm in coastal and other exposure assessments, researchers will need to integrate interdisciplinary innovation-driven research into the existing traditional methods.

This paper provides positive associations between the ocean and human health, and calls to policy makers to assure the coastal salutogenic resources in the future for continued public use. We encourage policy-makers to consider the health benefits that are associated with living near the coast. However, policy-makers should take into account the accessibility of these benefits for all socio-economic classes in society. Research learns us for example that seeing the sea can be especially relevant for coastal residents (Dempsey et al., 2018; Nutsford et al., 2016), but that for example having a sea-view is also reflected in real estate prices (Lange and Schaeffer, 2001). As such, this study answers and contributes to the call for action for sustainable use of our ocean, seas and marine resources for sustainable development (Fleming et al., 2019; UN Secretary General, 2017). In this respect, linking Sustainable Development Goal (SDG) 3 on human health with SDG 14 on the ocean and marine resources will require joint effort and collaboration of environmental researchers and clinicians (Depledge et al., 2019). Targeting specific health outcomes that can be translated in monetary values will be most relevant for the landscape decision-making processes (e.g. physical activity and quality-adjusted life years – QALYs in Papathanasopoulou et al., 2016; White et al., 2016a).

4.1. Limitations

This study's findings are based on large representative samples of the Belgian population over several years and robust methods were used not only to test the direct association between general health and residential proximity to the coast, but also to explore the mediation effects by hypothesized mechanisms. This study additionally included a lot of demographic, health behaviour, lifestyle, and environmental covariates, many of which were not included in similar previous research. This resulted in substantial data reduction, which was not age, sex or income specific. This study did not incorporate data on the frequency and type of coastal visits to assess intentional contact with the coast. Such visit data could have provided additional information that could potentially explain the absence of any of the mediation effects, and may have provided useful suggestions for other mechanisms at play. Additionnally, the present study did not test for the combined effects of multiple hypothesized mechanisms. Doing so may be possible using emerging pan-European survey evidence of the effect of blue spaces on public health (i.e. from the H2020 BlueHealth project, Grellier et al. (2017)). Finally, the ability to draw conclusions is still limited by the repeat cross-sectional design of the survey. For example, it is not possible to exclude potential selection effects which may have arisen because more healthy (and more wealthy) people tend to choose to live in coastal areas ('healthy migrant effect', Wheeler et al., 2012).

5. Conclusion

In conclusion, by analysing a cross-sectional national health survey of the Belgian population, this study found that living in proximity to the coast is associated with better general health. People who reside at the coast (i.e. at 0–5 km) reported better general health, but this was not mediated by mental health, physical activity, appreciation of social interactions or air pollution. The absence of any mediation effects may be caused by the spatial heterogeneity of the Belgian coast, or the presence of alternative unexplored mechanisms. The positive associations between the ocean and human health observed in this study encourage policy makers to manage coastal seas sustainably to maintain continued public use of its salutogenic resources throughout the future.

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Declaration of competing interests

We declare no actual or potential conflicts of interests.

Role of the funding source

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envres.2020.109225.

References

Ashbullby, K.J., Pahl, S., Webley, P., White, M.P., 2013. The beach as a setting for families' health promotion: a qualitative study with parents and children living in coastal regions in Southwest England. Health Place 23, 138–147. https://doi.org/10.1016/j.healthplace.2013.06.005.
Asselman, J., Van Acker, E., De Rijcke, M., Tilleman, L., Van Nieuwerburgh, F., Mees, J., De Schamphelaere, K.A.C., Janssen, C.R., 2019. Marine biogenics in sea spray aerosols interact with the mTOR signaling pathway. Sci. Rep. 9, 675. https://doi.org/10.1038/s41598-018-36866-3.
Bauman, A., Smith, B., Stoker, L., Bellew, B., Booth, M., 1999. Geographical influences upon physical activity participation: evidence of a 'coastal effect. Aust. N. Z. J. Publ. Health 23, 322–324. https://doi.org/10.1111/j.1467-842X.1999.tb01265.x.
Bell, S.L., Phoenix, C., Lovell, R., Wheeler, B.W., 2015. Seeking everyday wellbeing: the coast as a therapeutic landscape. Soc. Sci. Med. 142, 56–67. https://doi.org/10.1016/j.socscimed.2015.08.011.
Boyd, F., White, M.P., Bell, S.L., Burt, J., 2018. Who doesn't visit natural environments for recreation and why: a population representative analysis of spatial, individual and temporal factors among adults in England. Landsc. Urban Plann. 175, 102–113. https://doi.org/10.1016/j.landurbplan.2018.03.016.
Brereton, F., Clinch, J.P., Ferreira, S., 2008. Happiness, geography and the environment. Ecol. Econ. 65, 386–396. https://doi.org/10.1016/j.ecolecon.2007.07.008.
Charlier, R.H., Chaineux, M.-C.P., 2009. The healing sea: a sustainable coastal ocean resource: thalassotherapy. J. Coast Res. 254, 838–856. https://doi.org/10.2112/08A-0008.1.
Clitherow, T., Garrett, J., White, M.P., Wheeler, B.W., Fleming, L.E., 2019. Coastal proximity and mental health among urban populations in England: the moderating effect of household income. Health Place 102200. https://doi.org/10.1016/j.healthplace.2019.102200.
Cracknell, D., 2019. By the Sea: the Therapeutic Benefits of Being in, on and by the Water. Aster, Great Britain.

Cracknell, D., White, M.P., Pahl, S., Nichols, W.J., Depledge, M.H., 2016. Marine biota and psychological well-being: a preliminary examination of dose–response effects in an aquarium setting. Environ. Behav. 48, 1242–1269. https://doi.org/10.1177/0013916515597512.

Cracknell, D., White, M.P., Pahl, S., Depledge, M.H., 2017. A preliminary investigation into the restorative potential of public aquaria exhibits: a UK student-based study. Landsc. Res. 42, 18–32. https://doi.org/10.1080/01426397.2016.1243236.

Cracknell, D.L., Pahl, S., White, M.P., Depledge, M.H., 2018. Reviewing the role of aquaria as restorative settings: how subaquatic diversity in public aquaria can influence preferences, and human health and well-being. Hum. Dimens. Wildl. 23, 446–460. https://doi.org/10.1080/10871209.2018.1449039.

Craig, C.L., Marshall, A.L., Sjöström, M., Bauman, A.E., Booth, M.L., Ainsworth, B.E., Pratt, M., Ekelund, U., Yngve, A., Sallis, J.F., Oja, P., 2003. International physical activity questionnaire: 12-Country reliability and validity. Med. Sci. Sports Exerc. 35, 1381–1395. https://doi.org/10.1249/01.MSS.0000078924.61453.FB.

Davidson, C.I., Phalen, R.F., Solomon, P.A., 2005. Airborne particulate matter and human health: a review. Aerosol Sci. Technol. 39, 737–749. https://doi.org/10.1080/02786820500191348.

de Keijzer, C., Tonne, C., Sabia, S., Basagaña, X., Valentín, A., Singh-Manoux, A., Antó, J.M., Alonso, J., Nieuwenhuijsen, M.J., Sunyer, J., Dadvand, P., 2019. Green and blue spaces and physical functioning in older adults: longitudinal analyses of the Whitehall II study. Environ. Int. 122, 346–356. https://doi.org/10.1016/j.envint.2018.11.046.

Dempsey, S., Devine, M.T., Gillespie, T., Lyons, S., Nolan, A., 2018. Coastal blue space and depression in older adults. Health Place 54, 110–117. https://doi.org/10.1016/j.healthplace.2018.09.002.

Depledge, M.H., White, M.P., Maycock, B., Fleming, L.E., 2019. Time and tide. BMJ 366, l4671. https://doi.org/10.1136/bmj.l4671.

Dormann, C.F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carré, G., Marquéz, J.R.G., Gruber, B., Lafourcade, B., Leitão, P.J., Münkemüller, T., Mcclean, C., Osborne, P.E., Reineking, B., Schröder, B., Skidmore, A.K., Zurell, D., Lautenbach, S., 2013. Collinearity: a review of methods to deal with it and a simulation study evaluating their performance. Ecography 36https://doi.org/10.1111/j.1600-0587.2012.07348.x. 027–046.

Dzhambov, A.M., Markevych, I., Hartig, T., Tilov, B., Arabadzhiev, Z., Stoyanov, D., Gatseva, P., Dimitrova, D.D., 2018. Multiple pathways link urban green- and blue-space to mental health in young adults. Environ. Res. 166, 223–233. https://doi.org/10.1016/j.envres.2018.06.004.

Elliott, L.R., White, M.P., Sarran, C., Grellier, J., Garrett, J.K., Scoccimarro, E., Smalley, A.J., Fleming, L.E., 2019. The effects of meteorological conditions and daylight on nature-based recreational physical activity in England. Urban Forestry & Urban Greening 42, 39–50. https://doi.org/10.1016/j.ufug.2019.05.005.

Elliott, L.R., White, M.P., Taylor, A.H., Herbert, S., 2015. Energy expenditure on recreational visits to different natural environments. Soc. Sci. Med. 139, 53–60. https://doi.org/10.1016/j.socscimed.2015.06.038.

Elliott, L.R., White, M.P., Grellier, J., Rees, S.E., Waters, R.D., Fleming, L.E., 2018. Recreational visits to marine and coastal environments in England: where, what, who, why, and when? Mar. Pol. 97, 305–314. https://doi.org/10.1016/j.marpol.2018.03.013.

European Commission, 2003. Regulation No 1059/2003 of the European Parliament and of the Council of 26 May 2003 on the Establishment of a Common Classification of Territorial Units for Statistics (NUTS).

European Marine Board, 2013. Position Paper 19: Linking Oceans and Human Health: a Strategic Research Priority for Europe. Ostend, Belgium.

Eurostat, 2013. Archive: coastal regions - population statistics: coastal regions: people living along the coastline, integration od NUTS 2010 and latest population grid [WWW Document]. URL. https://ec.europa.eu/eurostat/statistics-explained/index.php/Archive:Coastal_regions_-_population_statistics#Distribution_of_the_population_within_coastal_strips accessed 4.4.19.

Ferrer-i-Carbonell, A., Frijters, P., 2004. How important is methodology for the estimates of the determinants of happiness? Econ. J. 114, 641–659. https://doi.org/10.1111/j.1468-0297.2004.00235.x.

Fleming, L.E., Kirkpatrick, B., Backer, L.C., Walsh, C.J., Nierenberg, K., Clark, J., Reich, A., Hollenbeck, J., Benson, J., Cheng, Y.S., Naar, J., Pierce, R., Bourdelais, A.J., Abraham, W.M., Kirkpatrick, G., Zaias, J., Wanner, A., Mendes, E., Shalat, S., Hoagland, P., Stephan, W., Bean, J., Watkins, S., Clarke, T., Byrne, M., Baden, D.G., 2011. Review of Florida red tide and human health effects. Harmful Algae 10, 224–233. https://doi.org/10.1016/j.hal.2010.08.006.

Fleming, L.E., Maycock, B., White, M.P., Depledge, M.H., 2019. Fostering human health through ocean sustainability in the 21st century. People Nat 1–8. https://doi.org/10.1002/pan3.10038.

Garrett, J.K., Clitherow, T.J., White, M.P., Wheeler, B.W., Fleming, L.E., 2019a. Coastal proximity and mental health among urban adults in England: the moderating effect of household income. Health Place 59, 102200. https://doi.org/10.1016/j.healthplace.2019.102200.

Garrett, J.K., White, M.P., Huang, J., Ng, S., Hui, Z., Leung, C., Tse, L.A., Fung, F., Elliott, L.R., Depledge, M.H., Wong, M.C.S., 2019b. Urban blue space and health and well-being in Hong Kong: results from a survey of older adults. Health Place 55, 100–110. https://doi.org/10.1016/j.healthplace.2018.11.003.

Gascon, M., Mas, M.T., Martínez, D., Dadvand, P., Forns, J., Plasència, A., Nieuwenhuijsen, M.J., 2015. Mental health benefits of long-term exposure to residential green and blue spaces: a systematic review. Int. J. Environ. Res. Publ. Health 12, 4354–4379. https://doi.org/10.3390/ijerph120404354.

Gascon, M., Zijlema, W., Vert, C., White, M.P., Nieuwenhuijsen, M.J., 2017. Outdoor blue spaces, human health and well-being: a systematic review of quantitative studies. Int. J. Hyg Environ. Health 220, 1207–1221. https://doi.org/10.1016/j.ijheh.2017.08.004.

Goldberg, D.P., 1972. The Detection of Psychiatric Illness by Questionnaire. Oxford University Press, London.

Grellier, J., White, M.P., Albin, M., Bell, S., Elliott, L.R., Gascón, M., Gualdi, S., Mancini, L., Nieuwenhuijsen, M.J., Sarigiannis, D.A., Van Den Bosch, M., Wolf, T., Wuijts, S., Fleming, L.E., 2017. BlueHealth: a study programme protocol for mapping and quantifying the potential benefits to public health and well-being from Europe's blue spaces. BMJ Open 7, 1–10. https://doi.org/10.1136/bmjopen-2017-016188.

Hartig, T., Mitchell, R., de Vries, S., Frumkin, H., 2014. Nature and health. Annu. Rev. Publ. Health 35, 207–228. https://doi.org/10.1146/annurev-publhealth-032013-182443.

IRCEL - CELINE, 2019. Open data (Manipulated to complement HIS data. [WWW Document]. URL. http://www.irceline.be/documentation accessed 4.1.19.

Kabisch, N., Qureshi, S., Haase, D., 2015. Human-environment interactions in urban green spaces - a systematic review of contemporary issues and prospects for future research. Environ. Impact Assess. Rev. 50, 25–34. https://doi.org/10.1016/j.eiar.2014.08.007.

Kaplan, R., Kaplan, S., 1989. The Experience of Nature: A Psychological Perspective. Cambridge University Presshttps://doi.org/10.1037/030621.

Kerr, J., Norman, G., Millstein, R., Adams, M.A., Morgan, C., Langer, R.D., Allison, M., 2014. Neighborhood environment and physical activity among older women: findings from the san diego cohort of the women's health initiative. J. Phys. Activ. Health 11, 1070–1077. https://doi.org/10.1123/jpah.2012-0159.

Kim, B.M., Teffera, S., Zeldin, M.D., 2000. Characterization of PM25 and PM10 in the south coast air basin of southern California: Part 1 - spatial variations. J. Air Waste Manag. Assoc. 50https://doi.org/10.1080/10473289.2000.10464242. 2034–2044.

Lahart, I., Darcy, P., Gidlow, C., Calogiuri, G., 2019. The effects of green exercise on physical and mental wellbeing: a systematic review. Int. J. Environ. Res. Publ. Health 16, 1352. https://doi.org/10.3390/ijerph16081352.

Lange, E., Schaeffer, P.V., 2001. A comment on the market value of a room with a view. Landsc. Urban Plann. 55, 113–120. https://doi.org/10.1016/S0169-2046(01)00148-7.

Lu, F., Xu, D., Cheng, Y., Dong, S., Guo, C., Jiang, X., Zheng, X., 2015. Systematic review and meta-analysis of the adverse health effects of ambient PM2.5 and PM10 pollution in the Chinese population. Environ. Res. 136, 196–204. https://doi.org/10.1016/j.envres.2014.06.029.

Lumley, T., 2004. Analysis of complex survey samples. J. Stat. Software 9, 1–19. https://doi.org/10.18637/jss.v009.i08.

Lumley, T., 2017. survey: Analysis of complex survey samples. R Package version 3.32.

Maas, J., Verheij, R.A., Groenewegen, P.P., De Vries, S., Spreeuwenberg, P., 2006. Green space, urbanity, and health: how strong is the relation? J. Epidemiol. Community Health 60, 587–592. https://doi.org/10.1136/jech.2005.043125.

Maas, J., van Dillen, S.M.E., Verheij, R.A., Groenewegen, P.P., 2009. Social contacts as a possible mechanism behind the relation between green space and health. Health Place 15, 586–595. https://doi.org/10.1016/j.healthplace.2008.09.006.

MacKinnon, D.P., Lockwood, C.M., Williams, J., 2004. Confidence limits for the indirect effect: distribution of the product and resampling methods. Multivariate Behav. Res. 39, 99–128. https://doi.org/10.1207/s15327906mbr3901_4.

Markevych, I., Schoierer, J., Hartig, T., Chudnovsky, A., Hystad, P., Dzhambov, A.M., de Vries, S., Triguero-Mas, M., Brauer, M., Nieuwenhuijsen, M.J., Lupp, G., Richardson, E.A., Astell-Burt, T., Dimitrova, D., Feng, X., Sadeh, M., Standl, M., Heinrich, J., Fuertes, E., 2017. Exploring pathways linking greenspace to health: theoretical and methodological guidance. Environ. Res. 158, 301–317. https://doi.org/10.1016/j.envres.2017.06.028.

McManus, A., Fielder, L., Newton, W., White, J., 2011. Health benefits of seafood for men. J. Mens Health 8, 252–257. https://doi.org/10.1016/j.jomh.2011.04.004.

Miller, G., 2014. The Exposome, the Exposome: A Primer. Elsevierhttps://doi.org/10.1016/C2013-0-06870-3.

Nieuwenhuijsen, M.J., Khreis, H., Triguero-Mas, M., Gascon, M., Dadvand, P., 2017. Fifty shades of green. Pathway to healthy urban living. Epidemiology 28, 63–71. https://doi.org/10.1097/EDE.0000000000000549.

Nomenclature of Territorial Units for Statistics (Nuts), 2013. Eurostat coastline data.

Nutsford, D., Pearson, A.L., Kingham, S., Reitsma, F., 2016. Residential exposure to visible blue space (but not green space) associated with lower psychological distress in a capital city. Health Place 39, 70–78. https://doi.org/10.1016/j.healthplace.2016.03.002.

OpenStreetMap contributors, 2018. OpenStreetMap road network [WWW Document]. URL. https://download.geofabrik.de/ accessed 11.13.18.

Papathanasopoulou, E., White, M.P., Hattam, C., Lannin, A., Harvey, A., Spencer, A., 2016. Valuing the health benefits of physical activities in the marine environment and their importance for marine spatial planning. Mar. Pol. 63, 144–152. https://doi.org/10.1016/j.marpol.2015.10.009.

Pasanen, T.P., White, M.P., Wheeler, B.W., Garrett, J.K., Elliott, L.R., 2019. Neighbourhood blue space, health and wellbeing: the mediating role of different types of physical activity. Environ. Int. 131, 105016. https://doi.org/10.1016/j.envint.2019.105016.

Peng, C., Yamashita, K., 2016. Effects of the coastal environment on well-being. J. Coast. Zo. Manag. 19. https://doi.org/10.4172/2473-3350.1000421.

Pirlet, R., 2016. Het Zeegevoel. Zeewater als wondermiddel - louois Verhaeghe en de Thalassotherapie. In: Seys, J., Fockedey, N. (Eds.), De Grote Rede. Jan Mees, VLIZ, Ostend, Belgium, pp. 30.

Pope III, C.A., 2002. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. J. Am. Med. Assoc. 287, 1132. https://doi.org/10.1001/jama.287.9.1132.

Pope, C.A., Dockery, D.W., 2006. Health effects of fine particulate air pollution: lines that connect. J. Air Waste Manag. Assoc. 56, 709–742. https://doi.org/10.1080/

10473289.2006.10464485.

Preacher, K.J., 2015. Advances in mediation analysis: a survey and synthesis of new developments. Annu. Rev. Psychol. 66, 825–852. https://doi.org/10.1146/annurev-psych-010814-015258.

Prüss-Ustün, A., Wolf, J., C Corvalán, R.B., MN, ., 2016. Preventing Disease through Healthy Environments - A Global Assessment of the Burden of Disease from Environmental Risks.

Prüss-Ustün, A., Wolf, J., Corvalán, C., Neville, T., Bos, R., Neira, M., 2017. Diseases due to unhealthy environments: an updated estimate of the global burden of disease attributable to environmental determinants of health. J. Public Health 39, 464–475. https://doi.org/10.1093/pubmed/fdw085.

R Core Team, 2018. R: A Language and Environment for Statistical Computing.

Robine, J., Jagger, C., Mathers, C., Crimmins, E., Suzman, R. (Eds.), 2003. Determining Health Expectancies. Wiley, Chichester, UK.

Statbel, 2019. Bodembezetting volgens de kadastrale oppervlakte: Gemeente. [WWW Document]. URL. https://statbel.fgov.be/ accessed 4.1.19.

Stranger, M., Potgieter-Vermaak, S.S., Van Grieken, R., 2009. Particulate matter and gaseous pollutants in residences in Antwerp, Belgium. Sci. Total Environ. 407, 1182–1192. https://doi.org/10.1016/j.scitotenv.2008.10.019.

UN Secretary General, 2017. Draft resolution submitted by the President of the General Assembly: our ocean, our future: call for action. https://doi.org/10.1016/s1365-182x(17)30723-2.

Van Aart, C.J.C., Michels, N., Sioen, I., De Decker, A., Bijnens, E.M., Janssen, B.G., De Henauw, S., Nawrot, T.S., 2018. Residential landscape as a predictor of psychosocial stress in the life course from childhood to adolescence. Environ. Int. 120, 456–463. https://doi.org/10.1016/j.envint.2018.08.028.

Van Acker, E., De Rijcke, M., Asselman, J., Beck, I.M., Huysman, S., Vanhaecke, L., De Schamphelaere, K.A.C.D., Janssen, C.R., 2020. Aerosolizable marine phycotoxins and human health effects: in vitro support for the biogenics hypothesis. Mar. Drugs 18. https://doi.org/10.3390/md18010046.

Verkest, M., 1898. Een hoekje der Vlaamsche kust: nieuwpoort - veurne - diksmuide. Boekhandel J. Vuylsteke, Gent, Koestraat. 15.

Viana, M., Hammingh, P., Colette, A., Querol, X., Degraeuwe, B., Vlieger, I. de, van Aardenne, J., 2014. Impact of maritime transport emissions on coastal air quality in Europe. Atmos. Environ. 90, 96–105. https://doi.org/10.1016/j.atmosenv.2014.03.046.

Völker, S., Kistemann, T., 2015. Developing the urban blue: comparative health responses to blue and green urban open spaces in Germany. Health Place 35, 196–205. https://doi.org/10.1016/j.healthplace.2014.10.015.

Vrijheid, M., 2014. The exposome: a new paradigm to study the impact of environment on health. Thorax 69, 876–878. https://doi.org/10.1136/thoraxjnl-2013-204949.

Wheeler, B.W., White, M., Stahl-Timmins, W., Depledge, M.H., 2012. Does living by the coast improve health and wellbeing. Health Place 18, 1198–1201. https://doi.org/10.1016/j.healthplace.2012.06.015.

White, M., Smith, A., Humphryes, K., Pahl, S., Snelling, D., Depledge, M., 2010. Blue space: the importance of water for preference, affect, and restorativeness ratings of natural and built scenes. J. Environ. Psychol. 30, 482–493. https://doi.org/10.1016/j.jenvp.2010.04.004.

White, M.P., Alcock, I., Wheeler, B.W., Depledge, M.H., 2013a. Coastal proximity, health and well-being: results from a longitudinal panel survey. Health Place 23, 97–103. https://doi.org/10.1016/j.healthplace.2013.05.006.

White, M.P., Pahl, S., Ashbullby, K., Herbert, S., Depledge, M.H., 2013b. Feelings of restoration from recent nature visits. J. Environ. Psychol. 35, 40–51. https://doi.org/10.1016/j.jenvp.2013.04.002.

White, M.P., Wheeler, B.W., Herbert, S., Alcock, I., Depledge, M.H., 2014. Coastal proximity and physical activity: is the coast an under-appreciated public health resource? Prev. Med. 69, 135–140. https://doi.org/10.1016/j.ypmed.2014.09.016.

White, M.P., Elliott, L.R., Taylor, T., Wheeler, B.W., Spencer, A., Bone, A., Depledge, M.H., Fleming, L.E., 2016a. Recreational physical activity in natural environments and implications for health: a population based cross-sectional study in England. Prev. Med. 91, 383–388. https://doi.org/10.1016/j.ypmed.2016.08.023.

White, M.P., Pahl, S., Wheeler, B.W., Fleming, L.E.F., Depledge, M.H., 2016b. The "Blue Gym": what can blue space do for you and what can you do for blue space? J. Mar. Biol. Assoc. U. K. 96, 5–12. https://doi.org/10.1017/S0025315415002209.

White, M.P., Weeks, A., Hooper, T., Bleakley, L., Cracknell, D., Lovell, R., Jefferson, R.L., 2017. Marine wildlife as an important component of coastal visits: the role of perceived biodiversity and species behaviour. Mar. Pol. 78, 80–89. https://doi.org/10.1016/j.marpol.2017.01.005.

Wild, C.P., 2012. The exposome: from concept to utility. Int. J. Epidemiol. 41, 24–32. https://doi.org/10.1093/ije/dyr236.

Wood, S.L., Demougin, P.R., Higgins, S., Husk, K., Wheeler, B.W., White, M., 2016. Exploring the relationship between childhood obesity and proximity to the coast: a rural/urban perspective. Health Place 40, 129–136. https://doi.org/10.1016/j.healthplace.2016.05.010.

Zuur, A.F., Ieno, E.N., Walker, N.J., Saveliev, A.A., Smith, G.M., 2009. Mixed Effects Models and Extensions in Ecology with R. Springer.