D2.4

Valuation of ES demand

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Acronyms

BCS	Belgian Continental Shelf
CPI	Consumer Price Index
DVA	Direct value-added
ES	Ecosystem Services
ETS	Emissions Trading System
EUMOFA	European Market Observatory for Fisheries and Aquaculture
MORA	Mobility Council of Flanders
NBB	National Bank of Belgium
OVAM	Flemish Waste Agency
PPP	Purchasing Power Parity
PUD	Photo-user-days
TS	Time-series
VLAM	Flemish Centre for Agri- and Fishery Marketing
VMM	Flemish Environment Agency
WTP	Willingness to Pay

1. Executive summary

The SUMES project aims to develop a decision-support tool that can inform marine stakeholders and decision-makers about the environmental sustainability of human activities in the Belgian Continental Shelf (BCS). One of its focuses is on the generation of marine ecosystem services (ES) supply estimates based on ecosystem functioning and the impact of marine activities. However, the estimation of the demand for those ES from society is a key element of the ES equation which helps put into perspective the ES supply by discerning how much of the (potential) supply is actually required. This report, therefore, focuses on the quantification of ES demand by the Belgian society, complementing the work being done by the other work packages of the SUMES project. Until now, no specific project or study looked specifically into the demand for ES at the national level, such as the need for carbon regulation, nutrient waste remediation, seafood consumption and preferences for recreational activities. This work is a first step at filling this research gap and is aimed particularly at developing ES demand indicators and selecting appropriate monetary valuation methods, estimating the quantities and values of that demand today, and forecasting the demand for the next decade. This work shows the significant demand for provisioning, regulation and maintenance, and cultural ES that the BCS is capable of delivering. On an annual basis, the national apparent consumption of wild aquatic animals (i.e. top landed fish species) is currently valued between 127 and 484 million €, based on port first sales and home consumption prices respectively. Imports of sand are valued at an average of 84 million €, shipping direct-value-added at 1.4 billion €, and electricity consumption at an average of 4.3 billion €. The load of nitrogen and phosphorous that enter the North Sea annualy are valued at an average of 3.5 billion € and 250 million € respectively, the annual carbon dioxide emitted in Belgium is valued 2 million €. In terms of habitat maintenance, estimates of people's willingness to pay indicate a value of 552 million € by the whole Belgian population. Recreational fishing activities are valued at 7.5 million € annually based on recreationists' expenditure, and coastal day-tourists are worth a total of 823 million € every year on average. The aesthetic value of the seascape is valued in terms of the coastal population's willingness to pay to keep it less impacted by offshore structures, which equates to 0.2 million € per year. The actual biophysical quantities from which these values were estimated are shown in detail throughout the document, Overall, this work successfully developed ES demand indicators and compiled different monetary valuation methods from the literature suitable for the monetization of ES. With that, the biophysical quantification and monetary valuation of ES demand were performed, providing the first-ever assessment of ES demand in Belgium.

2. Goal and scope of the deliverable

This deliverable presents the work developed in the context of Task 2.3 - *(Semi-)quantification of BCS ES demand in Flanders* – whose main objective is, as the title suggests, to quantify ES demand at the Belgian Continental Shelf (BCS) by using state-of-the-art indicators and valuation methods. In conjugation with the quantification of ES supply (WP3), these results can provide evidence of the potential unbalance between marine ES supply from the BCS and demand in Belgium. Overall, this document i) introduces a definition for ES demand, ii) describes the general approach to quantification and valuation of the demand, iii) presents in detail the results for each of the relevant ES, and iv) provides an outlook on the future demand for those ES. The data collection and results of this task will be integrated into the SUMES decision-support framework to provide quantitative information about ES demand.

3. Introduction

One of the main objectives of the SUMES project is to quantify both the *supply* of and the *demand* for marine ecosystem services (ES) from the Belgian Continental Shelf (BCS). The supply side of the ES cascade (Figure 1) can be defined as the quantity of ES delivered by the ecosystem components (e.g. habitats, species) and their functions, and the demand side refers to the socioeconomic components (e.g. people, human activities) that benefit from those ES (Potschin & Haines-Young, 2011).

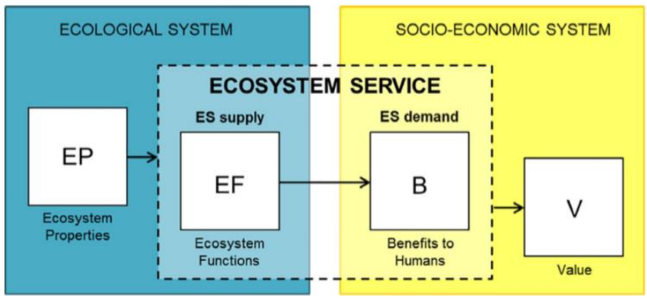

Figure 1: The ecosystem services cascade (Boerema et al., 2017)

ES supply and demand are rarely realized at the same location (Syrbe & Grunewald, 2017) and this is particularly evident in marine social-ecological[1] systems for obvious reasons. It was, therefore, important to clearly define the boundaries of the ecological and socioeconomic systems. In SUMES, the ecological system (supply-side) was spatially defined as the area within the boundaries of the BCS. However, the spatial boundaries of the socioeconomic system were less specifically defined ("*WP2 focuses on the demand for ES in Flanders and beyond*"). Moreover, the definition of the concept of ES demand itself ought to be clarified to avoid any misinterpretations moving forward. Therefore, this introductory chapter provides a definition and establishes the boundaries of the demand side.

According to the ES literature, ES demand can either be framed as *consumption* or *desire* (Villamagna et al., 2013; Wei et al., 2017; Wolff et al., 2015). Demand for commodity services (i.e. provisioning ES and some cultural ES) can be captured by the amount of *consumption*, while demand for non-commodity services (i.e. regulating ES and most cultural ES) can be captured by *desires*. Wolff et al. (2015) proposed a categorization of demand into four different types, based on the aforementioned categories of consumption and desire (Table 1). The *consumption* category can be sub-divided into two types*:* *consumption* and *direct-use* type. The *desire* category can be sub-divided into two types as well: *risk reduction* and *preferences*.

Table 1: Classification of demand types (Wolff et al., 2015).

Category	Type	Definition
Consumption	Consumption	A consumption perspective is typically applied to quantify demands for provisioning ES. It is associated with the actual consumption of goods (e.g. biomass) provided by the ecosystem.
	Direct-use	A direct-use perspective is typically applied to quantify demands for tangible cultural ES. It is associated mainly with the use of the ecosystem for recreational activities.

[1] A social-ecological system is "a linked system of people and nature" (Berkes & Folke, 1998; Colding & Barthel, 2019), emphasizing that humans must be seen as a part of, not apart from, nature. The ES concept therefore only makes sense in the context of social-ecological systems (as it refers to the benefits people obtain from nature). This conceptualization is highlighted by the ES cascade.

Desire	Risk reduction	A risk perspective is applied to quantify demands for regulating ES. It is associated with the need for protection, risk mitigation, or achievement of predetermined conditions in the system.
	Preferences	A preference perspective (individual or collective) is normally applied to quantify the demand for non-tangible cultural ES. It is associated with people's perceptions of value. This type may also be applied to other ES, namely those that can be linked to policy targets (e.g. climate regulation).

Some previous land-based studies have quantified the demand for ES, demonstrating the use of those demand types. For instance, González-García et al. (2020) assessed supply-demand mismatches for three ES within Madrid's administrative area. The demand for 'water provision' was based on water consumption (by the population and agriculture sector) (*consumption type*), the demand for 'climate regulation' was based on carbon emissions (*risk reduction type*), and the demand for 'recreation' was based on the basic human right to be in contact with nature (as defined by the World Health Organization) (*preferences type*).

Another example is the study of Schirpke et al. (2019), who have quantified the demand for ES in the Alpine region. They defined the demand for both 'water provision' and 'fuelwood provision' as consumption (*consumption*), the demand for 'carbon sequestration' as carbon emissions (*risk reduction*), the demand for 'water filtration' as nitrogen loads (*risk reduction*), the demand for 'protections against mass movements' as the area of human infrastructure in hazard zones (*risk reduction*) and the demand for 'recreation' as visitation rates based on georeferenced photos on image-sharing platforms (*direct use*).

A demand analysis has rarely been performed in marine social-ecological systems though. To date, one of the very few studies available in the scientific literature that explicitly quantified the demand is that of Inácio et al. (2020) who mainly looked at 'wild seafood provision' in the Lithuanian exclusive economic zone. They defined demand as the quantity of seafood consumed within Lithuania (*consumption*). By setting the spatial boundaries of the demand as the country's territory they were able to determine the degree of self-sufficiency or dependency on external sources for wild seafood (i.e. establish domestic supply-demand mismatches).

In SUMES, and according to the previous introduction. ES demand is understood as the amount of ES consumed or desired by society, at a defined spatial scale. The type of demand for each ES follows the classification by Wolff et al. (2015) which helped us to frame the selection of demand indicators.

4. Method

4.1. Indicators selection

A selection of appropriate indicators was necessary in order to quantify the demand for each ES. Moreover, the previous tasks have identified the relevant ES for the BCS and, more specifically, for the case-study (see also SUMES Deliverables 2.2, 1.1, 4.1). Therefore, only those ES were considered. For each of these ES (Table 2), appropriate *Class-types* are given to define precisely *what* is being measured as the ES (in the hierarchical structure of the CICES classification, *Class-type* is the lowest level of disaggregation of an ES) (Haines-Young & Potschin, 2018). At least one demand indicator was selected for each ES to define exactly *how* to measure them. This selection was based on a literature search and subsequent inputs from stakeholders, scientific experts, and internal bilateral meetings. For each indicator, appropriate units were selected to account for the ES flow (i.e. quantity per year) and to be able to match with supply indicators.

Table 2: Nine relevant ES from the BCS as considered for the SUMES case-study on offshore wind energy

Category	Terminology	Class-type
Provisioning ES	Wild aquatic animals	Cod; plaice; common sole; ray; squid; shrimp; gurnard; lemon sole (top landed species)
	Surface for navigation	Ships; cargo
	Sand and other minerals	Sand
	Renewable offshore energy	Electricity
Regulating & maintenance ES	Mediation of wastes	Nitrogen; phosphorous
	Nursery and habitat maintenance	Habitat
	Climate regulation	Carbon dioxide
Cultural ES	Recreation	Coastal tourism; recreational fisheries birdwatching
	Aesthetic value	Seascape

4.2. Monetary valuation techniques

A literature review was carried-out to get an overview of which monetary valuation methods are commonly used to monetize marine ES. This information was used to guide the selection of appropriate techniques for each ES. The literature was retrieved from the Scopus database using the search query: *("monetary valu*" OR "economic valu*") AND "ecosystem services" AND (coast* OR marine OR offshore OR aquatic OR sea OR ocean OR maritime).*

4.3. Quantification approach

The geographical boundary of demand (the spatial scale) was defined as the Belgian territory (country-level) for the generality of the ES to allow for the assessment of the degree of self-sufficiency in terms of marine ES when analyzing the supply-demand mismatch. Yet, for some ES, demand always occurs at the local-level (e.g. recreation, aesthetic value) and data availability may also put limitations on the spatial scale (e.g. data available only at the regional level of Flanders). Therefore, the boundaries of demand have been defined for each individual ES. A temporal scale was also defined, according to the objectives of the project which aims at quantifying current demand but also estimating future demand. Therefore, the reference year for quantifying current demand was set as 2019 or 2020 (depending on data availability) and the reference year for future demand was set as 2030 for all ES. The general approach to the quantification and valuation of the demand for each ES was as follows:

I. **Data collection –** based on the indicator(s) selected for each particular ES (see SUMES Milestone 2.2), a data search was carried out by searching the internet and contacting key data providers to obtain secondary data (mainly time-series datasets and statistical reports).
II. **Calculation of present demand –** for each indicator, we selected a reference year that represents the present moment and it is based on the latest available datapoint of the time-series (often 2019 or 2020). Then, we report *present demand* in two different ways. As the i) the datapoint reported for the reference year (*e.g.* 2019); and as the ii) mean value of the past five data points, counting from the reference year (e.g. 2015 – 2019).
III. **Calculation of future demand –** for all the indicators, we selected the future reference year to be 2030 (this year is also associated with many of the environmental policy targets at the EU level). To estimate the value of each indicator at t=2030 we employed a statistical forecasting method for the time-series data (see paragraph 4.4). Then, we report *future demand* in two different ways. As the i) mean value estimated by the forecasting model, and as the ii) 95 % confidence interval estimated by the same model. For a couple of indicators without time-series data available or associated, other estimates are reported based on literature reports and policy targets.
IV. **Calculation of monetary value –** for each ES/indicator, we selected an appropriate monetary valuation method (see paragraph 5.2). Through the selected method, a monetary value unit (e.g. €/ton) was

estimated and multiplied by the annual estimates of present/future demand to obtain an annual monetary value (e.g. €/year).

The quantification results are presented in Chapter 5.3.

4.4. Time-series forecasting analysis

To make quantitative forecasts of future demand, numerical information about the past is necessary (for which time-series data is essential) and the assumption that some aspects of past patterns will continue into the future must be acknowledged. Given that future events are always unknown (and arguably unknowable) until they happen, the main goal for attempting to forecast demand in 2030 is to provide a best-informed and educated guess of whether demand is more likely to increase or decrease by analyzing time-series (TS) data. In some cases, forecasts will be made qualitatively due to lack of a time series or due the nature of the indicator (e.g. policy-targets) based on predictions in literature.

A forecast is normally presented as the mean value of the forecast distribution, but it can also be reported as a prediction interval which gives us an idea of the degree of uncertainty of the estimate. That is why we report both the mean forecast and a confidence interval for each TS analyzed. *Exponential smoothing* was the forecasting method selected for this work. This methodology uses only information on the variable to be forecasted, and makes no attempt to discover the factors that affect its behavior. Therefore, this method extrapolates trends and seasonal patterns of the TS but ignores other potentially influencing factors that may alter the TS such as for example extreme weather events, political incentives, and/or changes in economic conditions. This can be seen as a limitation of the method but is also one of its main strengths, as it allows for the computation of forecasts estimates for a wide range of TS (Hyndman & Athanasopoulos, 2021). The forecasts based on *exponential smoothing* are weighted averages of past observations, with the weights decaying exponentially as the observations get older.

The TS datasets analyzed in the present study are annual observations where seasonality patterns are normally absent and, therefore, we only analyze trend patterns. For each indicator, we tested three exponential smoothing models with and without trend component, namely the i) simple exponential smoothing, ii) Holt's linear method and iii) damped trend method, following Hyndman & Athanasopoulos (2021). Each model was tested with and without a log-transformation applied to the data. The *simple exponential smoothing* is suitable for forecasting TS with no clear trend (nor seasonal pattern). *Holt's linear trend* extends the simple exponential smoothing to allow the forecasting of TS with a trend. The *damped trend* introduces a parameter to Holt's linear method that dampens the trend to a flat line somewhere in the future.

A cross-validation procedure was used to select the best exponential smoothing model for each TS. The procedure uses a series of *test sets*, each consisting of a single observation, and their corresponding *training sets* which consist of observations that occurred before the *test set* observation (i.e. the *training set* is used to train models that will predict the *test set*). For illustration, each line of Figure 2 corresponds to one iteration of the cross-validation procedure (*training set* observations in blue and *test set* 1-step ahead observation in orange), with the training and test tests observations rolling forward in time at each iteration. The forecast accuracy is computed by averaging over the test sets.

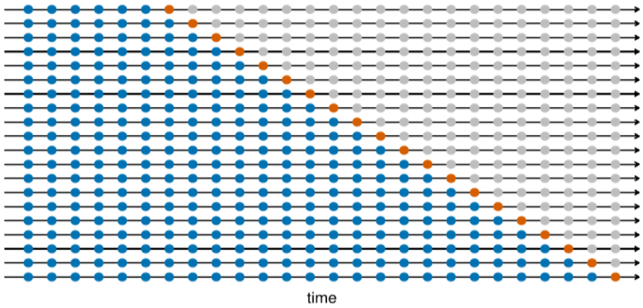

Figure 2: Series of training and test sets. Blue observations - training sets; orange observations - test sets (from Hyndman & Athanasopoulos, 2021)

5. Results

5.1. Selection of demand indicators

A pre-selection of demand indicators was done through scientific literature searches. The main literature sources of demand indicators were the works of (Burkhard et al., 2014; Dvarskas et al., 2020; Lillebø et al., 2017; Pouso et al., 2020; Schirpke et al., 2019; Villamagna et al., 2014; von Thenen et al., 2020). The pre-selection was presented to a group of stakeholders during a stakeholder workshop in April 2021 and also to the SUMES Scientific Advisory Board (ScAB) in May 2021. Their input provided strategic guidance in the selection of the final indicators (

Table 3). Note that for some ES (e.g. surface for navigation) there were no indicators available for the workshop and the stakeholders were also asked for suggestions. All indicators were presented to the ScAB for feedback. In June and November 2021, two bilateral meetings with the partners from the University of Antwerp were organized to analyze those inputs and create a final list of demand indicators that were also matched (as much as possible) with the supply indicators. These results are available as SUMES Milestone 2.2 and have been delivered in November 2021.

Table 3: Indicators preference by stakeholders (n= 18) and scientific experts (n= 5).

ES	Indicators	Stakeholder workshop	Scientific advisory board
Wild aquatic animals	Seafood consumption	64%	66%
	Seafood port landings	29%	17%
	None/other	7%	17%
Surface for navigation*	Ships circulating in the BCS	*Suggestions:* Amount of ships circulating, port activity, marine traffic, passages through ports, quantity of cargo shipped	67%
	Ships passages through ports		33%
	Cargo traffic in ports		0%
	None/other		0%
Sand and other minerals*	Sand consumption	*Suggestions:* Sand used by human activities, beach nourishment, sand extracted from the BCS	83%
	Sand extraction		17%
	None/other		0%
Renewable offshore energy	Renewable energy targets	34%	67%
	Energy consumption	52%	33%
	Other	14%	0%

Climate regulation	Carbon emissions	60%	33%
	Carbon reduction targets	40%	67%
	None/other	0%	0%
Mediation of wastes**	Nutrient loadings from land	(Missing input due to time limitations)	50%
	Dissolved nutrients in the sea		50%
	None/other		0%
Nursery and habitat maintenance	Willingness-to-pay for habitat protection	*Suggestions*: Willingness-to-pay, intrinsic value, contribution to biomass, fisheries dependence on habitat	0%
	Fisheries species dependence on habitat		50%
	None/other		50%
Recreation**	Number of users/trips to recreation site	(Missing input due to time limitations)	100%
	Number of licenses/permits for recreation		0%
	None/other		0%
Aesthetic value**	Pictures shared in social media	(Missing input due to time limitations)	60%
	Willingness-to-pay for seascape conservation		40%
	None/other		0%

*Indicators proposed based on stakeholder workshop suggestions (only voted by the ScAB)
**Indicators proposed based on a post-workshop selection (only voted by the ScAB)

Below, Table 4 summarizes the final selection of demand indicators. It is worth noting that, during the selection process, some ES ended up with more than one suitable indicator. Given that for the same ES/class-type, two different indicators will always provide two different values, we understood that, where data was available to quantify more than one indicator, it is a decision of the end-user to quantify and interpret one or two indicators.

Table 4: SUMES Ecosystem Services demand indicators.

ES	Class-type	Indicator	Unit	Type	Spatial boundary	Data provider/source
Wild aquatic animals*	Cod, plaice, common sole, ray, squid, shrimp, gurnard, lemon sole	a) Apparent consumption b) Household consumption	tons/year tons/year	Consumption	Belgium (country-level)	EUMOFA; Eurostat; Flemish Centre for Agri- and Fishery Marketing (VLAM)
Surface for navigation	Ships, cargo	a) Seagoing ship arrivals b) Cargo traffic	tons/year tons/year	Direct use	Flanders † (regional-level)	Mobility Council of Flanders (MORA); National Bank of Belgium (NBB)
Sand and other minerals	Sand	a) Sand consumption (imports)	tons/year	Consumption	Flanders ε (regional-level)	Flanders Environment Department; Flemish Waste Agency (OVAM);
Renewable offshore energy	Electricity	a) Electricity consumption b) Offshore renewables target	TWh/year TWh/year	Consumption; Preference	Belgium (country-level)	Our World in Data; International Energy Association (IEA)
Climate regulation	Carbon dioxide	a) Production-based emissions b) Carbon reduction target	tons/year tons/year	Risk reduction; Preference	Belgium (country-level)	Federal Public Service of Health, Food Chain, Safety and Environment
Mediation of wastes	Nitrogen, phosphorous	a) Nutrient loads to the sea	tons/year	Risk reduction	Belgium (country-level)	Flemish Environment Agency (VMM)

Nursery and habitat maintenance	Habitat protection	a) WTP for habitat protection	€/year	Risk reduction	Belgium (country-level)	Brouwer et al. (2016); Velasco et al. (2018); Ferreira et al. (2017)
Recreation	Recreational fishing, birdwatching, coastal tourism	a) Number of visitors/users/trips	#/year	Direct use	BCS/coast † (local-level)	Westtoer; VLIZ/ILVO; eBird
Aesthetic value	Seascape	a) Photos shared on social media b) WTP for seascape conservation	#/year €/year	Preference	Coast † (local-level)	Flickr; Wen et al. (2018)

* Class-types correspond to the eight top landed species in Belgian ports
† Spatial scale reduced due to intrinsic nature of the ES (i.e. ES demand is local/regional)
£ Spatial scale reduced due to data limitation

5.2. Selection of monetary valuation methods

The literature search resulted in a total of 445 papers published between 1998 to 2021 and a database listing the results of this review is available on SUMES SharePoint[2]. The abstracts of this selection were read to integrate only those scientific publication that were in the scope of the objective of quantifying the demand side of ES. More specifically, to be considered relevant, abstracts must have reported at least one monetary valuation method and the monetary value for at least one ES. This step resulted in a total of 154 papers. Grey literature (e.g. conference proceedings) and non-English papers were not considered. The retained papers were fully read and only those publications addressing quantification and monetary valuation of marine ES, in particular, were selected to be part of the final reference list (e.g. coastal wetlands and mangrove studies were excluded). Valuation studies using the emergy evaluation methodology were also excluded. The final number of marine ES valuation studies was 66. Figure 3 provides an overview of the monetary valuation methods used in these studies, summarized per category of ES using a relative percentage (e.g. sum of Provisioning ES methods is equal to 100%).

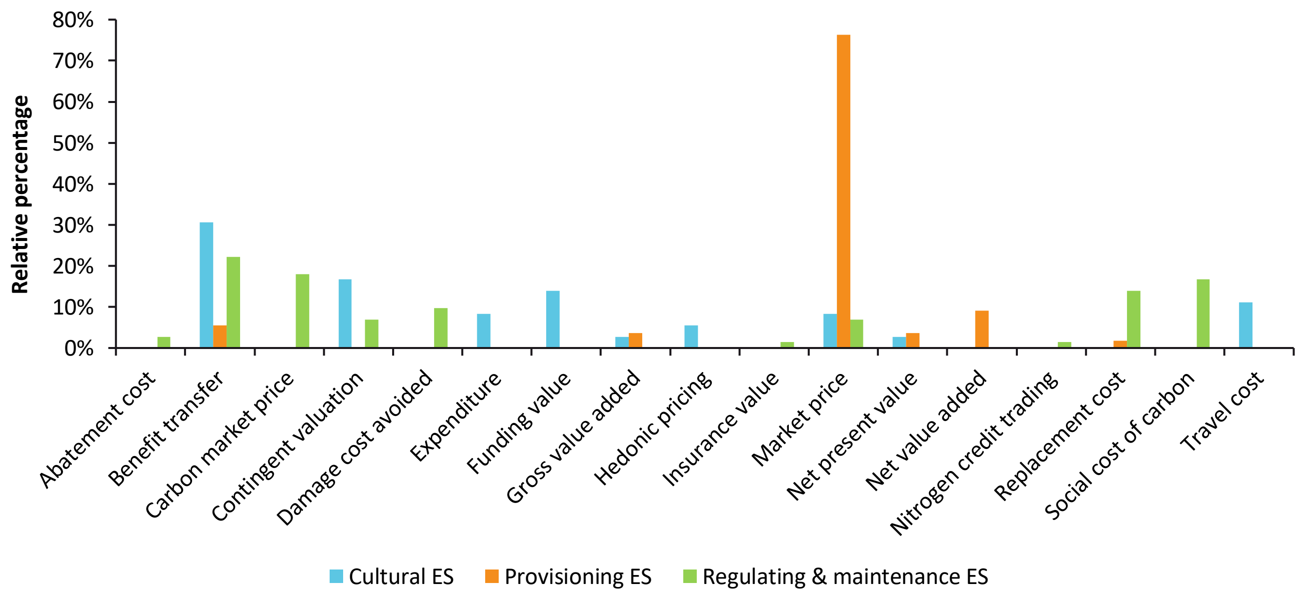

Figure 3: Overview of monetary valuation methods and their usage rate (per ES category) in marine ES studies.

[2] https://sharepoint.ugent.be/projects/202006323/Documents/Work%20packages/WP%202/Monetary%20valuation%20methods_14062021.xlsx?Web=1

For provisioning ES, the market price method was used 76 % of the time, followed by the net value-added method which was used 9 % of the time. For regulating ES, some form of carbon pricing (market price and social cost) was used in 35 % of the valuations. However, this method is exclusively used in the context of the ES Climate regulation. In the same ES category, the benefit-transfer method was used about 20 % of the time and the replacement cost was used in 14 % of the valuations and is mainly associated with the ES Remediation of waste. Lastly, for the cultural ES, the most used valuation method was the benefit-transfer method as well, in 30 % of the studies, followed by the contingent valuation method used 17 % of the time. This summary provided us with an overall understanding of the different methods available per ES category and validated from the published marine ES literature.

The market price and the benefit-transfer are two of the most used methods and are also some of the most practical and flexible methods in generating monetary estimates from ES indicators in a timely fashion (despite some potential costs in terms of decreased accuracy and increased uncertainty, particularly in the case of benefit-transfer). The market price method can be used to value ES that are traded in markets, such as most of those in the provisioning ES category (e.g. seafood, sand, energy) and also a few in the regulating ES category (i.e. carbon and nitrogen). The per-unit market values can then be multiplied by existing levels of ES supply or demand.

The benefit-transfer method can be seen as a short-cut method for generating valuation estimates based on the use of estimates from other contexts. As such, this method needs to be used with caution and be limited to circumstances in which value estimates are being transferred from sites with similar biophysical and socioeconomic characteristics. To ensure some level of adjustment to the novel context, a transferring technique called *adjusted unit value transfer* is used, which uses simple adjustments based on purchasing power (country-transfer) and inflation rates (time-transfer). When available, a *meta-analytic function transfer* can also be used with relative ease, as its value function is generated from a meta-analysis of different valuation study sites.

5.3.Quantification and valuation of ES demand

Next, the results of the quantification of demand for each ES will be presented. Links will be provided at the beginning of each sub-chapter to access the relevant datasets (and sources therein) that were used to quantify demand. Therefore, for each ES there we provide the links to spreadsheets available in the SUMES Marine Data Archive folder[3], namely the i) indicator quantification spreadsheet, ii) forecasting spreadsheet, and iii) monetary valuation method spreadsheet. Within each of these spreadsheets there are references to the original online sources, datasets and documents from which the data were retrieved. Alternatively, a folder with supporting files (named 'Support files') is included inside each ES's folder where those data can be found. A summary spreadsheet that includes the indicators quantification, forecasts and monetization results is also provided and is available at: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_6245741bcb8a0340434236 (a copy is also available on SUMES SharePoint).

5.3.1. Wild aquatic animals

- Indicator quantification: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_623de8f5c1585101695758
- Forecast estimates: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_623de8f5c170d686738597
- Monetization method: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_623de8f5c1874781511756

The demand for *Wild aquatic animals* is defined by 8 different class-types which correspond to the top landed species in Belgian ports, according to the latest data reported by the Departement Landbouw en Visserij

[3]To access the SUMES MDA folder, please contact Carolien Knockaert (carolien.knockaert@vliz.be) or Gert Everaert (gert.everaert@vliz.be) at VLIZ.

(2020b). The top species are the European plaice (*Pleuronectes platessa*), Common sole (*Solea solea*), ray (*Raja* spp.), squid (*Loligo* spp.), shrimp (*Crangon* spp), Atlantic cod (*Gadus morhua*), gurnard (*Eutrigla gurnardus + Chelidonichthys cuculus + Chelidonichthys lucerna*), and lemon sole (*Microstomus kitt*). Additionally, despite not belonging to the list of top landed species, mussels (*Mytilus* spp.) and oysters (*Ostrea* spp. + *Crassostrea* spp.) are also included in the analysis given their potential for shellfish aquaculture in the BCS which will be useful for the complex SUMES case-study (integration of OWF and aquaculture) which will likely include the ES *Farmed aquatic animals*.

Two demand indicators were selected (Table 4): *apparent consumption* and *household consumption*. *Apparent consumption* represents the quantity of seafood products consumed within a given geographic area (typically a country). This indicator was developed by the European Market Observatory for Fisheries and Aquaculture (EUMOFA) and is commonly used in its market reports (EUMOFA, 2021). The formula is:

Apparent consumption = (catches + aquaculture production + imports) – exports

where *catches* is the quantity of species fished by the Belgian fleet in total (i.e. any fishing area independently from of landing place); *aquaculture production* is the quantity of species produced in Belgium; *imports/exports* are the quantity of species imported/exported by Belgium (non-food uses are not included, e.g. fishmeal). The main data sources for this indicator were EUMOFA and Eurostat databases.

Household consumption represents the purchases of fish, molluscs and crustaceans in Belgium for home consumption. A time-series with more than 30 categories of seafood was obtained from the Flemish Centre for Agri- and Fishery Marketing (Vlaams Centrum voor Agro- en Visserijmarketing, VLAM), with the total volume purchased, total value spent, and price per unit. Both indicators were calculated for each of the aforementioned species. However, due to the lack of import/export data for gurnards and lemon sole, their *apparent consumption* was not calculated (only *household consumption* data is available). The quantification results are presented in

Table 5 and the graphic charts of the time-series and forecast projections are available in the Annex section (Chapter 8).

The monetary valuation method used was the Market Price. Given that different prices are available along the value-chain of seafood products, we decided to use a lower-end price given by first sales at Belgian ports (Departement Landbouw en Visserij, 2020a) and an upper-end price given by sales for home consumption (*household consumption* dataset from VLAM) (

Table 5). The formula used to calculate the monetary value is: $V_p = Q_p \times P_p$; where V_p: value of species (€/year); Q_p: amount of species consumed (tons/year); P_p: market price of species (€/ton).

From the results, it follows that the species with the highest *apparent consumption* in recent years are, by far, Atlantic cod (25188 tons/year) and mussels (23575 tons/year). All other species display an *apparent consumption* below 3000 tons/year. According to the generated forecast estimates, *apparent consumption* is likely to follow a decreasing trend in the next decade for European plaice, oysters, and mussels and an increasing trend for shrimp. A sideways trend (i.e. horizontal mean forecast) is apparent for squid, Atlantic cod, common sole and ray, with forecast intervals suggesting that demand can either increase or decrease from current values (Table 5). In terms of *household consumption*, the species with the highest demand in recent years is the mussel (17285 tons/year), followed by Atlantic cod (6444 tons/year) and shrimp (3601 tons/year). All other species display a *household consumption* below 1500 tons/year. According to the forecast estimates we generated, *household consumption* is likely to follow a decreasing trend for mussels, Atlantic cod and lemon sole and an increasing trend for squid. Oyster, European plaice, gurnard, ray, shrimp and common sole seem to follow a sideways trend and demand could either increase or decrease in the future (Table 5).

Looking at the results of the monetization of *apparent consumption*, currently, the most valuable species are Atlantic cod (74 - 360 million €/year), followed by mussel (80 million €/year; only home sales price available) common sole (32 - 50 million €/year) and shrimp (15 – 50 million €/year). To calculate future monetary values, we assumed a 3% inflation rate on current prices given the impossibility of predicting the true future prices. Given demand estimates, even though the same species will remain the most valuable, shrimp will likely surpass mussels in terms of monetary value. Presently, the aggregated monetary value of demand for the top-8 landed species is 127 - 484 million €/year and the aggregated monetary value of shellfish aquaculture species (mussel and oyster; home consumption prices only) is 102 million €/year.

Table 5: Demand for Wild aquatic animals.

Class-type	Indicator	Unit	Monetary method	PRESENT Ref. year	PRESENT Actual value	PRESENT 5-Y mean	FORECAST Ref. year	FORECAST Mean value	FORECAST 95 % C. I.	MONETARY VALUE € value-unit (€/unit)	MONETARY VALUE Present € (€/y)	MONETARY VALUE 2030 € (€/y)
Cod	Apparent consumption	tons (live weight eq.)	Market price - Port first sale	2019	20683	25188	2030	21390	[12389 - 34530]	2952	74354777	84611995
Cod	Apparent consumption	tons (live weight eq.)	Market price - home consumption	2019	20683	25188	2030	21390	[12389 - 34530]	14417	363138488	413233329
Cod	Household consumption	tons (net weight)	Market price - Port first sale	2019	5780	6444	2030	5346	[2411 - 8282]	2952	19023736	21147065
Cod	Household consumption	tons (net weight)	Market price - home consumption	2019	5780	6444	2030	5346	[2411 - 8282]	14417	92909305	103279354
European plaice	Apparent consumption	tons (live weight eq.)	Market price - Port first sale	2019	-146	-223	2030	-3171	[-6834 - 492]	1978	-440796	-8404799
European plaice	Apparent consumption	tons (live weight eq.)	Market price - home consumption	2019	-146	-223	2030	-3171	[-6834 - 492]	13420	-2990697	-57024563
European plaice	Household consumption	tons (net weight)	Market price - Port first sale	2019	492	764	2030	492	[-708 - 1692]	1978	1511866	1304056
European plaice	Household consumption	tons (net weight)	Market price - home consumption	2019	492	764	2030	492	[-708 - 1692]	13420	10257649	8847709
Common sole	Apparent consumption	tons (live weight eq.)	Market price - Port first sale	2019	2665	2750	2030	2665	[1462 - 3869]	11602	31903256	41431902
Common sole	Apparent consumption	tons (live weight eq.)	Market price - home consumption	2019	2665	2750	2030	2665	[1462 - 3869]	18674	51349116	66685718
Common sole	Household consumption	tons (net weight)	Market price - Port first sale	2019	709	703	2030	709	[-304 - 1722]	11602	8151240	11022596
Common sole	Household consumption	tons (net weight)	Market price - home consumption	2019	709	703	2030	709	[-304 - 1722]	18674	13119632	17741153
Lemon sole	Apparent consumption	tons (live weight eq.)	Market price - Port first sale	2019	-	-	2030	-	-	4974	-	-
Lemon sole	Apparent consumption	tons (live weight eq.)	Market price - home consumption	2019	-	-	2030	-	-	17690	-	-
Lemon sole	Household consumption	tons (net weight)	Market price - Port first sale	2019	73	96	2030	105	[-122, 331]	4974	475226	699842
Lemon sole	Household consumption	tons (net weight)	Market price - home consumption	2019	73	96	2030	105	[-122, 331]	17690	1690102	2488930

Gurnard	Apparent consumption	tons (live weight eq.)	Market price - Port first sale	2019	-	-	2030	-	-	742	-	-
Gurnard	Apparent consumption	tons (live weight eq.)	Market price - home consumption	2019	-	-	2030	-	-	14148	-	-
Gurnard	Household consumption	tons (net weight)	Market price - Port first sale	2019	105	102	2030	30	[-39, 99]	742	75315	29828
Gurnard	Household consumption	tons (net weight)	Market price - home consumption	2019	105	102	2030	30	[-39, 99]	14148	1436064	568753
Rays	Apparent consumption	tons (live weight eq.)	Market price - Port first sale	2019	1241	1176	2030	1202	[633 - 1772]	1383	1626544	2228107
Ray	Apparent consumption	tons (live weight eq.)	Market price - home consumption	2019	1241	1176	2030	1202	[633 - 1772]	15539	18271552	25029125
Rays	Household consumption	tons (net weight)	Market price - Port first sale	2019	347	350	2030	347	[36 - 658]	1383	484200	643222
Ray	Household consumption	tons (net weight)	Market price - home consumption	2019	347	350	2030	347	[36 - 658]	15539	5439190	7225546
Shrimp	Apparent consumption	tons (live weight eq.)	Market price - Port first sale	2019	3053	2825	2030	4810	[2950 - 7427]	5272	14895910	33980149
Shrimp	Apparent consumption	tons (live weight eq.)	Market price - home consumption	2019	3053	2825	2030	4810	[2950 - 7427]	17428	49242109	112329773
Shrimp	Household consumption	tons (net weight)	Market price - Port first sale	2019	3852	3601	2030	3852	[-1610 - 9314]	5272	18985563	27212377
Shrimp	Household consumption	tons (net weight)	Market price - home consumption	2019	3852	3601	2030	3852	[-1610 - 9314]	17428	62761467	89957232
Squids	Apparent consumption	tons (live weight eq.)	Market price - Port first sale	2019	556	832	2030	862	[269 - 1454]	5826	4846040	6729496
Squid	Apparent consumption	tons (live weight eq.)	Market price - home consumption	2019	556	832	2030	862	[269 - 1454]	5724	4761332	6611866
Squid	Household consumption	tons (net weight)	Market price - Port first sale	2019	476	527	2030	577	[462 - 691]	5826	3073093	4504547
Squid	Household consumption	tons (net weight)	Market price - home consumption	2019	476	527	2030	577	[462 - 691]	5724	3019376	4425808
Top landed species*	Apparent consumption	tons (live weight eq.)	Market price - Port first sale	2019	28051	32548	2030	27758	-	(species unit prices above)	127185731	160576851
Top landed species*	Apparent consumption	tons (live weight eq.)	Market price - home consumption	2019	28051	32548	2030	27758	-	(species unit prices above)	483771900	566865249
Top landed species*	Household consumption	tons (net weight)	Market price - Port first sale	2019	11834	12587	2030	11458	-	(species unit prices above)	51780238	66563533
Top landed species*	Household consumption	tons (net weight)	Market price - home consumption	2019	11834	12587	2030	11458	-	(species unit prices above)	190632785	234534485
Mussel	Apparent consumption	tons (live weight eq.)	Market price - Port first sale	2019	22520	23575	2030	20415	[18317 - 22512]	-	-	-

Mussel	Apparent consumption	tons (live weight eq.)	Market price - home consumption	2019	22520	23575	2030	20415	[18317 - 22512]	3380	79688363	92470745
Mussel	Household consumption	tons (net weight)	Market price - Port first sale	2019	16180	17285	2030	12803	[10458 - 15516]	-	-	-
Mussel	Household consumption	tons (net weight)	Market price - home consumption	2019	16180	17285	2030	12803	[10458 - 15516]	3380	58428335	57991817
Oyster	Apparent consumption	tons (live weight eq.)	Market price - Port first sale	2019	2100	1968	2030	1508	[1189 - 1886]	-	-	-
Oyster	Apparent consumption	tons (live weight eq.)	Market price - home consumption	2019	2100	1968	2030	1508	[1189 - 1886]	11270	22178149	22773645
Oyster	Household consumption	tons (net weight)	Market price - Port first sale	2019	550	597	2030	612	[506 - 717]	-	-	-
Oyster	Household consumption	tons (net weight)	Market price - home consumption	2019	550	597	2030	612	[506 - 717]	11270	6722986	9242355
Mussel + oyster**	Apparent consumption	tons (live weight eq.)	Market price - Port first sale	2019	24620	25543	2030	21923	-	-	-	-
Mussel + oyster**	Apparent consumption	tons (live weight eq.)	Market price - home consumption	2019	24620	25543	2030	21923	-	(species unit prices above)	101866511	115244390
Mussel + oyster**	Household consumption	tons (net weight)	Market price - Port first sale	2019	16729	17882	2030	13415	-	-	-	-
Mussel + oyster**	Household consumption	tons (net weight)	Market price - home consumption	2019	16729	17882	2030	13415	-	(species unit prices above)	65151321	115244390

*Aggregated value of the top eight landed species (i.e. values are the sum of individual species values)

**Aggregated value of mussel and oyster (i.e. values are the sum of individual species values)

5.3.2. Sand and other minerals

- Indicator quantification: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_623df1a074e8e210880729
- Forecast estimates: Not applicable (no time series available)
- Monetization method: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_623df1a074f48631630398

The demand for *Sand and other minerals* is defined only by the class-type *sand* given this is the only mineral being exploited in the BCS for human use. The quantity of sand consumption, based on imports, was selected as the demand indicator (Table 4). Sand import data was only obtained for the region of Flanders and represents the total quantities of construction sand (defined as *bouwzand* in the data reports) imported to the region. Since the sand extracted from the BCS sand is exclusively construction sand according to Van den Abeele et al.(2019), we only quantify the demand for this type of sand. Construction sand is mainly imported from the BCS, Netherlands, Germany, Wallonia, Brussels, UK and France. Sand imports data is not available as a time-series but data points were retrieved from the different reports from Flanders Environment Department and OVAM[4]. Given the lack of a time-series, a statistical forecasting analysis was not performed for this indicator. The quantification results are presented in Table 6.

The monetary valuation method used was the Market Price. The monetary value-unit was derived from the Intrastat trade statistics of the National Bank of Belgium[5] (

Table 5). The formula used to calculate the monetary value is: $V_s = Q_s \times P_s$; where V_s: value of sand (€/year); Q_s: amount of sand (tons/year); P_s: market price of sand (€/ton). The price per unit of sand (€/ton) was calculated as the average price of the last five years of available statistical data (2016 – 2020).

The results suggest that Flanders imported approximately 10.6 million tons/year in recent years, which correspond to a monetary value of about 84.5 million €/year. Despite the lack of a time-series to obtain forecast estimates for future construction sand demand, the literature can provide us with some information. In the Long-Term Vision North Sea 2050, De Backer (2017) estimates that 8.75 million m^3 of sand will be needed annually by 2050, which corresponds to approximately 13.8 million tons/year. Van den Abeele et al. (2019) predicted that the demand for construction sand will either remain stable or experience a slight increase in the future. The BCS will probably not be able to supply all the sand necessary given that limits are imposed on extraction (e.g. a maximum of 15 million m^3 of sand can be extracted by all concession holders every 5 years) (FPS Economie, 2020). Nonetheless, new areas have been reserved for sand extraction in the BCS in the current marine spatial plan and quotas might change in the future to meet a potential increase in demand (Belgisch Staatsblad, 2019).

5.3.3. Surface for navigation

- Indicator quantification: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_624168dcb8a85430952642
- Forecast estimates: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_624168dcb8919880992237
- Monetization method: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_624168dcb87a0784708289

The demand for *Surface for navigation* is quantified using proxy indicators that reflect port activity, which are *seagoing vessels arrivals* and *cargo traffic* (Table 4). Seagoing vessels arrivals represents the total number of

[4] https://omgeving.vlaanderen.be/monitoringsysteem-duurzaam-oppervlaktedelfstoffenbeleid-mdo
[5] https://stat.nbb.be/Index.aspx

vessels arriving at Flemish ports from the sea per year, which provides an indirect indication of the trend in ships circulating in the BCS. Cargo traffic represents the total cargo moved around in ports (i.e. transshipments) per year, which includes all types of cargo, namely: containers, dry bulk, liquid bulk, roll-on-roll-off, and conventional. This data was obtained from Mobiliteitsraad van Vlaanderen (MORA) and is available in its annual reports entitled *Zeehavens en luchthavens in Vlaanderen: Feiten, statistieken en indicatoren* (e.g. Merckx, 2019). The quantification results are presented in Table 7 (time-series charts available in Annex).

The monetary valuation method used was the Market Price. Two monetary value-units were calculated for each indicator separately. Both were derived from the annual direct value-added (DVA) to ports available in Rubbrecht et al. (2021). The value-unit of shipping (€/ship) was calculated by dividing the shipping DVA with the total number of ship arrivals. The value-unit of cargo traffic (€/ton) was calculated by dividing the cargo-handling DVA with the volume of cargo handled. The formula used to calculate the monetary value is: $V_c = Q_c \times P_c$; where V_c: value of shipping/cargo (€/year); Q_c: amount of ship arrivals/cargo traffic (#/year; tons/year); P_c: market price of shipping/cargo (€/ship; €/ton).

The results suggest that cargo traffic in Flemish ports amounted to an average of 296 million tons/year in recent years, which corresponds to a monetary value of about 2.25 billion €/year for cargo handling alone. Shipping arrivals in Flemish ports amounted to an average of almost 30,000 ships/year, corresponding to a monetary value of 1.37 billion €/year Note that these values are only a fraction of the total value-added in ports, which develop many other economic activities that may or may not be related to maritime activities (Merckx, 2020).

According to the forecasting analysis results, cargo traffic is very likely to increase in the future, reaching values probably within 333 and 384 million tons/year by 2030. The potential increase in cargo traffic suggests a potential increase in demand for *Surface for navigation* in the BCS. However, this is not totally granted given that total ship arrivals in Belgian have remained relatively stable and forecasts estimates suggest a sideways trend, with numbers between 22,000 and 40,000 ships/year in 2030. The increase in cargo traffic will likely continue to be accompanied by an increase in cargo capacity per ship (a steady increase in ship tonnage is reported in the reports) rather than an increase in ship circulation (Merckx, 2020).

A particularity of this provisioning ES is that the supply is defined as a surface that is used but not depleted by usage, contrarily to the other provisioning ES which are defined as biomass/volume that is depleted by its usage. While in the later cases, supply and demand can be linked because of that production-consumption relationship that can be expressed in the same units, the former cannot. Therefore, supply and demand cannot be linked directly to obtain a supply-demand mismatch.

To allow for a monetary expression of the supply-side, which will be quantified as a distance measure (i.e. available routes for navigation), a monetary value-unit in € per distance navigated was identified. Maibach et al. (2006) estimated the cost of sea transport in the EU to be 0.009 €/ton.km in 2005 which, adjusted for inflation, corresponds to 0.012 €/ton.km in 2020. Thus, in order to know how much is the cost of navigating 1 km, only the quantity of cargo transported needs to be known. This can be calculated for individual ships or for aggregated cargo values from several ships. For example, considering the total annual cargo traffic value previously provided, it costed about 430,000 €/km (i.e. 358,327,000 tons X 0.012 €/ton.km) to transport that cargo. Thus, the cost to shipping of a route closure (e.g. due to an offshore windfarm installment) is equal to the cost of the extra distance travelled to reach the destination. This can be calculated using the general formula: *Cost (€) = Cargo (tons) × Distance navigated (km) × 0.012 (€/ton.km).*

5.3.4. Renewable offshore energy

- Indicator quantification: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_62416e467aa43319303873

- Forecast estimates: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_62416e467acc5208395112
- Monetization method: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_62416e467ac6d627686252

The demand for *Renewable offshore energy* is defined by the class-type *wind power* and whose demand is measured using two different indicators: a) electricity consumption and b) renewable energy targets (Table 4). *Electricity consumption* represents the total electricity consumed in Belgium, for which wind power is expected to contribute more and more. This data is available from different sources and we used the dataset provided in Our World in Data[6], an online scientific database that shares a variety of country-specific datasets, including energy-related data. *Renewable energy target* represents the amount of electricity that is expected to be generated by offshore renewables in 2030 based on policy targets. This data is obtained from official government sources[7]. The quantification results are presented in Table 8 (time-series charts available in Annex).

The monetary valuation method used was the Market Price. For this case, two monetary value-units are provided given the high volatility in electricity prices in the market. These correspond the minimum and maximum monthly electricity prices, registered between Jan-2016 and Dec-2021, available from Elia[8]. They were 14.7 euro/MWh (Apr-2020) and 245.4 euro/MWh (Dec-2021), respectively. The average price within those same dates was 50.9 euro/MWh. The formula used to calculate the monetary value is: $V_e = Q_e \times P_e$; where V_e: value of electricity (€/year); Q_e: amount of electricity (TWh/year); P_e: market price of electricity (€/TWh).

Results suggest that electricity consumption in Belgium has been, on average, 84 TWh/year, which corresponds to a monetary value between 1.2 and 20.6 billion €/year according to the minimum and maximum electricity prices in Belgium in recent years. Using the average price, that amount of energy is worth 4.3 billion €/year. The forecast results display a sideways trend with constant mean and confidence intervals, suggesting that electricity consumption should vary between 71 and 95 TWh/year during the next decade. In terms of the *renewable energy targets*, by 2030, around 25% of Belgian electricity production is expected to come from offshore renewables. Assuming the current total electricity generation of 85.9 TWh (2020; data available from the International Energy Agency[9]) remains relatively constant through the next decade, about 22.2 TWh should come from offshore renewables in 2030. Using a simple inflation adjustment of 3% from 2020 on the price interval provided, the offshore electricity target is valued between 0.4 and 7.3 billion €/year (at the 2016-2021 average price, the value is equal to 1.5 billion €/year).

[6] https://ourworldindata.org/energy/country/belgium
[7] https://economie.fgov.be/en/themes/energy/belgian-offshore-wind-energy;
https://economie.fgov.be/sites/default/files/Files/Energy/public-consultation-on-the-offshore-wind-tender-for-the-princess-elisabethzone.pdf
[8] https://www.elia.be/-/media/project/elia/shared/documents/press-releases/2022/20220107_belgium-2021-electricity-mix_en_v2.pdf
[9] https://www.iea.org/countries/belgium

Table 6: Demand for Sand and other minerals.

Class-type	Indicator	Unit	Monetary method	PRESENT Ref. year	Actual value	5-Y mean	FORECAST Ref. year	Mean value	95 % C. I.	MONETARY VALUE € value-unit (€/unit)	Present € (€/y)	2030 € (€/y)
Sand	Construction sand imports	tons	Market price - sand imports to Flanders	2018	10806000	10625000	2030	NA	NA	7.95	84468750	NA

Table 7: Demand for Surface for navigation.

Class-type	Indicator	Unit	Monetary method	PRESENT Ref. year	Actual value	5-Y mean	FORECAST Ref. year	Mean value	95 % C. I.	MONETARY VALUE € value-unit (€/unit)	Present € (€/y)	2030 € (€/y)
Cargo	Cargo traffic in ports	tons	Market price – cargo handling direct value added	2019	318043000	295829400	2030	358327000	[332989800 - 383664300]	7.61	2251932762	3655092890
Ships	Seagoing ship arrivals in ports	n	Market price – shipping direct value added	2019	31451	29971	2030	31356	[22582 - 40129]	45777.7	1371994545	1923443808

Table 8: Demand for Renewable offshore energy.

Class-type	Indicator	Unit	Monetary method	PRESENT Ref. year	Actual value	5-Y mean	FORECAST Ref. year	Mean value	95 % C. I.	MONETARY VALUE € value-unit, (€/unit)	Present € (€/y)	2030 € * (€/y)
Wind power (electricity)	Electricity consumption	TWh	Market price - electricity cost	2020	86	84	2030	83	[71 – 95]	Min.: 14700000	1232000061	1622733000
										Avg.: 50914000	4267078305	5620396460
										Max.: 245400000	20566858153	27293388000
	Offshore renewable energy target	TWh	Market price - electricity cost	-	-	-	2030	25% of electricity comes from offshore renewables. Assuming 2020 total generation of 88.9 TWh, target = 22.2 TWh		Min.: 14700000	-	434032200
										Avg.: 50914000	-	1503286764
										Max.: 245400000	-	7300159200

* Reminder: the 2030 value simply assumes an annual 3% inflation rate on the value-unit.

5.3.5. Mediation of wastes

- Indicator quantification: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_624172bbe38cd023969746
- Forecast estimates: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_624172bbe21c0665025156
- Monetization method: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_624172bc102db279442546

The demand for *Mediation of wastes* is quantified for two class-types, *Nitrogen* and *Phosphorous,* and the demand is measured using the indicator *Nutrient loads* (Table 4). Nutrients produced from human activities on land end up reaching marine waters through inflow from rivers and tributaries (Brion et al., 2006; Desmit et al., 2018) and represent a societal demand for waste remediation by marine ecosystems. Therefore, this indicator presents the total nutrient loads to the BCS from river sources (Scheldt, Canal Ghent-Terneuzen and the rivers of the coastal area). This time-series data was obtained from Vlaamse Milieumaatschappij (VMM) which was part of their latest OSPAR reporting. The quantification results are presented in Table 11 (time-series charts available in Annex).

The monetary valuation method used was the Benefit-transfer. Adjusted-unit value transfers were estimated based on shadow prices for nitrogen (N) and phosphorous (P) removal/offset reported in the literature. The estimates obtained were based essentially on the works of Hernández-Sancho et al. (2010) and Watson et al. (2020). Other reports were found that provided estimates but, upon closer look, these were mostly based on the work of Hernández-Sancho et al. (2010) (e.g. Boerema et al., 2016; Liekens et al., 2013; Norton et al., 2014). The price adjustments took into consideration the Purchasing Power Parity (PPP), to adjust the original price to Belgium purchasing power, and the Consumer Price Index (CPI) to adjust the Belgian price for 2020 inflation. Using this procedure, we obtained a minimum and maximum shadow price for the removal of N and P in Belgium in 2020 (Table 9). The shadow price range for N remediation is 7.5 - 319.2 €/kg, and for P remediation is 11.7 – 305.1 €/kg (average prices are 163.2 €/kg N and 158.4 €/kg P) The formula used to calculate the monetary value is: $V_n = Q_n \times P_n$; where V_n: value of nutrient remediation (€/year); Q_n: amount of nutrient loaded (tons/year); P_n: shadow price for nutrient remediation (€/ton).

Table 9: Shadow price of N and P removal (values in bold are the adjusted-unit monetary value transfers used).

Nutrient	Country	Study year	Original monetary value	PPP-adjusted price (€/kg)	CPI-adjusted price, (2020) (€/kg)	Source
Nitrogen	UK	2020	295 £/kg	319.2	**319.2**	(Watson et al., 2020)
	Spain	2004	4.6 €/kg	5.3	**7.2**	(Hernández-Sancho et al., 2010)
Phosphorous	UK	2020	282 £/kg	305.1	**305.1**	(Watson et al., 2020)
	Spain	2004	7.5 €/kg	8.7	**11.7**	(Hernández-Sancho et al., 2010)

Results suggest that N loads from Belgian rivers were, on average, 21389 tons N/year between 2016 and 2020, which corresponds to a monetary value between 0.2 and 6.8 billion €/year (3.5 billion €/year on average). The P loads were, on average, 1575 tons P/year during the same time, corresponding to a monetary value between 18 and 481 million €/year (250 million €/year on average). The forecast results suggest a slight downward trend for N loads, with a confidence interval however between 9741 and 34290 tons/year in 2030. For P loads, the forecast generated a sideways trend with constant mean and confidence intervals, suggesting that P loads are likely to continue relatively stable and vary between 1053 and 3018 tons/year during the next decade.

5.3.6. Nursery and habitat maintenance

- Indicator quantification: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_6241793b24dd0139957896
- Forecast estimates: Not applicable (no time series available)
- Monetization method: same link as *Indicator quantification*

The demand for *Nursery and habitat maintenance* was quantified directly as a monetary quantity based on people's willingness-to-pay (WTP) estimates for the conservation of marine/coastal habitats. Despite not being the preferred indicator by the scientific experts (

Table 3), it was found to be the best indicator to provide a monetary value estimate for this non-tangible regulating service (the most voted indicator - *fisheries species dependent on the habitat* – makes more sense as a supply-indicator since it represents the quantity of fisheries that originates from the habitat).

The WTP estimates were obtained from three contingent valuation studies in European-only coastal/marine areas in order to approximate as much as possible to the Belgian context (Table 10). The Benefit-transfer method was employed to obtain adjusted-unit value transfer estimates of WTP for habitat protection. The minimum and maximum adjusted value unit of WTP are is 90.6 and 130.7 €/household (average = 112.2 €/household). The formula used to calculate the monetary value is: $V_h = WTP_h \times households_{BE}$; where V_h: value of habitat maintenance (€/year); WTP_h: willingness-to-pay for habitat maintenance (€/household/year); $households_{BE}$: number of households in Belgium. The valuation results are presented in Table 12.

Table 10: WTP estimates for habitat protection (values in bold are the adjusted-unit monetary value transfers used).

Habitat	Country (marine area)	Study year	Mean WTP (€/household/y)	PPP-adjusted (€/household/y)	CPI-adjusted (2020) (€/household/y)	Source
Marine protected area	Netherlands (North Sea)	2006	101.7	101.97	**130.74**	(Brouwer et al., 2016)
Coastal zone	Portugal (Atlantic)	2014	60	82.94	**90.59**	(Ferreira et al., 2017)
Coastal lagoon	Spain (Mediterranean)	2013	87.96	105.08	**115.16**	(Velasco et al., 2018)

The monetary value obtained is referent to the WTP extrapolated to the whole Belgium population. Official data sources of population statistics state that the Belgian population in 2020 was equal to 11492641 people and the average household size was equal to 2.3 people, which results in a total of 4996800 household in Belgium in 2020. According to the results, total WTP for marine habitat maintenance in Belgium is estimated to range between 453 and 653 million €/year (the average WTP is about 560 million €/year). A forecast is not provided for this ES because there is a lack of time-series data on the indicator. However, based on BCS literature it is expected that the demand for this ES will increase. For instance, De Backer (2017) states that naturalness will be a basic precondition for the development of the BCS in all its dimensions in the future and, therefore, implying that maintaining BCS habitats will be continuously demanded. Moreover, as the public becomes more aware of the overarching importance of marine ecosystems, the more they are willing-to-pay for the protection of marine habitats (Brouwer et al., 2016). Therefore, if public awareness of this subject increases by 2030 it is safe to expect an increase in their WTP for habitat protection.

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5.3.7. Climate regulation

- Indicator quantification: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_62417d7e2cfe2034610671
- Forecast estimates: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_62417d7e2a6b8076440151
- Monetization method: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_62417d7e2a530910307571

The demand for *Climate regulation* is defined by the class-type *Carbon dioxide* and the demand is measured using two different indicators: a) production-based CO_2 emissions; and b) carbon emissions reduction target (Table 4). Note that the other greenhouses gases (GHG; CH_4, N_2O and F-gases) were not considered because, from the supply-side, we are only looking at the ecosystem capacity to store CO_2 and not the other GHG.

Production-based CO_2 emissions account for the emissions that are generated from the domestic production of goods and services. This time-series data was obtained from official sources and is available with the FOD Volksgezondheid, Veiligheid van de Voedselketen en Leefmilieu (at klimaat.be) and the European Environment Agency. Note that values presented do not include the effect from Land Use Change and Forestry, and therefore represent gross emissions. *Carbon emissions reduction target* represents the maximum amount of carbon that is expected to be emitted by Belgium in 2030 based on policy targets. This data is obtained from official government sources[10]. The quantification results are presented in Table 13 (time-series charts available in Annex).

The monetary valuation method used was the Carbon Market Price. In this case, two monetary value-units are also provided given the high volatility in traded carbon market prices. These are derived from the minimum and maximum monthly prices reported in the EU Emissions Trading System (ETS) between Jan-2016 and Dec-2021 (a real-time price chart can be consulted at e.g. https://sandbag.be/index.php/carbon-price-viewer/). These were 4.3 euro/ton CO_2 (Sep-2016) and 79.7 euro/ton CO_2 (Dec-2021). The average price within the same time period was 21.6 euro/ton CO_2. The formula used to calculate the monetary value is: $V_c = Q_c \times P_c$; where V_c: value of carbon (€/year); Q_c: amount of carbon (tons/year); P_c: market price of carbon (€/ton).

Results suggest that production-based CO_2 emissions in Belgium were, on average, 100 ktons/year, which corresponds to a monetary value between 0.4 and 8.0 million €/year according to the minimum and maximum carbon prices in the EU ETS. Using the average price, the value is equal to 2.2 million €/year. The forecast results display a downward trend, suggesting that emissions will possibly vary between 63 and 99 ktons/year in 2030. In terms of the *carbon emissions reduction target*, by 2030, according to the EU Effort Sharing Regulation (which establishes binding annual greenhouse gas emission reductions by the EU Member States from 2021 to 2030) Belgium is expected to reduce by 35% its 2005 annual emissions (which were 125.5 ktons)[11]. This means that Belgium must keep its annual emissions below 81.6 ktons per year by 2030. Assuming current average emission levels would remain constant through the next decade, approximately 18.5 ktons of CO_2 should be avoided/offset to reach that target. Using the inflation adjusted prices from 2019 to 2030, the amount of CO_2 that needs to be offset from current emission levels is valued at 0.5 million €/year acroding to the average inflated price (or between 0.1 and 2.0 million €/year assuming the minimum and maximum prices).

[10] https://www.plannationalenergieclimat.be/admin/storage/nekp/pnec-version-finale.pdf

[11] https://unfccc.int/sites/default/files/resource/BR4_EN_LR.pdf

Table 11: Demand for Mediation of wastes.

Class-type	Indicator	Unit	Monetary method	PRESENT Ref. year	PRESENT Actual value	PRESENT 5-Y mean	FORECAST Ref. year	FORECAST Mean value	FORECAST 95 % C. I.	MONETARY VALUE € value-unit (€/unit)	MONETARY VALUE Present € (€/y)	MONETARY VALUE 2030 € (€/y)
Nitrogen	Loads from rivers to the sea	tons	Benefit-transfer -adjusted unit value transfer of shadow prices for nutrient removal	2020	22450	21389	2030	19218	[9741 – 34290]	Min.: 7200	153997980	184031568
										Avg.: 163185	3490295720	4170993638
										Max.: 319200	6827243773	8158732848
Phosphorous	Loads from rivers to the sea	tons	Benefit-transfer -adjusted unit value transfer of shadow prices for nutrient removal	2020	1474	1575	2030	1847	[1053 - 3018	Min.: 11700	18433301	28741167
										Avg.: 158424	249596255	389169993
										Max.: 305100	480683775	749481201

Table 12: Demand for Nursery and habitat maintenance.

Class-type	Indicator	Unit	Monetary method	PRESENT Ref. year	PRESENT Actual value	PRESENT 5-Y mean	FORECAST Ref. year	FORECAST Mean value	FORECAST 95 % C. I.	MONETARY VALUE € value-unit (€/unit)	MONETARY VALUE Present € (€/y)	MONETARY VALUE 2030 € (€/y)
Habitat protection	Willingness-to-pay for habitat protection	€/household	Benefit-transfer -adjusted unit value transfer of WTP estimates	2020	*Monetary value only*		2030	-	-	Min.: 90.6	452660151	602038001
										Avg.: 112.2	560441137	745386712
										Max.: 130.7	653281689	868864646

Table 13: Demand for Climate for regulation.

Class-type	Indicator	Unit	Monetary method	PRESENT Ref. year	PRESENT Actual value	PRESENT 5-Y mean	FORECAST Ref. year	FORECAST Mean value	FORECAST 95 % C. I.	MONETARY VALUE € value-unit (€/unit)	MONETARY VALUE Present € (€/y)	MONETARY VALUE 2030 € * (€/y)
Carbon dioxide	Production-based CO_2 emissions	tons	Carbon market price	2019	99746	100070	2030	81100	[63129 - 99106]	Min.: 4.3	431301	468385
										Avg.: 21.6	2164218	2350302
										Max.: 79.7	7977564	8663491
	Carbon emissions reduction target	ton	Carbon market price	-	-	-	2030	-35% of 2005 emissions, which = 81.6 ktons. Assuming recent emissions 100.1 ktons, reduction target = 18.5 ktons		Min.: 4.3	-	106989
										Avg.: 21.6	-	536860
										Max.: 79.7	-	1978929

5.3.8. Recreation

- Indicator quantification: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_624185a5d99a1533224447
- Forecast estimates: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_624185a5d8d2c864780519
- Monetization method: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_624185a5d8b04777796197

The *Recreation* service can be sub-divided into *active* and *passive* recreation to distinguish between recreational activities that involve active interactions (e.g. physical activity) and those that involve passive interactions with nature (e.g. wildlife observation). Despite different class-types could potentially represent active recreation in the BCS, due to data availability reasons only demand for *recreational fishing* and *coastal tourism* were quantified. In terms of passive recreation, *birdwatching* was selected as the only class-type. The demand for these class-types was measured through engagement indicators, namely number of users or number of trips to the place of recreation (Table 4).

Number of coastal day-tourists was used as proxy indicator of *coastal tourism* demand, which focus only on number of visitors who visit the coast during the day but do not stay overnight. This indicator had the advantage of providing a clear monetary value-unit (e.g. euro/person/day) based on day-expenditure, while this value was not so straightforward to obtain for overnight tourists. The time-series data was obtained from several reports of Westtoer, namely the Trendrapporten Kust between 2007 and 2020 (note that the 2020 datapoint was ignored due to the significant impact of COVID-19 restriction on day-tourism number).

Number of recreational fishing trips was used as indicator of *recreational fishing* demand, and it includes the total number of recreational trips using fishing vessels (angling and trawling) and at the coast (beach, dam and horse anglers, porters and passive beach fishing). The data was retrieved from two recent reports (Verleye et al., 2019, 2020) that were pioneers in comprehensively assessing marine recreational fisheries in Belgium. Given that, there is not yet a time-series available for recreational fishing data for forecasting analysis. However, those reports seem to suggest that the recreational fishermen population is aging (average = 56-year-old) and therefore it seems unlikely that this sector will grow substantially in the future.

Number of coastal birdwatching users of eBird platform was used as a proxy indicator for the demand of *birdwatching.* The eBird[12] platform is an online database of bird observations that relies on amateurs and professional birders to capture and register geotagged observations of bird distribution and abundance. It provides a comprehensive time-series real-time dataset that also includes anonymized user data that can be used to quantify the number of users. Making use of the full Belgian dataset (requested to the platform), a subset of observations was created to only include those observations registered at the coast (~ 5 km) and quantify the indicator. The quantification results of the three indicators as mentioned above are presented in Table 14 (time-series charts available in Annex).

To monetize the *coastal day-tourist* indicator, the average daily expenditure of day-tourists reported in Westtoer (2020) was used. For the *recreational fishing trips* indicator, the annual expenditure per recreational fishing type reported in Verleye et al. (2019) was used to estimate an average monetary value per trip. Reliable monetary information of *birdwatching* in Belgium is non-existent and in Europe only one source was found to report day-expenditure of organized ornithological tourism in Spain (Roig, 2008). It was decided not to monetize *birdwatching* given the shortage of reliable estimates in the literature that could be linked to the

[12] https://ebird.org/

indicator. The formula used to calculate the monetary value is: $V_r = Q_r \times P_r$; where V_r: value of recreation (€/year); Q_r: number of persons/trips (n/year); P_r: expenditure (€/n).

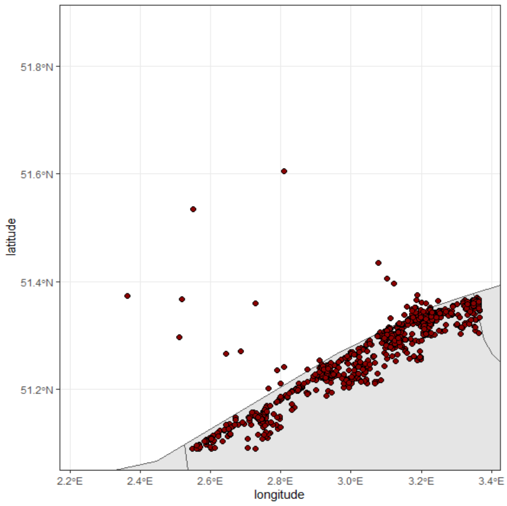


Figure 4: Coastal bird observations registered on eBird database.

The results suggest that, on average, 17.7 million day-tourists visited the coast per year between 2015 and 2019. This corresponds to a value of about 813 million €/year based on the average day-tourist expenditure to at the coast. The forecast results towards 2030 display a sideways trend with constant mean and confidence intervals (see Annex figures), suggesting a relatively stable demand between 16 and 19 million coastal day-tourists per year. Regarding recreational fishing, in 2018-2019, recreational fishermen made on average 33275 trips/year (9800 trips/year for boat-fishing and 23475 trips/year for coast-fishing).

In terms of monetary value, this corresponds to about 7.5 million €/year. Note that the monetary value-unit per trip is an average value calculated from the total expenditure and total number of trips for all fishing types, however the costs can vary greatly depending on fishing type (e.g. boat angling = 773 €/trip, boat trawling = 387 €/trip, coast fishing = 23 €/trip) (Verleye et al., 2019). Concerning birdwatching, on average 63 people/year used the platform eBird to register their bird observations near the coast between 2015 and 2019. The forecasting analysis suggests an exponential increase in future users of the platform, with a confidence interval between 129 and 288 annual active birdwatchers in the platform by 2030.

5.3.9. Aesthetic value

- Indicator quantification: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_62418c2be4e2a370625557
- Forecast estimates: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_62418c2be4c5b860922012
- Monetization method: https://mda.vliz.be/directlink.php?fid=VLIZ_00000932_62418c2be4d33975196191

The ES *Aesthetic value* is defined by the class-type *Seascape* and the demand is measured using two different indicators: a) *photos shared on social media;* and b) *willingness-to-pay (WTP) for seascape maintenance* (Table 4). The first indicator is a proxy indicator that is commonly used to assess people's preferences for places and landscapes and the image-sharing platform Flickr is commonly used for this purpose, also providing insight into users (Oteros-Rozas et al., 2018; Wood et al., 2013). The second indicator directly estimates a monetary value for the seascape using people's WTP to reduce the visual impact of offshore wind farms on the seascape as a proxy. This approach was followed in previously published Choice Experiment studies as way to account for the visual impact of offshore windfarms on an undisturbed seascape for cost-benefit analysis (Krueger et al., 2011;

Ladenburg & Dubgaard, 2007, 2009; Westerberg et al., 2013). Wen et al. (2018) developed a useful meta-analytical equation to calculate people's WTP based on a farm's distance to the coast.

To quantify the photo-sharing indicator we followed the method described in Fox et al. (2020) which allows to retrieve metadata from Flickr geotagged photos. More precisely, we quantified the photo-user-days (PUD) from a dataset with geotagged photos taken in Belgium between 2007 and 2021 and tagged with seascape-related keywords. To bound the Flickr search to the coastal zone, a bounding box was defined with coordinates that included the Belgian coastline (**Fout! Verwijzingsbron niet gevonden.**A). Within this bounding box, only pictures tagged with anyone of the following (Flemish, French or English) keywords were considered to be seascape-related: *noordzee, northsea, merdunord, zee, sea, mer, coast, beach, seascape, belgiancoast* (**Fout! Verwijzingsbron niet gevonden.**B).

With the resulting dataset and its user-data, the PUD were calculated. One PUD represents one unique photographer who took at least one photo on a specific day. In other words, PUD is defined as the total number of days, across all users, that each person took at least one photograph (e.g. 10 PUD/year indicates that there are on average 10 visitors per day who take at least one picture). We used PUD as our indicator unit instead of total number of photos in order to normalize for the very active users (i.e. numerous photographs uploaded from the same person on the same day).

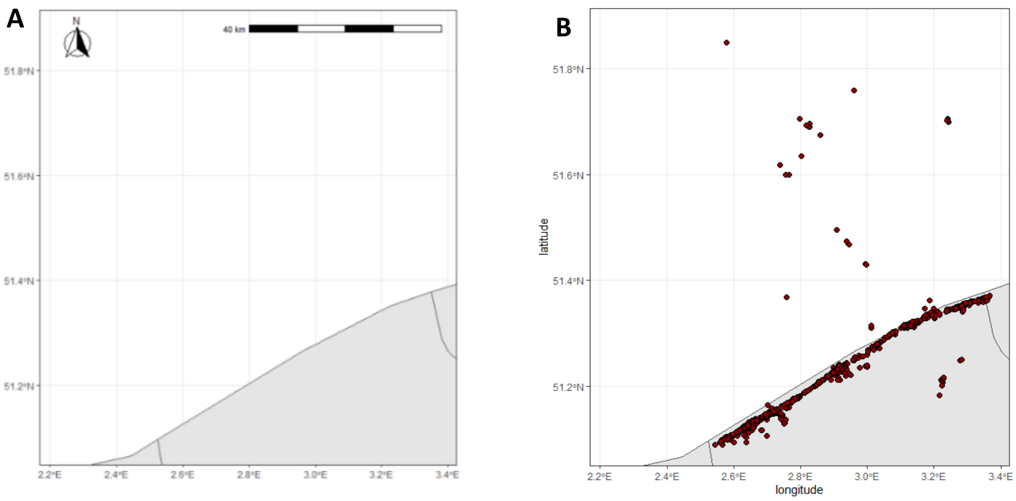


Figure 5: Bounding box (A) and seascape-tagged geotagged photos between 2005-2021 (B).

For the monetary valuation, since we were unable to monetize the photo-sharing indicator, we relied on WTP estimates to provide a proxy value of the seascape to coastal inhabitants. The Benefit-transfer method was employed to generate adjusted value-unit estimates calculated using the meta-analytic function developed by Wen et al. (2018). The function gives as output United Kingdom households' WTP to reduce the visual impact of offshore windfarms by moving it 1 km further offshore and is defined as follows: $y = 12.9/x + 0.88, 1.5 < x < 50$ where y= WTP to reduce the visual impact (£/household/year/km), x= distance from windfarm to coast (km). The function is valid between 1.5 and 50 km. The output values were adjusted for Belgium in 2020 using PPP and CPI rates.

Given it is the showcase in SUMES, Belwind's windfarm was used as the reference windfarm that is potentially impacting the seascape. Therefore, the demand to improve the seascape by reducing Belwind's visibility was calculated. The household's WTP was first assessed for each coastal municipality based on their distance to Belwind, resulting on an average WTP of 1.37 €/household/year/km. This value was then divided by the average household size across all coastal municipalities (from Census 2011 = 2.05 people/household) to obtain an individual WTP estimate of coastal inhabitants - 0.67 €/person/year/km - the monetary value unit. The quantification results are shown in Table 15.

The results suggest that, between 2015 and 2019, per year there were on average 0.18 Flickr users per day who took at least one picture. Forecasting estimates suggest that this value in unlikely to grow given past user trends, suggesting values of PUD between 0.10 and 0.23 in 2030. Non-monetary estimates of aesthetic value demand based on this indicator must of course consider that Flickr is only one of many image-sharing platforms and overall active users of the platform seem to have been decaying over the recent years which can bias the estimates. The WTP estimate was extrapolated to the coastal municipalities' population, which according to Statbel was equal to 338926 people in 2020. In total, coastal inhabitants average WTP to reduce the visual impact of offshore windfarms by moving them further offshore amounts to 0.2 million €/year/km.

Table 14: Demand for Recreation.

				PRESENT			FORECAST			MONETARY VALUE		
Class-type	Indicator	Unit	Monetary method	Ref. year	Actual value	5-Y mean	Ref. year	Mean value	95 % C. I.	€ value-unit (€/unit)	Present € (€/y)	2030 € (€/y)
Coastal tourism	Number of coastal day-tourists	n	Expenditure	2019	17241000	17679800	2030	17600000	[16049540 - 19243430]	46	813270800	1084864000
Recreational fishing	Number of recreational fishing trips	n	Expenditure	2019	28350	33275	2030	-	-	225	7486875	-
Birdwatching	Number of coastal birdwatchers using the eBird platform	n	-	2019	88	63	2030	197	[129 - 288]	-	-	-

Table 15: Demand for Aesthetic value.

				PRESENT			FORECAST			MONETARY VALUE		
Class-type	Indicator	Unit	Monetary method	Ref. year	Actual value	5-Y mean	Ref. year	Mean value	95 % C. I.	€ value-unit (€/unit)	Present € (€/y)	2030 € (€/y)
Seascape	Photos at the coast shared on Flickr	Photo-user-days	-	2019	0.15	0.18	2030	0.17	[0.10 - 0.23]	-	-	-
	Willingness-to-pay for reducing visual impact of offshore windfarms	€/person/km	Benefit-transfer - meta-analytic function transfer of WTP estimates	2020	*Monetary value only*		2030	-	-	0.67	227080	302017

6. Overview and future outlook

This deliverable presents the work of SUMES in developing indicators to quantify the demand for different types of ES and using monetary valuation methods to monetize those indicators. The results provide a solid quantitative basis of ES demand estimates from Belgium that may inform other assessments and decision-making processes concerning the management of ES. Quantitative information of the demand-side is key to putting into perspective the supply-side of ES to understand what fraction of the potential supply is theoretically being used and, being at the Belgian scale, inform decision-makers on nationals needs for that supply.

A general overview of the quantification, valuation, and forecasting results is presented in Table 16. The last column provides a qualitative parameter that indicates the future trend for the demand. This parameter takes the form of a directional arrow that illustrates the likely trend and is based on the forecasting results. The figures in the Annex section are chart projections of the time-series and forecasting results and can help better visualize these trends. Note that the values of the ES categories presented should not be aggregated as they represent only a fraction of the total economic value of the demand. Moreover, the values were not always estimated with the same monetary valuation method, and, therefore, direct cross-comparisons between them are not recommended. While being aware that value estimates across the different ES may not be directly comparable because of this, certain marine ES do stand out as being more demanded (either in quantity or in monetary value).

In the provisioning ES overall, *Sand* and *Surface for navigation* are the most demanded in terms of the volume of traded products. But, in terms of monetary value, *Wild aquatic animals* surpasses *Sand* as the latter is traded at much lower prices. To be specific, Belgian households have been consuming over 12,000 tons of *Wild aquatic animals* per year which is valued at over 190 million €, while the 10 million tons of construction sand imported annually to Flanders are worth about 84 million €. However, in terms of monetary value, energy was the most valuable provisioning ES and overall as well. The demand for electricity in Belgium has been on average about 83.8 TWh per year, for which *Renewable offshore energy* is expected to contribute with at least 20 TWh in 2030 if future consumption remains above current values. The estimated annual value of that contribution, assuming recent average electricity prices, is over 1.5 billion €, an underestimation considering the currently high inflation rates. Belgian ports are important entry points to Europe for global shipping transport and *Surface for navigation* is essential to it. Almost 300 million tons of cargo on average, valued at 2.3 billion €, are handled by Belgian ports annually, putting *Surface for navigation* also as one of the most valuable ES overall.

Regulating and maintenance ES can also provide significant value to Belgian society. Regarding *Mediation of wastes*, nitrogen loads from Belgian rivers to the marine environment have been estimated at 21,000 tons per year, whose removal is valued at an average of 3.5 billion €, making it one the most demanded ES in terms of monetary value. In terms of *Climate regulation,* currently, Belgium emits on average 100,000 tons of CO_2 per year from which a fraction needs to be reduced or offset to meet emission targets in 2030. By assuming current emission levels stay constant, it amounts to about 18,000 tons of CO_2 per year that need to be avoided (or offset) annually to reach that target. However, given the relatively low prices of carbon in carbon trading markets (compared to other ES value-units), this only corresponds to an average value of about 0.5 million €. *Nursery and habitat maintenance* is also a key ES for sustaining biodiversity and is valued at 550 million €, based on the estimates of how much the Belgian population would be willing-to-pay for protecting marine habitats.

As for the cultural ES, *Recreation* opportunities abound in the BCS and at the coast and approximately 18 million day-tourists visit the Belgian coast per year with an estimated annual value of 800 million €. However, it is obvious to assume that not all day-visitors will engage on marine-related recreational activities and therefore the value is likely overestimated and actual marine-based *Recreation* only represent a fraction of that. Recreational fisheries, both at sea and on the coast is practiced by some recreationists and in recent years the average number of trips was about 33,000 per year, valued at approximately 7.5 million €/year. The *Aesthetic value* of the seascape was a more difficult feature to assess given its intangibility, yet an attempt was made through the estimation of the coastal population WTP to reduce the visual impact of offshore windfarms on the seascape, which was about 0.2 million € per year.

Table 16: Summary of current demand for BCS ES and future trends.

ES	Class-type demand	Estimated quantity per year	Valuation method	Estimated value per year **	Forecasted trend***
Provisioning ES					
Farmed aquatic animals	Mussels & oysters – national household consumption	17,882 tons	Market price	65,151,321 €	↘
Wild aquatic animals	Top landed species – national household consumption	12,587 tons	Market price	190,632,785 €	?
Sand and other minerals	Construction sand – Flemish importations	10,625,000 tons	Market price	84,468,750 €	↗ †
Surface for navigation	Cargo - traffic in Belgian ports	295,829,400 tons	Market price	2,251,932,762 €	↗
	Ships – arrivals in Belgian ports	29971 ships	Market price	1,371,994,545 €	→
Renewable offshore energy	Electricity – national consumption	83.8 TWh	Market price	4,267,078,305 €	→
	Electricity – offshore renewables production target (2030) *	22.2 TWh	Market price	2,887,110,000 €	NA
Regulation & maintenance ES					
Mediation of wastes	Nitrogen – loads to the North Sea	21,389 tons	Benefit-transfer	3,490,620,876 €	→
	Phosphorous – loads to the North Sea	1,575 tons	Benefit-transfer	249,558,538 €	→
Nursery & habitat maintenance	Marine habitats – national WTP for protection	NA	Benefit-transfer	552,970,920 €	↗ †
Climate regulation	CO_2 – national production-based emissions	100,070 tons	Market price	2,164,218 €	↘
	CO_2 – national emissions reduction target (2030) *	18,525 tons	Market price	536,860 €	NA
Cultural ES					
Recreation	Coastal tourism – number of day-tourists	17,679,800	Expenditure	813,270,800 €	→
	Recreational fishing – number of trips	33,275	Expenditure	7,486,875 €	→ †
	Birdwatching – number of coastal birdwatchers on eBird	63		Not valued	↗
Aesthetic value	Seascape – photo-user-days of photos shared on Flickr	0.18		Not valued	→
	Seascape – local WTP to reduce OWF visual impact	NA	Benefit-transfer	227,080 €	NA

* Value at current price is presented for comparison (despite the target being for 2030).
** Average values are presented.
*** A forecast trend is not applicable in some cases, namely for the WTP and the target-based indicators.
† Future trend based on literature insights

Looking at the future trend, the time-series data on the consumption of mussels and oysters suggest that for these potential aquaculture species the demand in the future will decrease. Regarding those species with high commercial interest for the Belgian fisheries, the data on consumption is not so clear due to high variability in the time-series for most species. A closer look at each of the indicators per species helps us to provide an individual outlook. Concerning apparent consumption, a decrease in future demand is very likely for European plaice which oddly displays negative values in recent years (this may be interpreted as exports surpassing internal consumption, as the supply from a given year gets exported in the next). Apparent consumption is likely to remain relatively stable for squid, while for the cod, common sole, and ray it could go both ways (high uncertainty). An increasing trend in apparent consumption is only expected for shrimp. Regarding the consumption by households, the demand for cod and lemon sole is likely to decrease and the demand for squid is likely to increase. The household consumption trend for European plaice, gurnards, shrimp, and the common sole is not clear.

The future demand for construction sand (designated as *bouwzand* in importations reports) is very likely to remain stable or even increase in Flanders (De Backer, 2017; Van den Abeele et al., 2019). This estimation is based on available reports, as no time-series was available for sand imports. The demand for *Surface for navigation* is likely to remain stable in the future. Despite the apparent uptrend in cargo traffic at ports, sea vessels are becoming ever larger in size and cargo capacity and therefore the number of vessel arrivals has remained relatively stable over the last two decades (Merckx, 2020).

Electricity consumption in Belgium has been following a relatively stable sideways trend since the 2000s and is therefore expected to remain stable through 2030. However, in the context of the renewable energy targets set for Belgium, the contribution of offshore renewables to the total electricity generation must increase during the next decade and therefore demand for offshore wind-generated electricity will increase. An analogous outlook is predicted for the demand for CO_2 regulation. Despite the future trend in national emissions being a decreasing one, the carbon emission reduction target for 2030 begets an increase in the demand for CO_2 regulation for the next decade to help offset some of the emissions and help meet the target. The demand for nitrogen and phosphorous remediation is expected to remain relatively stable in the future as loads of both nutrients seem to have stabilized, despite some annual variability in the last decade.

The annual number of day-tourists in the last decade remained relatively stable. This was predicted by Westtoer in their 2015-2020 strategic plan for tourism and recreation at the coast (Westtoer, 2014) who envisioned a continuation of past levels of tourism. Our time-series analysis forecasts that this sideways trend will continue until 2030. The demand for marine recreational fisheries is expected to remain stable or decline in the future given the fact that these users are on average 56 years old (Verleye et al., 2019). Moreover, this activity is relatively small in Belgium compared to neighboring countries (Hyder et al., 2018). However, the low data availability for this socio-economic activity limits the capacity to make reliable forecasts.

The exponential increase in annual active users of the eBird platform seems to suggest that birdwatching is an activity that will probably increase in demand in the future. Actual numbers of birdwatchers are difficult to get otherwise given the lack of primary data, but such online platforms can give us a proxy indication of the trend. The demand for other recreational activities was checked but relevant data was unavailable or not accessible. These activities were diving, windfarm excursions, wildlife tours, mammal watching, swimming, and surfing. The demand for aesthetic experiences at the coast was assessed through photos taken at the coast and shared on Flickr and the number of annual photo-user-days since 2007 did not follow a particular trend. The demand for this ES is likely to remain stable in the future.

It is acknowledged that for two ES, there was insufficient time-series data for the chosen indicators to generate forecasting estimates (*Sand and other minerals* and *Habitat maintenance*). For two of the regulating and one of the cultural ES (*Mediation of wastes, Habitat maintenance* and *Aesthetic value*), monetary values used were sourced from international studies through the benefit-transfer method and, therefore, local primary studies are needed to more accurately assess the value of these ES in for the Belgian society. For the cultural ES, primary information about the use of the marine ecosystem for *Recreation* is also lacking (e.g. birdwatching) or is not yet captured regularly (e.g. recreational fishing).

In the other tasks of the SUMES project, a decision-support tool is being developed to model the ES supply in the BCS and account for the influence of marine activities on the supply. It is at that point that the demand scenarios (present and future) developed in this deliverable can be revisited to evaluate whether the supply can meet demand and discuss what possible measures (e.g marine activities development scenarios) could contribute to balancing the scale of supply-demand.

7. Conclusions

This document provides a first assessment of the demand for BCS-related ES (nine in total, linked to the showcase on OWF) through their quantification and monetary valuation and is an important step in incorporating ES analysis into decision making related to the BCS. Estimates for the demand quantity and value of several provisioning, regulation and maintenance, and cultural ES were generated. Based on data available and international tendencies, we also forecasted future demand for these ES to give some indication of the need to further support ES supply and establish management priorities. This work also provides a first overview of the data available that can be used to quantify and value marine ES demand in Belgium and, in that way, provides insight into data gaps regarding certain indicators and time series. The results of this work will also benefit the development of the SUMES decision-support tool (cfr. WP4 & WP5) by providing essential data points and estimates to determine ES supply-demand mismatches (cfr. WP3) and potentially inform marine ES management. The work being developed by SUMES to quantify the ES supply will be crucial to help us understand where environmental sustainability improvements are needed and how human activities may positively contribute to a sustainable Blue Economy.

8. Annex

This section displays the indicators charts showing the i) evolution of the time-series and ii) the estimated forecasts. The forecast visuals have three elements, the mean trend (blue line), the 80% confidence interval (strong blue shade) and the 95% confidence interval (light blue shade).

8.1. Wild aquatic animals

8.1.1. Atlantic cod

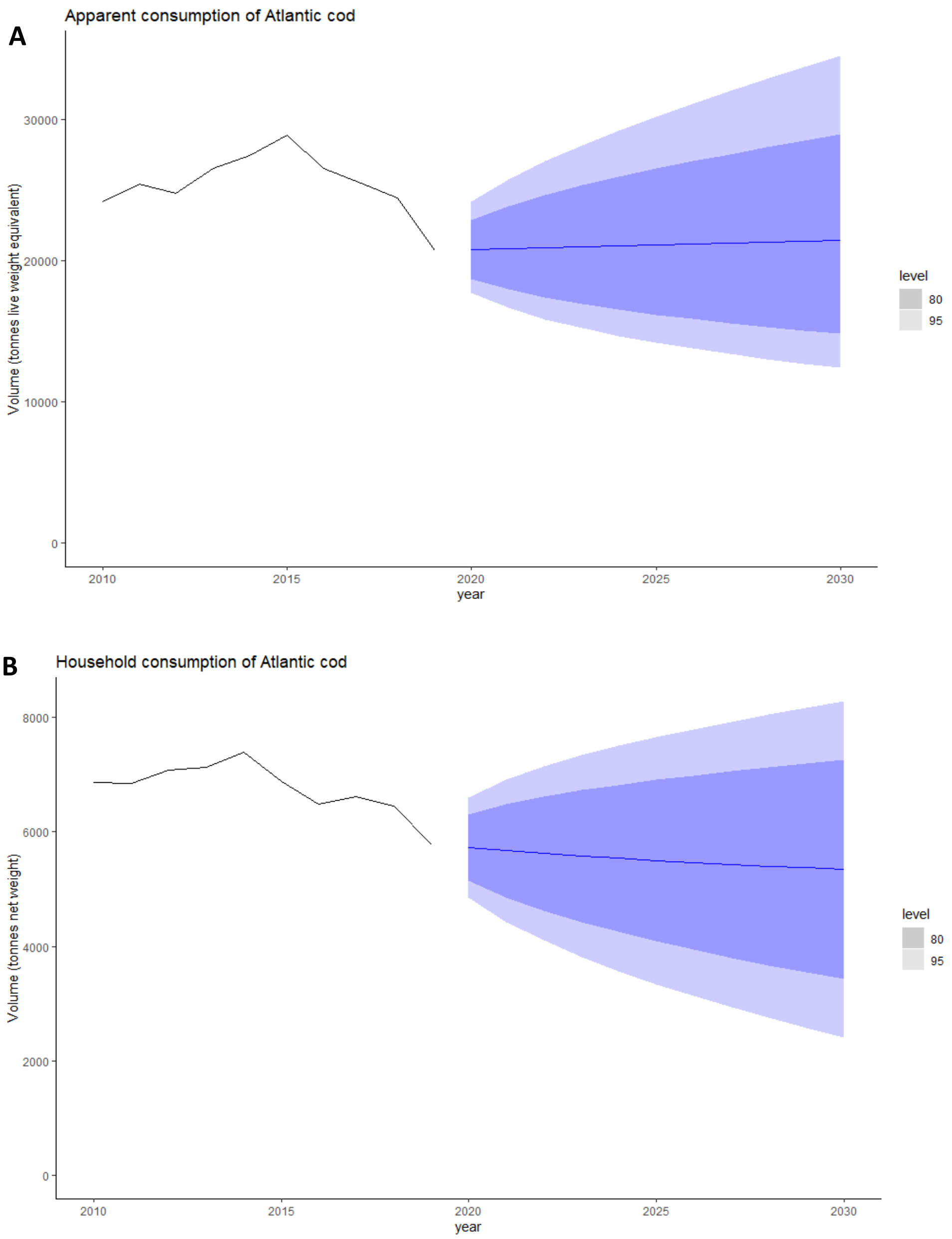


Figure 6: Time-series and forecasting estimates of Atlantic cod (*Gadus morhua)* A) apparent consumption and B) household consumption (2010-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast

8.1.2. European Plaice

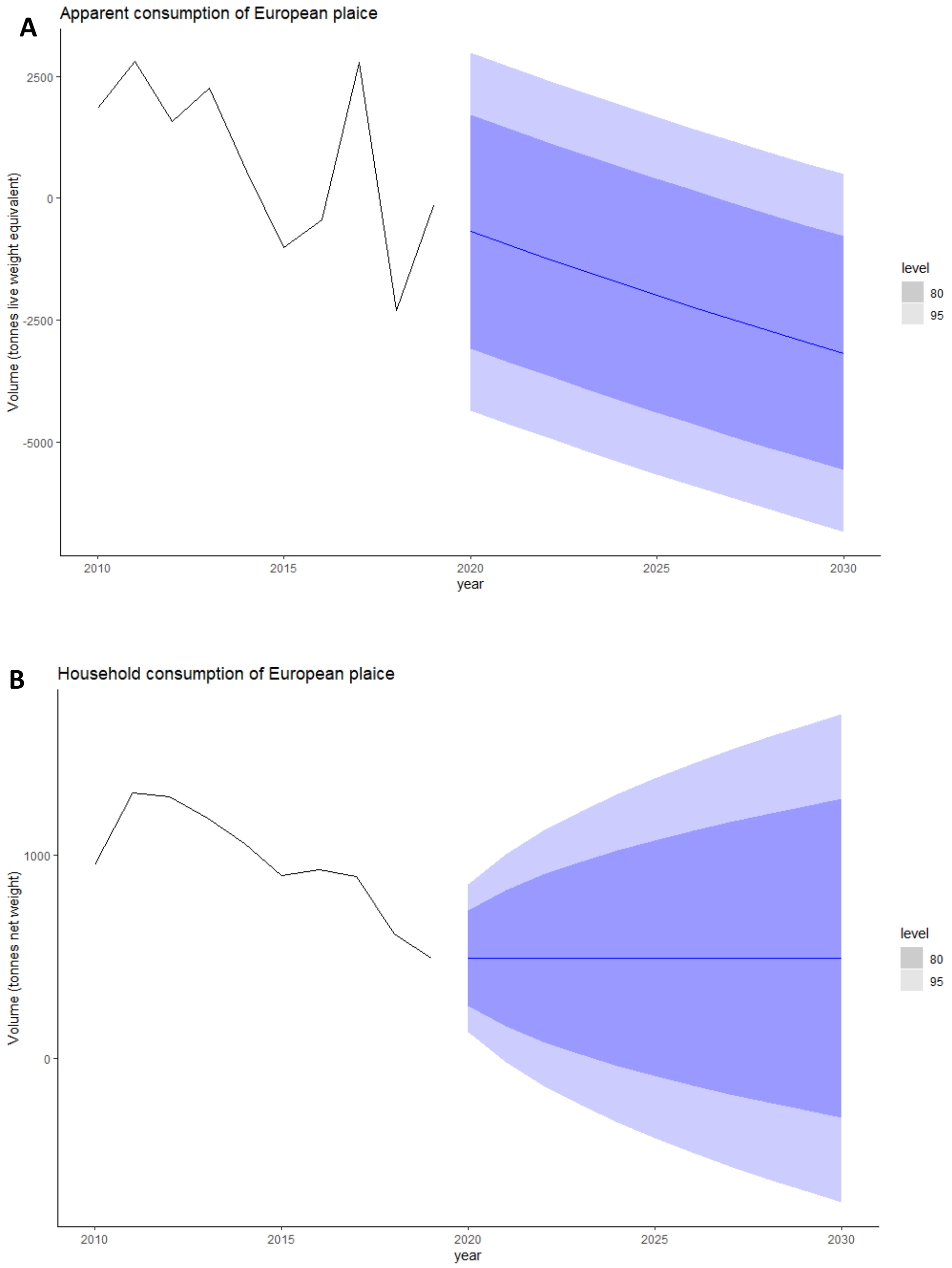
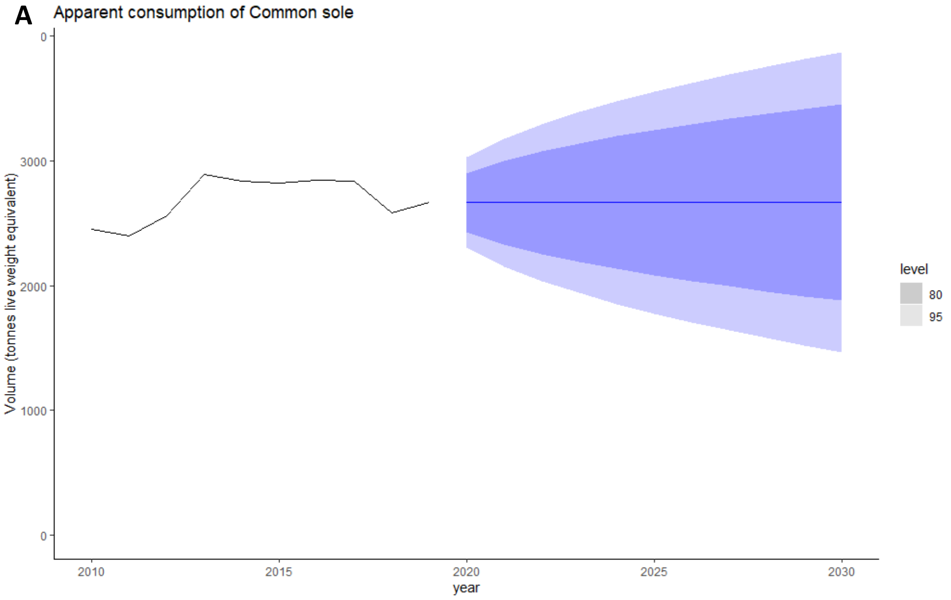


Figure 7: Time-series and forecasting estimates of European plaice (*Pleuronectes platessa*) A) apparent consumption and B) household consumption (2010-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast

8.1.3. Common sole



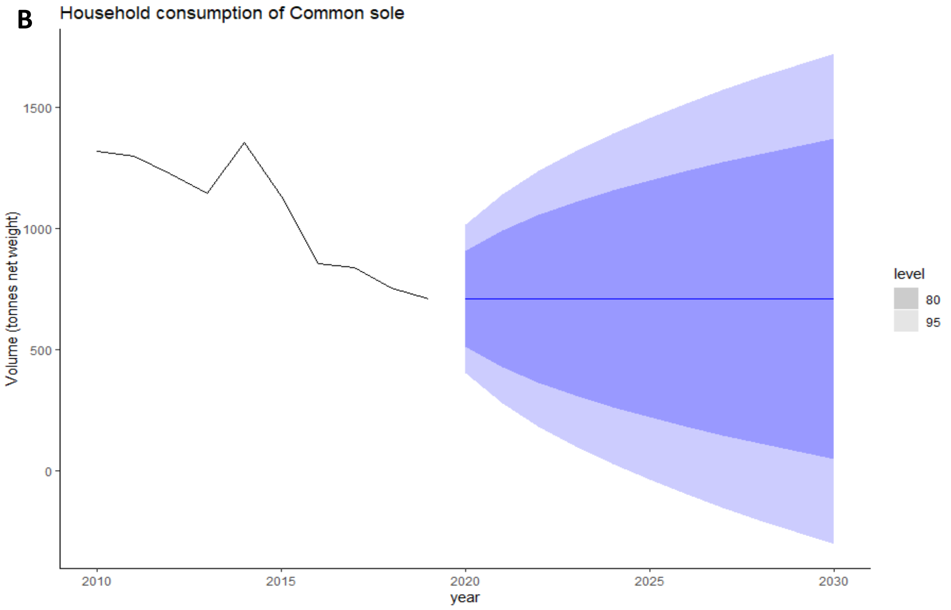
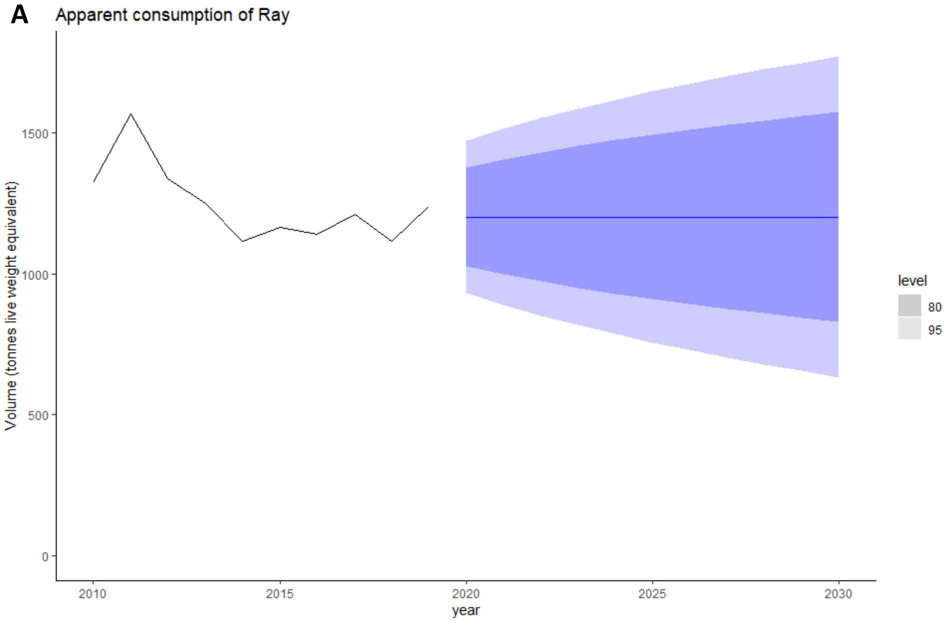


Figure 8: Time-series and forecasting estimates of Common sole (Solea solea) A) apparent consumption and B) household consumption (2010-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast.

8.1.4. Ray

A



B

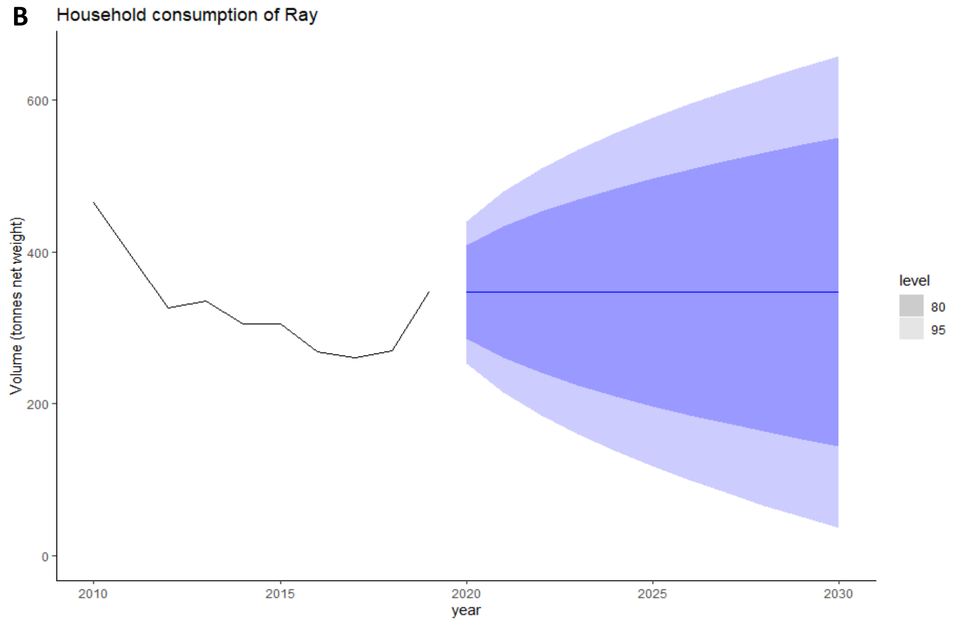


Figure 9: Time-series and forecasting estimates of rays (*Raja spp.*) A) apparent consumption and B) household consumption (2010-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast.

8.1.5.Shrimp

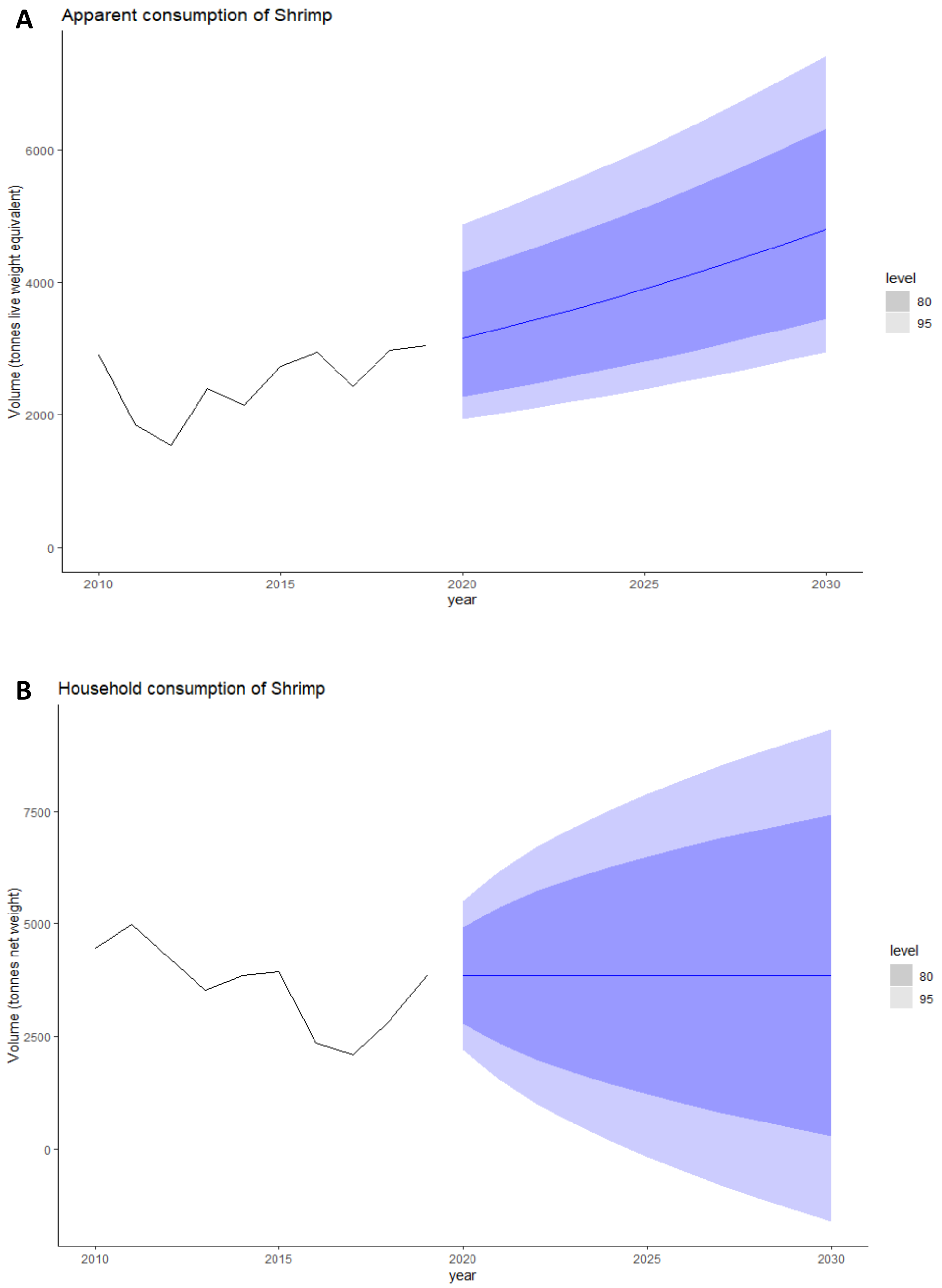


Figure 10: Time-series and forecasting estimates of shrimp (*Crangon spp.*) A) apparent consumption and B) household consumption (2010-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast.

8.1.6. Squid

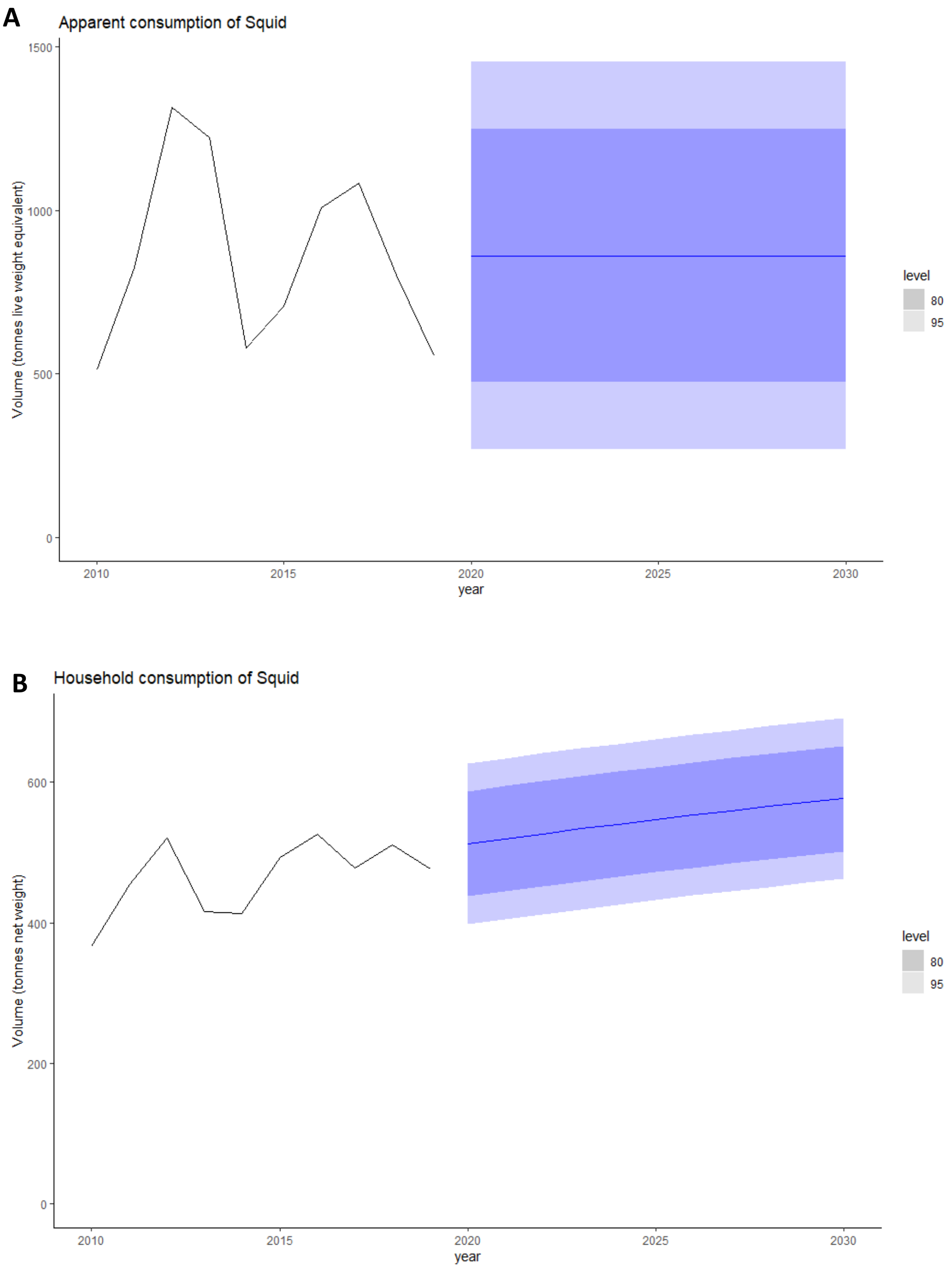
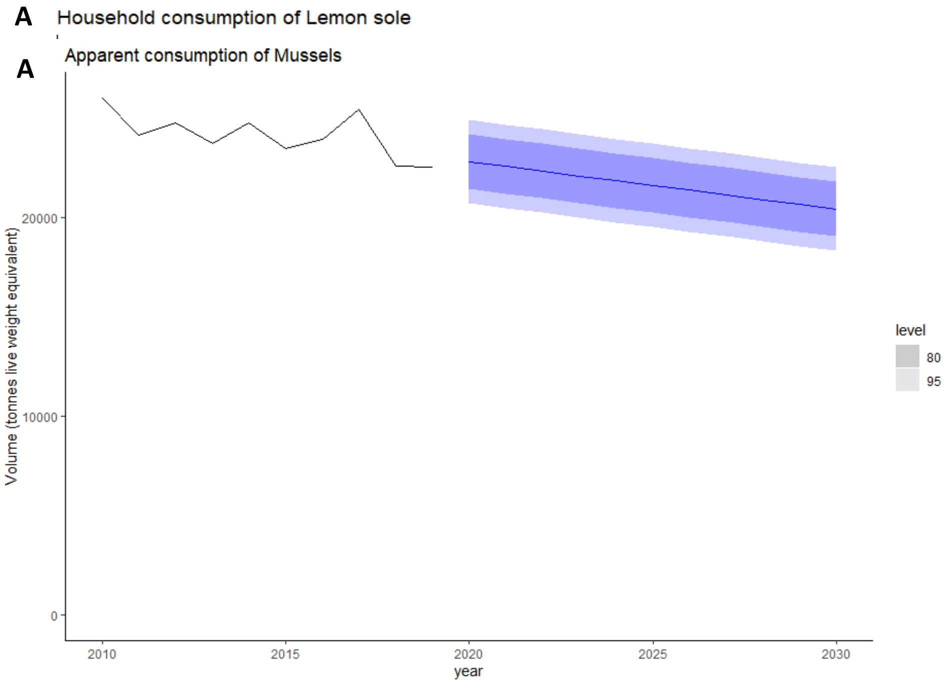


Figure 11: Time-series and forecasting estimates of squid (*Loligo spp.*) A) apparent consumption and B) household consumption (2010-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast.

8.1.7. Lemon sole & Gurnard



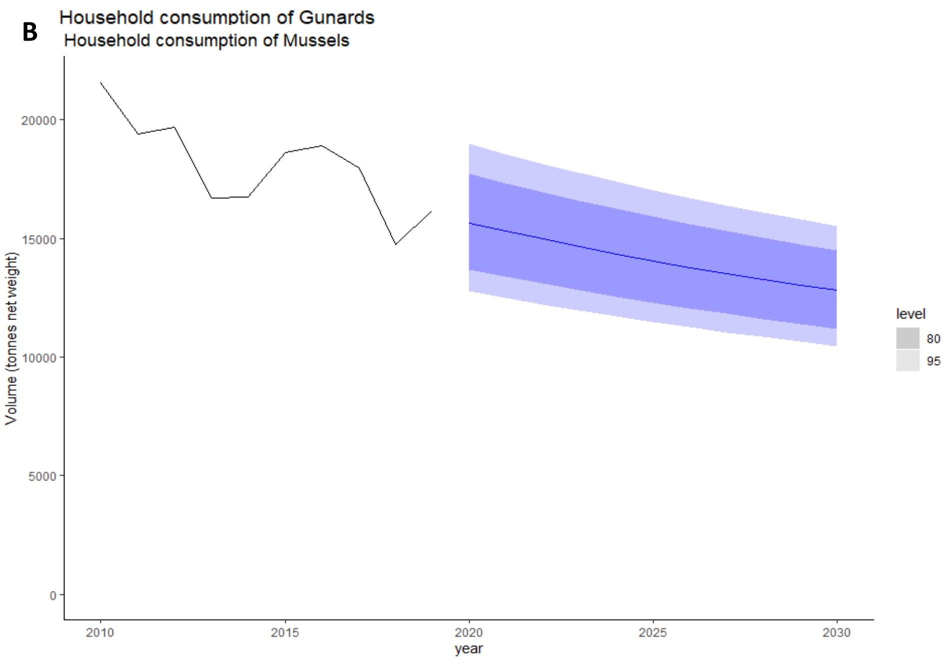


Figure 13: Time-series and forecasting estimates of mussels (*Mytilus spp*.) A) apparent consumption and B) household consumption (2010-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast.

8.1.8. Mussel

8.1.9. Oyster

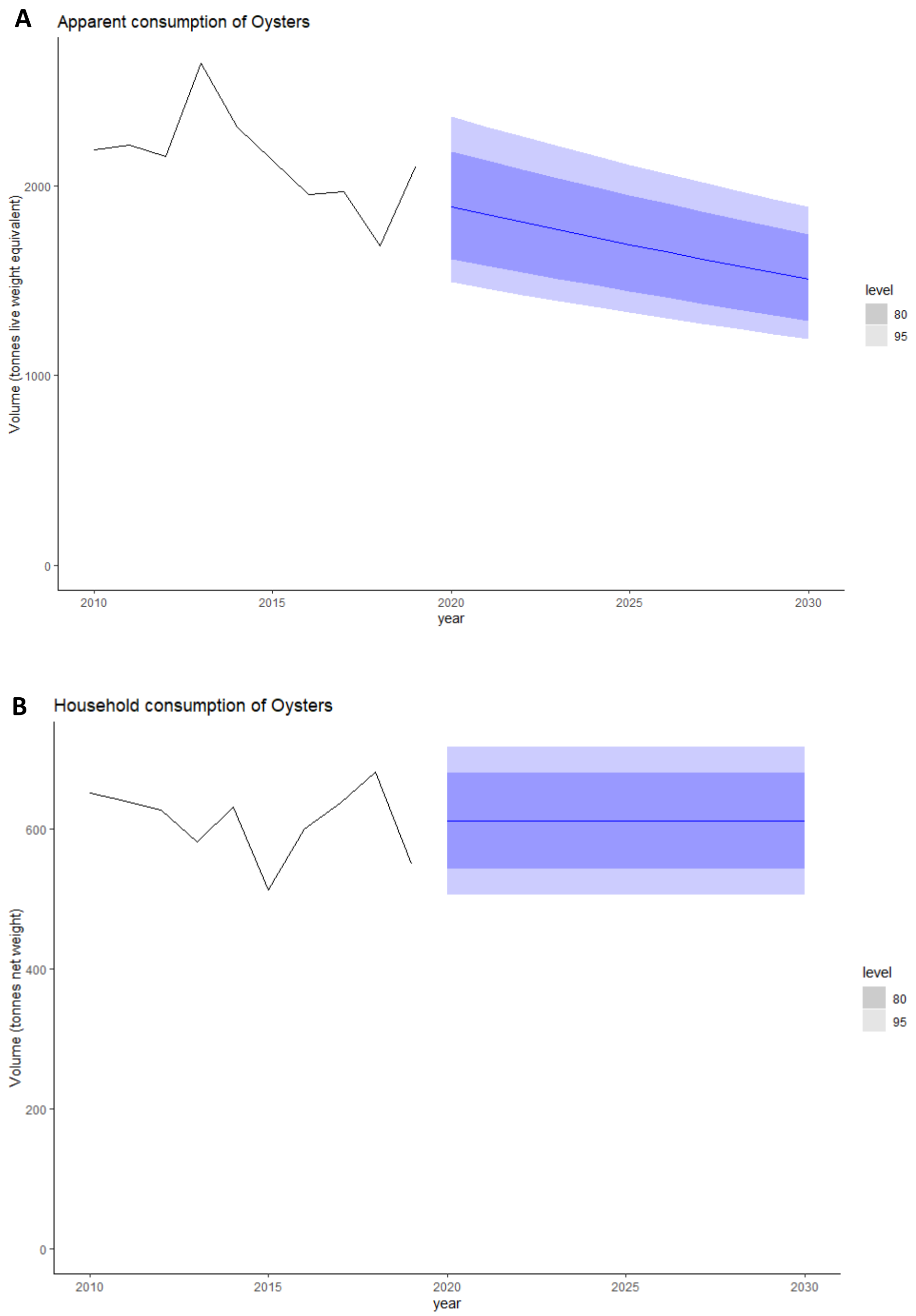


Figure 14: Time-series and forecasting estimates of oysters (*Ostrea spp. + Crassostrea spp.*) A) apparent consumption and B) household consumption (2010-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast.

8.2. Surface for navigation

8.2.1. Cargo

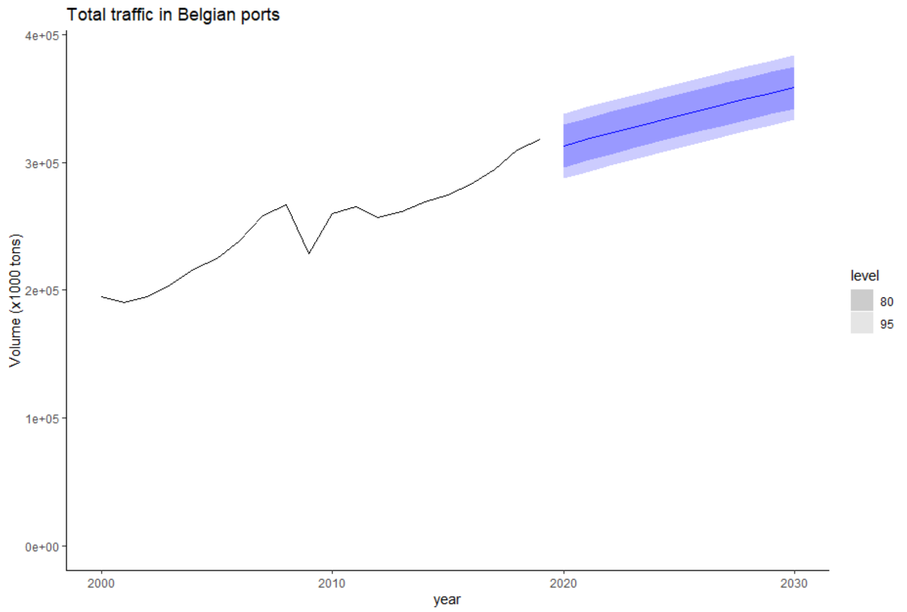


Figure 15: Time-series and forecasting estimates of cargo traffic in Belgian ports (2000-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast.

8.2.2. Ships

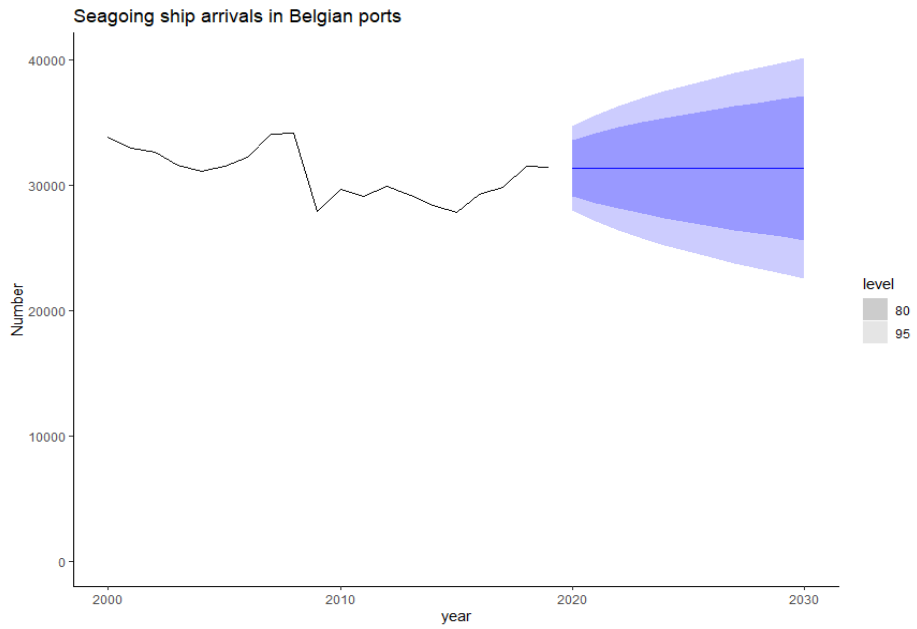


Figure 16: Time-series and forecasting estimates of seagoing ship arrivals in Belgian ports (2000-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast.

8.3. Renewable offshore energy

8.3.1. Electricity

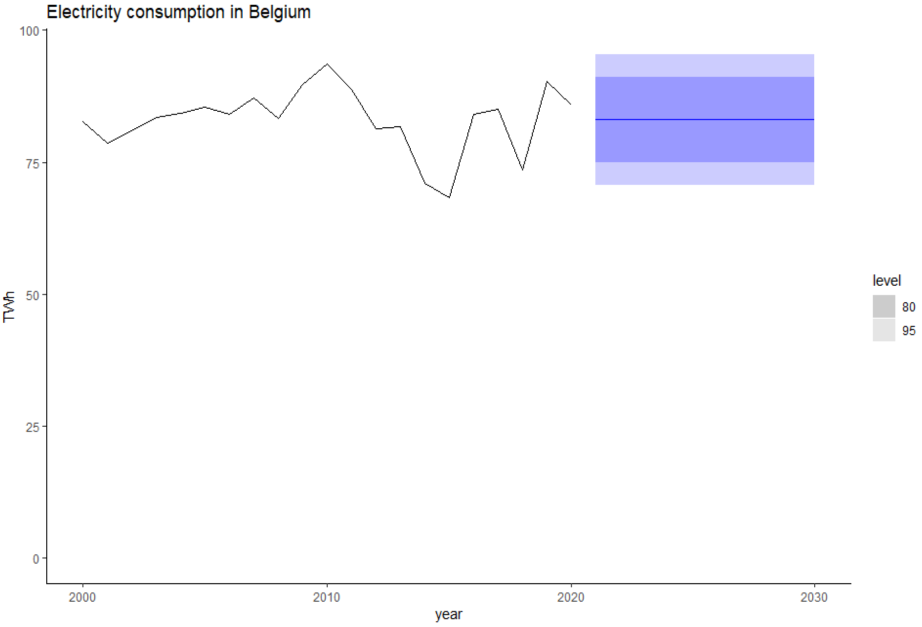


Figure 17: Time-series and forecasting estimates of electricity consumption in Belgium (2000-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast.

8.4. Mediation of wastes

8.4.1. Nitrogen

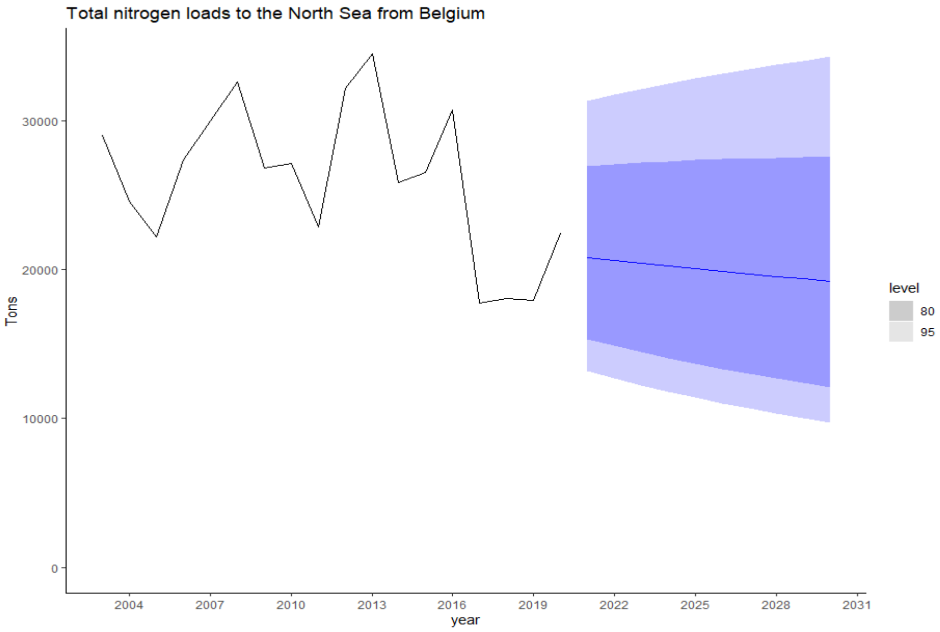


Figure 18: Time-series and forecasting estimates of nitrogen loads from Belgian rivers to the sea (2003-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast.

8.4.2. Phosphorous

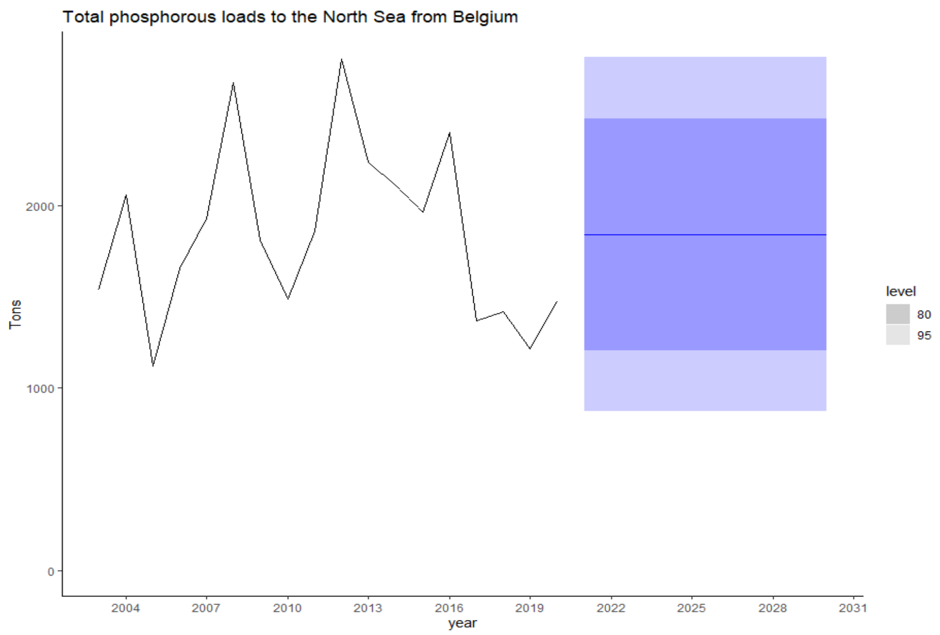


Figure 19: Time-series and forecasting estimates of phosphorous loads from Belgian rivers to the sea (2003-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast.

8.5. Climate regulation

8.5.1. CO_2

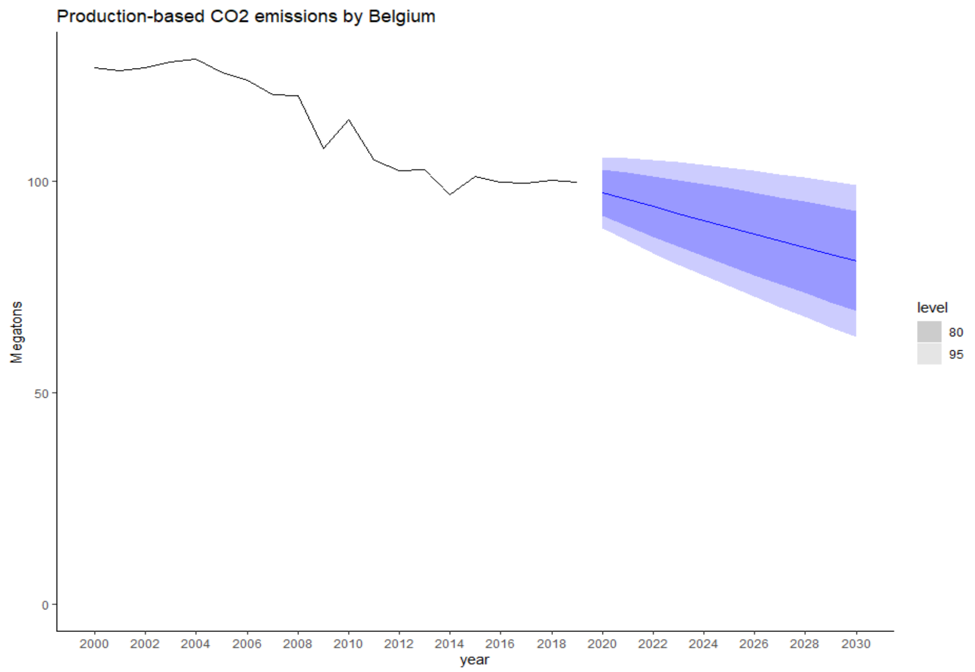


Figure 20: Time-series and forecasting estimates of production-based CO2 emissions in Belgium (2000-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast.

8.6. Recreation

8.6.1. Coastal day-tourists

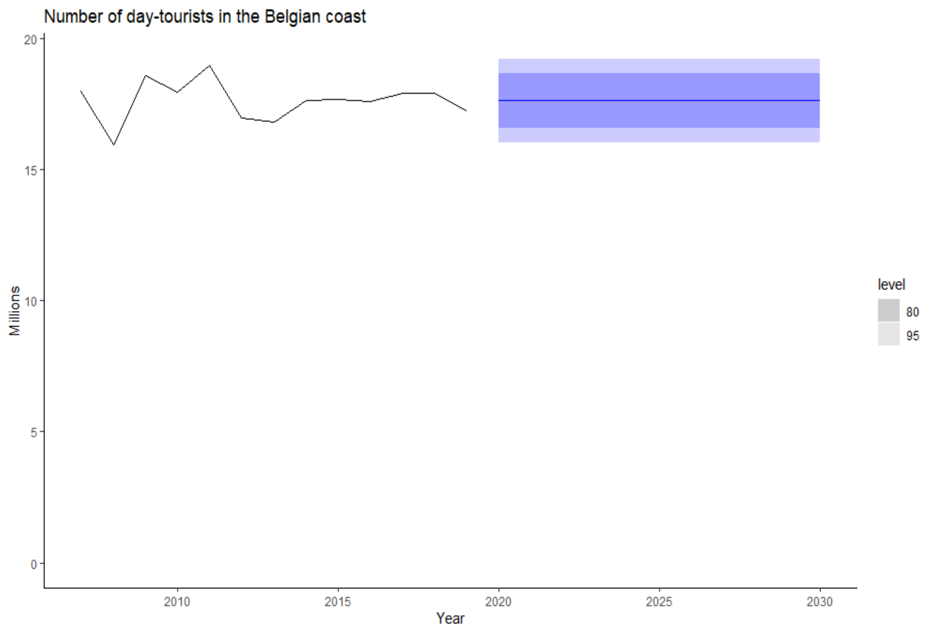


Figure 21: Time-series and forecasting estimates of day-tourists' visits to the coast (2007-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast.

8.6.2. Birdwatchers

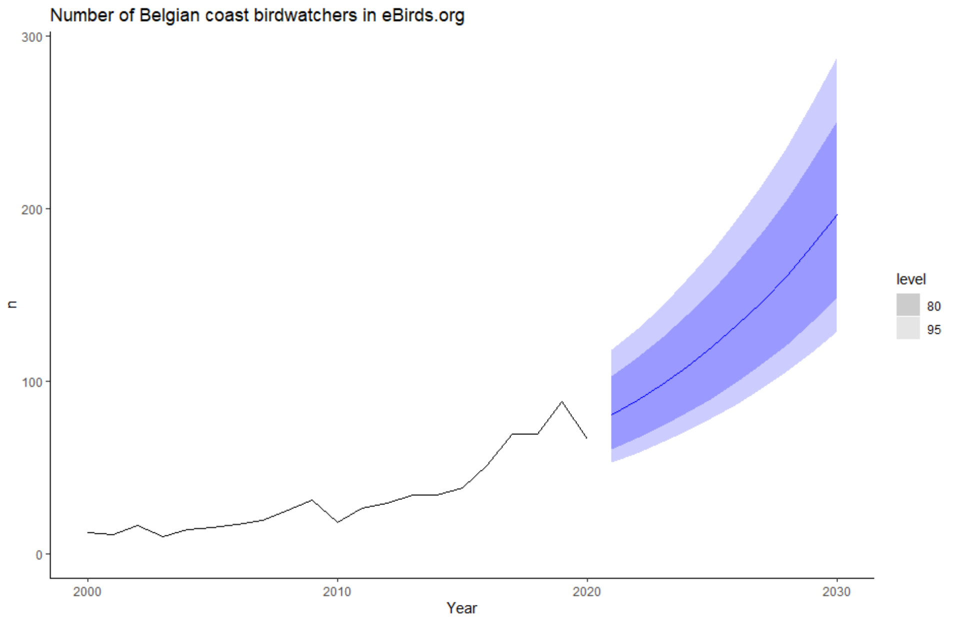


Figure 22: Time-series and forecasting estimates of coastal birdwatchers that use the eBird.org platform (2000-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast.

8.7. Aesthetic value

8.7.1.Seascape

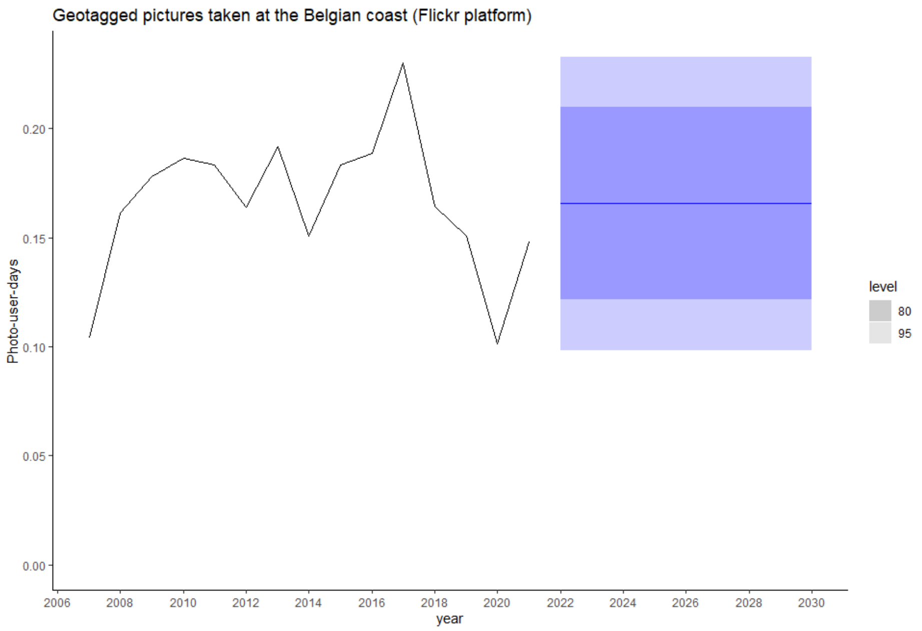


Figure 23: Time-series and forecasting estimates of BCS seascape-related pictures shared on the image-sharing platform Flick (2007-2030). Blue line – mean forecast; dark blue shade – 80% confidence interval forecast; light blue shade – 95% confidence interval forecast.

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