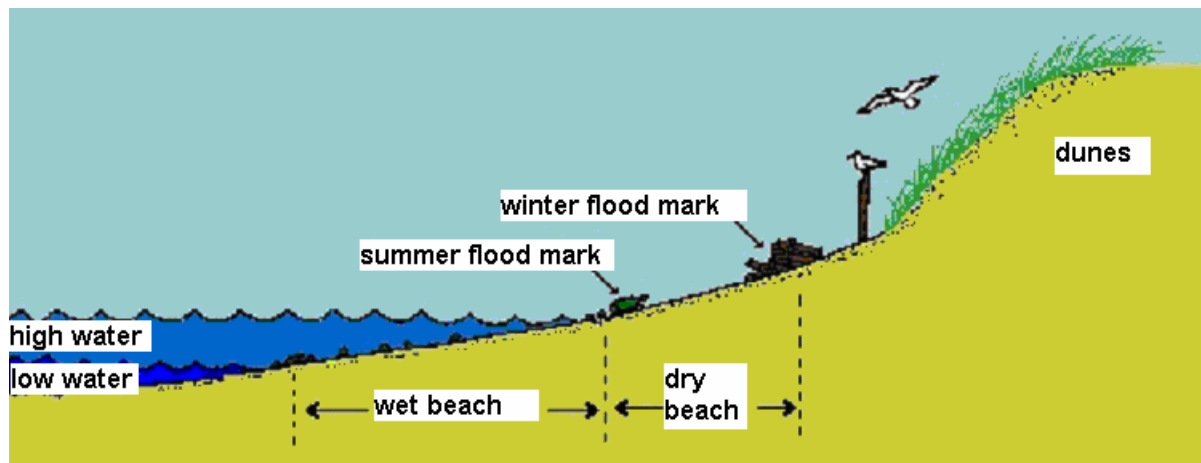


Figure I.2.3b: Illustrative picture of the different beach zones.



3.1 HARD COASTAL DEFENSE

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3.1.1 Description

Along the Belgian coast no natural hard substrates (rocky shores) are found. In the framework of coastal defense several artificial hard substrates have been built. Their most important function is the protection of the hinterland (dikes, groynes), the harbour (piers, moles) or the safeguarding of the shipping (buoys). Furthermore they form a substrate on which specific rocky shore communities can settle.

Along the Belgian coast four main types of hard substrates can be distinguished: groynes, dikes, moles and piers. Groynes, dikes and piers are directly exposed to waves, while moles (except the breakwaters of Zeebrugge) are found within the shelter of the harbour. In contrast to dikes that are orientated practically parallel with the wave activity, groynes are placed perpendicular to the waves. Besides, groynes are on base of their morphology differentiated in a rock-fill on the seaward side, a groyne top and two flanks, all subjected to a different hydrodynamic activity. Piers 'escort' all a harbour gully and consist of a complex construction of differently orientated balk- or pole-structures. These structures are made of wood or concrete.

A further division within the different types can be made on the basis of the following characteristics:

- The degree of exposure in relation to the waves. This is also determined by the degree of inclination (90° or 45°) and the orientation (parallel or perpendicular to the coastline) of the hard construction.
- The building material (concrete, (Belgian) blue stone (Du: Arduin), wood and/ or asphalt) that is determinative for e.g. the fixation of macro-algae.
- The length and height of the groynes that also influences the degree of exposure (in relation to the waves, sun).
- The shape (the presence/absence of a dump of stones, loose/fixed blocks) that is strongly correlated with the present habitat diversity.
- The degree of silting that strongly influences the absence of specific organisms.

Beside these coastal defense elements, also windmills and wrecks make part of the hard substrates along the Belgian coast.

3.1.2 Legislative framework

(updated by Cliquet A.)

3.1.2.1 Spatial delimitation

Competent authority

The competent authority for coastal defense is:

- Flemish Government, the Environment and Infrastructure Department (LIN), the Waterways and Maritime Affairs Administration (AWZ), Coastal Waterways (AWK).

Legislation

(Cliquet et al. 2004 ; Maes and Cliquet 2005)

The construction of coastal defense structures cannot be started before an EIA is executed and environmental permits are granted.

International legislation and Belgian implementation:

- Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment, *Official Journal L 175*, 5 July 1985, amended by Directive 97/11/EEC of 3 March 1997, *Official Journal L 73*, 14 March 1997:
- EC Directive 97/11/EC makes coastal defense EIA-obliged from 14/03/1999.
- Implementation in Belgium:
 - Decision of the Flemish Executive of 23 March 1989 on the organization of an environmental impact assessment for certain categories of harmful structures, *BS 17 mei 1989*, as amended: an EIA is needed for the construction of coastal defense structure or the building of a harbour.
 - Law of 20 January 1999 on the protection of the marine environment in the marine areas under Belgian jurisdiction, *BS 12 March 1999* as amended: an EIA is required for any activity at sea that requires a permit.

National legislation:

- Royal Decree of 4 August 1981 on a Police and Shipping Regulation for the Belgian territorial sea, the ports and beaches of the Belgian coast, *BS 1 September 1981*: this regulation declares that no works may be executed in the territorial sea, the harbours and on the beaches before a special permit of the valid authority is gained (art. 21).
- Royal Decree of 5 October 1992 concerning the determination of a list of waterways and their associated structures transferred from the State to the Flemish Region, *BS 6 November 1992*: the decree describes coastal defense as the entire public domain with as most important function the protection of the hinterland against the sea.
- Law of 20 January 1999 on the protection of the marine environment in the marine areas under Belgian jurisdiction, *BS 12 March 1999*; as amended: Coastal defense works that are executed at sea should normally be screened against the Law on protection of the marine environment, since

these can be considered as construction works that need a permit before execution (art. 25 §1). But in the same article (§3) an exception is made for activities that are necessary for the execution of the authority of the Flemish Government (according to article 6 §1, X, of the Special Law of 1980 on the state reform). These works still need an environmental impact assessment under the same law.

Flemish legislation:

- Decree of 18 May 1999 on the organization of spatial planning, *BS* 8 June 1999: the execution of coastal defense works can only go through after an urban planning permit is received. Changes of the relief of a terrain, by filling, elevating, excavating, is prohibited, unless an urban planning permit is granted.
- Decree of 14 July 1993 holding measures for the protection of coastal dunes, *BS* 31 August 1993: the Dune Decree establishes a prohibition of all construction works in protected dune areas. Construction works that need to be executed to maintain the nature conservation status of an area or coastal defense works are exceptions to this Decree.

Future perspectives

Not applicable

3.1.2.2 Type and intensity

Intensity per area-unit

There are no juridical restrictions on the number of coastal defense structures per area.

Frequency per unit of time

Not applicable

Future perspectives

Not applicable

3.1.3 Existing situation

3.1.3.1 Spatial delimitation

Artificial hard constructions are practically found along the entire Belgian coast. Near to all Belgian coastal cities promenades are constructed and different lines of dunes (e.g. Westhoek) are separated from the beach by dune base reinforcements (Du: duinvoetverstevingingen). A continuous series of groynes are found between Westende and Bredene and between Wenduine and Knokke. They are absent near to De Panne, Oostduinkerke, De Haan and the mouth of the Zwin. Harbour-related hard constructions (e.g. moles, breakwaters, piers and groynes accompanied by piers) are found in Nieuwpoort, Oostende, Blankenberge and Zeebrugge.

A high diversity of hard substrates are encountered along the Belgian coast:

Moles (Du: havenmuren) and breakwaters (Du: Strekdammen)

Harbour walls (moles) and breakwaters are found in all harbours (Nieuwpoort, Oostende, Blankenberge and Zeebrugge). Breakwaters are coastal defense structures that are mostly built parallel to the coast and that aim for the decrease of wave exposure. The longitudinal embankments in Zeebrugge are

currently the only forms of breakwaters along the Belgian coast. The enlargement project of the harbour of Oostende also foresees the construction of extended breakwaters.

Except the seaward side of both the breakwaters of Zeebrugge, all moles are strongly protected against wave exposure. They extend over the entire tidal zone. Moles have an inclination degree of 90° (quay) (e.g. Yacht basin of Oostende) to 45° (e.g. Harbour of Oostende).

The moles are constructed of blocks of concrete or (Belgian) blue stone (Arduin) (e.g. Oostende) or rock-fill, whether or not fixed with asphalt (e.g. parts of Zeebrugge). The blocks used vary strongly in size and form. The breakwaters are built of a core, a filter layer and a coating. The coating can exist of normal dumping stones, furrowed cubes or HARO-blocks, etc.

Dikes (Du: dijken) and dune base reinforcements (Du: duinvoet-versterking)

Dikes are found along practically the whole Belgian coast (e.g. in Oostende). They stretch out from far above the high water level to maximum one or two meters below the high waterline. Dikes are orientated parallel to the coastline which results in a strong exposure to the waves. Their degree of inclination is approximately 45°.

The dike-body exists mostly of a material that is found in the immediate vicinity as for example clay. Concrete blocks, nature stones, dumping stones (possibly impregnated with bitumen), asphalt or other materials protect the core.

Dune-fixations (e.g. De Panne (Nature reserve "De Westhoek")) stretch out to approximately 0.5 m below the high waterline. They can be constructed of gabion (Du: schanskorven), Dutch mattress (Du: zinkstukken) or rock fill and are often buried under a thick sand layer.

Groynes (Du: strandhoofden)

Groynes are relatively long, slender coastal defense elements that are built perpendicular to or under a great angle to the sea. Often they end landwards close to a dune-fixation or dike. Groynes are used to protect beaches against erosion.

Groynes are found along nearly the entire Belgian coast. In general they stretch out from above the high waterline to a few meters under the low waterline. Some groynes (Koksijde) stretch out approximately halfway into the intertidal zone. These are referred to as "beach groynes" (Dutch: strandkribbes). The height of the groynes varies between low (approx. 1 m; e.g. Koksijde) to high (to about 2 m; e.g. Oostende). Some groynes (e.g. Heist) are almost entirely buried under the sand.

In total 127 groynes and 33 beach groynes have been constructed. They show a high ecologically important morphological diversity.

A groyne can be divided in three zones:

- Section A between the dune and the crown of the groyne on the level of mean high water by dead tide (about 4 m T.A.W.).
- Section B: zone starting from section A to the intersection of the basis of the groyne with the mean low waterline by dead tide (about 0.5 – 1 m T.A.W.)
- Section C: zone from the mean low waterline by dead tide.

Groynes consist mostly of dumping material. The general building plan consists of a core of loose granular rubble that in the dry zone is held in place by a protecting coating of bricks, Blue Ashlarstone or concrete blocks. This coat layer is fixed with cement or sometimes covered with asphalt. Between the

stones wooden poles can sometimes be found (especially on the east coast). The head and the flanks in the wet part are protected by Dutch mattress in which stones are dumped. Between the blocks silted tide-pools can sometimes be found. Because of the arbitrarily piling up of the blocks, a great diversity of habitats can be found within the rock-fill (e.g. leaning over rocks).

Groynes can also be constructed of wooden poles. These are cheaper, but less efficient.

A further division on the basis of already mentioned selection criteria gives the following types of groynes along the Belgian coast (+ an example) (Table I.2.3a):

Table I.2.3a: Different types of groynes

Type	Type symbol	Characteristics	Example
Groyne	T1	Accompanied by a pier with a rock-fill	Blankenberge (BLSL)
	T2	High and long with a very high rock-fill	Knokke-Zoute (ZSL)
	T3	High and long with a rock-fill	Oostende (OSL)
	T4	Low and long with rock-fill	Koksijde (KSL)
	T3/T4	Middle high with rock-fill	Middelkerke
	T5	Low and long with wooden poles and rock-fill	Duinbergen (DSP)
Beach groyne	K	Low and short without rock-fill	Koksijde (KSK)

The biodiversity, the seasonality and the ecological interactions of the macro-fauna, macro-algae and avifauna of these different types of groynes (except of T3/T4) have been studied and the results can be found in Engledow et al. (2001) and Volckaert et al. (2003a; 2003b). In general, the ecological value on the groynes increases with the length, the height and the number of microhabitats. This explains the low diversity on beach groynes (Type K). Furthermore sand inundation has a negative effect. Finally, also the exposition gradient plays an important role. A greater diversity of algae are found in the more sheltered areas (T1, but especially in harbours (e.g. Zeebrugge), while the macro-fauna prefers a more exposed site.

Pier (Du: staketsel)

All piers "accompany" a harbour gully and are only found in the harbours of Nieuwpoort, Oostende and Blankenberge.

Piers exist of a complex construction of differently orientated balks or poles. These structures, built of wood (e.g. Duinbergen) or concrete (e.g. Blankenberge), stretch out from above the high waterline to some meters below the low waterline.

Others

Beside these four main types some other types have been distinguished e.g. drainpipes in Blankenberge, remnants of bunkers on the Belgian-French border and buoys.

Source

Administratie Waterwegen Zeewezen (AWZ), 2001. Oostende veilig voor overstromingen. Waterspiegel n°1, 4 p.

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Volckaert, A., Engledow, H., Beck, O., Degraer, S., Vincx, M., Coppejans, E. and Hoffmann, M., 2003b. *Onderzoek van de ecologische interacties van macroalgen, macrofauna en vogels geassocieerd met intertidale harde substraten langs de Vlaamse Kust*. Eindrapport in opdracht van het Min. Vlaamse Gemeenschap, Dept. Leefmilieu en Infrastructuur, Adm. Waterwegen en Zeewezen, Afd. Waterwegen Kust, 93 p.

Reliability margin

The reports about the biodiversity, seasonality and ecological interactions on artificial hard substrata are based on an intensive quantitative sampling campaign during 2000-2001. The study is very recent and of high quality.

Also the other literature used is of high standards and gives reliable information.

Future perspectives

No new groyne have been built in the last ten years. As a matter of fact, there is a current trend towards the use of soft coastal defense.

The planned enlargement of the harbour of Oostende will however lead to a big expansion of the area of coastal defense structures. The harbour project foresees in the building of two new moles (400 + 200 m) that will exercise a breakwater function. The new westerly dam will be situated near to the Capucijnenstraat and will also function as a promenade. The new easterly dam will be built as the extension of the Hendrik Baelskaai. Furthermore a new dike will be constructed in front of the Zeeheldenplein. This new dike will consist of a number of plateau's that will form a fluent transition from the beach to the dam. Finally a protection dam will be made to ensure the stability of the beach, to prevent the silting of the future harbour gully and to preserve the "Klein Strand".

Beside the construction of hard structures, the following elements will disappear: the eastern pier (Du: het Oosterstaketsel), the promenade (Du: de wandeldijk), the first groyne to the left of the "Klein strand".

Another future project could be the construction of a chaotic groyne in Lombardsijde (beach before the nature reserve "Ijzermonding").

3.1.3.2 Type and intensity

Intensity per surface-unit

Following appendices give an overview of the different coastal defense structures (hard substrates) along the Belgian coast and are digital available (source: data-base "Patrimonium" of AWK):

- Appendix 1: Inventory of the dikes along the Belgian coast (source AWK)
- Appendix 2: Inventory of the groynes along the Belgian coast (source AWK)
- Appendix 3: Inventory of the piers along the Belgian coast (source AWK)

Each appendix is digitally available with Ecolas and contains information about the length, the coating and the location of a specific hard structure. For the groynes also the type is mentioned (see also Table I.2.3b).

Table I.2.3b gives an overview of the number and total length per coastal defense type. Dikes and groynes form the two most important groupes.

Table I.2.3b: Coastal defense along the Belgian coast

Coastal defense	Number	Total length (m)
Moles/ breakwaters (only estimation of breakwaters available)	14	6560
Dike/ dune base reinforcement	163	39908
Groynes	171	45656
Piers	6	2977

A look at the dispersion of these 4 main types of coastal defenses along the Belgian coast reveals that the east coast (Oostende-East till Knokke-Heist) has the highest number (203). The most important cities are Middelkerke for the west coast (De Panne till Oostende-West) and Knokke-Heist for the east coast with respectively 58 and 72 coastal defense structures (Table I.2.3c).

Table I.2.3c: Dispersion of the 4 main types of coastal defense along the Belgian coast

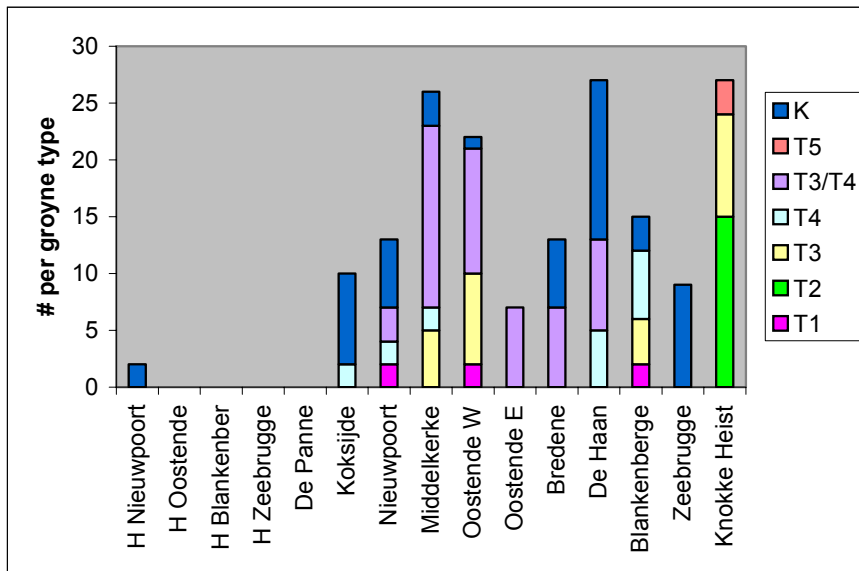
	Breakwater	Dikes	Groyne	Pier	Total
Harbour Nieuwpoort	1	0	2	2	5
Harbour Oostende	2	0	0	2	4
Harbour Blankenberge	2	0	0	2	4
Harbour Zeebrugge	9	2	0	0	11
De Panne	0	4	0	0	4
Koksijde	0	10	10	0	20
Nieuwpoort	0	12	13	0	25
Middelkerke	0	32	26	0	58
Oostende West	0	13	22	0	35
Oostende Oost	0	20	7	0	27
Bredene	0	3	13	0	16
De Haan	0	16	27	0	43
Blankenberge	0	3	15	0	18
Zeebrugge	0	3	9	0	12
Knokke Heist	0	45	27	0	72

As already mentioned, groynes can be divided in different types on the basis of several selection criteria (e.g. length, width, absence/presence rock-fill, etc.). Note: It is not always easy to make a distinction between the type T3, T4 and T3/T4. The distinction is subjective and depends mostly on the degree of sand inundation: the more sand, the

less substrate is available for the settlement of species. These groynes give the impression that they are low laying structures.

Figure I.2.3c gives an overview of these types of groynes along the Belgian coast. In the figure the harbours of the coastal cities are indicated with a H (harbour).

Figure I.2.3c: Dispersion of the different types of groynes along the Belgian coast



Groynes are typical coastal defense structures found along the open coast. The beach groynes (K) and the type T3/T4 are the most dominant types. The beach groynes are not being built anymore, because of their weak protection against coastal erosion. As already mentioned, their ecological value is also minimal (Engledow et al. 2001). In Knokke-Heist 2 typical types of groynes are found: T2 and T5. The first are very high groynes of which section C is characterised with a basin-structure that has an ecological importance for specific species like the hydrozoan *Tubularia indivisa*. Also lots of seastars (*A. rubens*) are found here. The other groyne type T5 is rarely found along the Belgian coast, in contrary to the Dutch coast. It consists of wooden poles and a rock-fill. Most of the groyne has disappeared by sand inundation.

Source

Data-base "Patrimonium" of AWK.

The information was provided by AWK (contact person: Dhr. Luc Linskens (Inspection), tel: 059/554 268, mobile: 0476/ 59 03 70, e-mail: luc.linskens@lin.vlaanderen.be).

Reliability margin

High

Future perspectives

For detailed information we refer to the MER Structureel herstel kustverdediging Oostende-centrum: http://www.lin.vlaanderen.be/awz/html/download/mer_oostende_centrum.pdf

Table I.2.3d: Harbour-project Oostende

New hard substrates	Disappearing hard substrates
2 harbour dams (400 m) ^{1 2}	Eastern Pier
Promenade on new dams ³	Promenade
Dike in front of Zeeheldenplein	Groyne n°1
Underwater dam (door TV Herbosch Kiere (Kallo)- Dredging International NV (Zwijndrecht)	

Frequency per time-unit

Not applicable

3.1.4 Interactions

3.1.4.1 Suitability for user

Biological suitability

Not applicable

Geological/physical suitability

Sinking in bottom

Hydrological suitability

Effects of currents, waves and sand movements on the construction has to be checked by use of models (e.g. WAVE, Delft 3D). This can be done in the "Waterbouwkundig Laboratorium" in Borgerhout (Golfgoot).

3.1.4.2 Impact on other users

Spatial conflict

Tourism:

- Positive: hard substrates as a place for mussels- or crab "fishers", educational (new biotope)
- Negative: danger zone for swimming; slippery because of algae; possible nuisance for e.g. beach sailing; disturbance of natural view

Shipping:

- Positive: safer shipping routes because of buoys, moles; the harbour complex itself

¹ First phase: construction western mole with promenade

² Second phase: construction eastern protection dam and the broadening and deepening of the harbour gully.

³ First phase: construction western mole with promenade

- Negative: nuisance of shipping traffic during repair/ construction coastal defense structures or dredging harbour gully.

Recreational fishery:

- Positive: creation of new fishing places on groynes, moles
- Negative: the underestimation of the risks of the hard substrates (e.g. slippery) by fishermen can cause serious accidents.

3.1.4.3 Impact on environment

Biological

- Positive: new habitat for rocky shore fauna (91 invertebrate spp.) and flora (78 macro-algae spp.); feeding-and foraging habitat for birds (gulls, *A.interpres*, *C.maritima*)
- Negative: permanent loss of habitat and biological productivity by the removal of intertidal and near-shore sections of the seabed (NOO 2002); disturbance of benthic communities of soft sediments during construction phase of new infrastructure; unnatural occurring substrates for the Belgian coast (originally sand beach ecosystem).

Geological/physical

- Positive: protection of inner land, deminishing beach/dune erosion
- Negative: former use of anti-fouling paints (toxic); asphalt fixation (leaking to surrounding environment); disturbance natural sand processes

Hydrological

- Positive: breaking of power of currents/ waves
- Negative: formation of eddies around groyne which can lead to depressions, gullies (possible danger)

3.1.4.4 Impact on socio-economy

Economic

Costs:

- The construction, the maintenance and the control of coastal defense structures is the authority of the Ministry of Flanders, the Environment and Infrastructure Department (LIN), the Waterways and Maritime Affairs Administration (AWZ), Coastal Waterways (AWK)
- Last 10 years no new investments in the construction of new groynes, only maintenance
- Cost of maintenance: no data
- Cost of groyne: depending on the length and width of groyne
- Costs totally financed by the State
- Estimation of groyne of 603 m length (source: AWK):
 - Section A (120 m long, about 3 m width): 272683 euro
 - Section B (98 m long, about 3 m width): 156173 euro
 - Section C (385 m long, up to 20 m width): 1115 million euro

- Total: 1544 million euro
- New harbour project Oostende:
 - cost for the construction of the harbour and the planned coastal defense: 37.2 million euro
 - cost underwater dam: 6.2 million euro

Income:

- Income because of greater touristical value (horeca, fishing, etc.)
- Temporary job creation

Social

- Positive: job creation
- Negative: nuisance during construction (noise, traffic, view etc.)

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Inventarisatie Coastal defense: dhr. Luc Linskens (tel: 059/ 554 268; gsm: 0476/ 59 03 70; email: luc.linskens@lin.vlaanderen.be): complete database with all hard substrates: "Databank patrimonium" op de site van LIN (internal access): contact person Filip Albregt (tel. 059/554.280, e-mail filip.albregt@lin.vlaanderen.be).

Information on Ports of Ostend and Zeebrugge: constructions situated in the area under responsibility of Maritieme Toegang are not inspected or available in the database.

3.1.6 Appendices

Following appendices are based on the data-base "Patrimonium" of AWK and are digitaly available with Ecolas:

Appendix 1: Inventory of the dikes along the Belgian coast (source AWK)

Appendix 2: Inventory of the groynes along the Belgian coast (source AWK)

Appendix 3: Inventory of the piers along the Belgian coast (source AWK)

Other:

Appendix 4: Specific terminology

Appendix 4: Specific terminology

Source: Translation of terms by Peter De Wolf (AWK)

Avifauna:	Vogels
(Belgian) Blue stone:	Arduin
Beach groyne:	Kribbe
Blue ashlarstone:	Blauwe hardsteen
Breakwater:	Strekdam
Concrete:	Beton
Dyke:	Dijk
Dune base reinforcement:	Duinvoetversterking
Dutch mattress:	Zinkstukken
Gabion:	Schanskorven
Groyne:	Strandhoofd
Macro-algae:	Macro-wieren (vb. blaaswier (<i>F. vesiculosus</i>), darmwier (<i>Enteromorpha</i> spp.))
Macro-fauna:	Macro-fauna (> 1 mm; vb. mossels (<i>M. edulis</i>), anemonen (vb. <i>Sagartia</i> spp.), wormen (vb. <i>Polydora</i> spp.), kreeftachtigen (vb. <i>Corophium</i> spp.), krabben (vb. <i>C. maenas</i>), etc.)
Mole:	Havenmuur
Pier:	Staketsel
Promenade:	Wandeldijk
Rock-fill:	Steenstort