SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY
(SPSD II)

Part 2:
Global change, Ecosystems and Biodiversity

Annex 1

BALANS

BALANCING IMPACTS OF HUMAN ACTIVITIES IN THE NORTH SEA

EV/21

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BELGIAN SCIENCE POLICY

ANNEX 1:
SAND AND GRAVEL EXTRACTION
DRIVING FORCE

1 MAIN STOCK AND FLOW

1.5 natural rate

DATA: available

- Source: Management Unit of the North Sea Mathematical Models, Royal Belgian Institute of Natural Sciences
- Dataset: According to the expert, the yearly balance of the sedimentary and erosive process is zero. Without further knowledge of the spreading around this value of the year, this parameter has been taken constant and equal to zero.

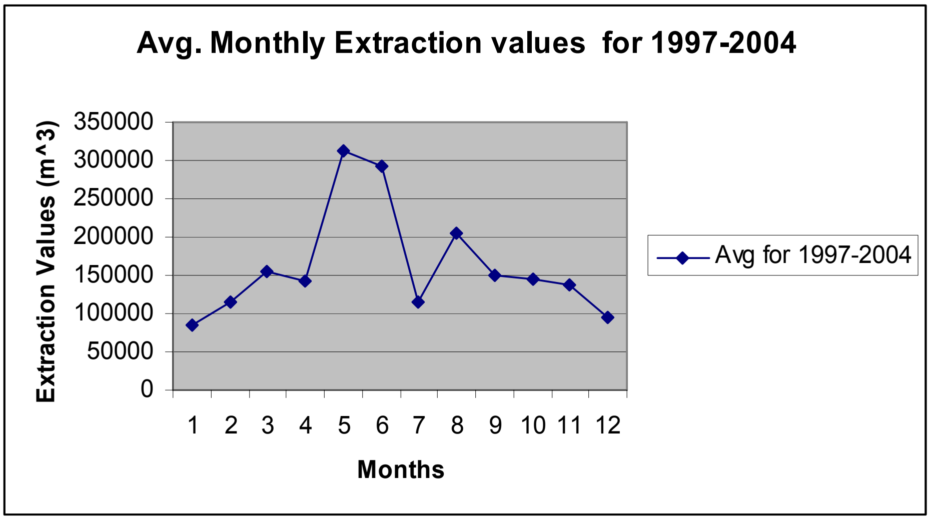
2 DEMAND FOR EXTRACTION

2.1 total demand

DATA: calculated and verifiable

- Source: FOD Economie, KMO, Middenstand en Energie
- Dataset: Extracted volume of sediment over all types per month over years 1997-2004.

MONTH	Volume Extracted in m³
January	85,017
February	116,201
March	154,587
April	142,275
May	313,029
June	291,466
July	115,560
August	206,109
September	150,410
October	144,673
November	137,177
December	95,464



Graph 1. Averaged monthly extraction values (m³) of sediment over years 1997-2004. Source of data is Federal Public Service of Economy, SME's, Self-Employment & Energy, 1997-2004.

2.3 Fraction

DATA: virtual values estimated from grey literature

- Fine sand: 10%; Medium and coarse sand: 85%; Gravel: 5%

2.6 Quotum over 5 years

DATA: available as one set value = 15,000,000 m³ for 5 years

- Source: Koninklijk besluit van 1 september 2004 betreffende de voorwaarden, de geografische begrenzing en de exploratie en de exploitatie van de minerale en andere niet-levende rijkdommen in de territoriale zee en op het continential plat, *O.J.* 7 october 2004

3 EXTRACTION

3.1 percentage of overlap

DATA: virtual

3.5 regime of the zones

- Source: virtual
- Dataset:

DEFAULT VALUES:

Zone	Flag
1a	1
1b	1
2a	1
2b	0
2c	1
3a	1
3b	0
4	0

3.7 surface of pockets

The classification scheme used by the geologists differs from the classification scheme of the 'extractors'. For example the classifications of the Renard Center of Marine Geology, University of Gent is following the Wentworth Scale that have grain fractions that take a median value for a grain type. Whereas, the extractor have a classification system that takes the maximum grain size into account when fulfilling a request for sand extraction by concession holders. To quantify the 'surface of the pockets' we have the information of the geologists. This then presents another issue where the grain sizes that are the focus of the extractors and the geologists differ in size scale. For the purpose of this model we have taken the datasets of the geologists and classified them into 3 grain fractions, these being 'fine sand', 'medium-coarse sand' and 'gravel'. We currently use the Folk Classification from the geologists that classifies according to percentage silt-clay, sand and gravel.

DATA:

- Source: Renard Center of Marine Geology, University of Gent
- Dataset: Surface area (m²) of 24 pockets; classified by Wentworth Scale

ZONE	**FS (0-250 mu)**	**MCS (250-500 mu)**	**Coarse Sand (>500mu)**
1A	0	78351048	0
1B	0	26365624	0
2A	1175838	9952507	437500
2B	14097899	22257829	0
2C	6670396	97448683	125000
3A	6722063	788082	0
3B	6764903	2625900	0
4	0	306693018	687500

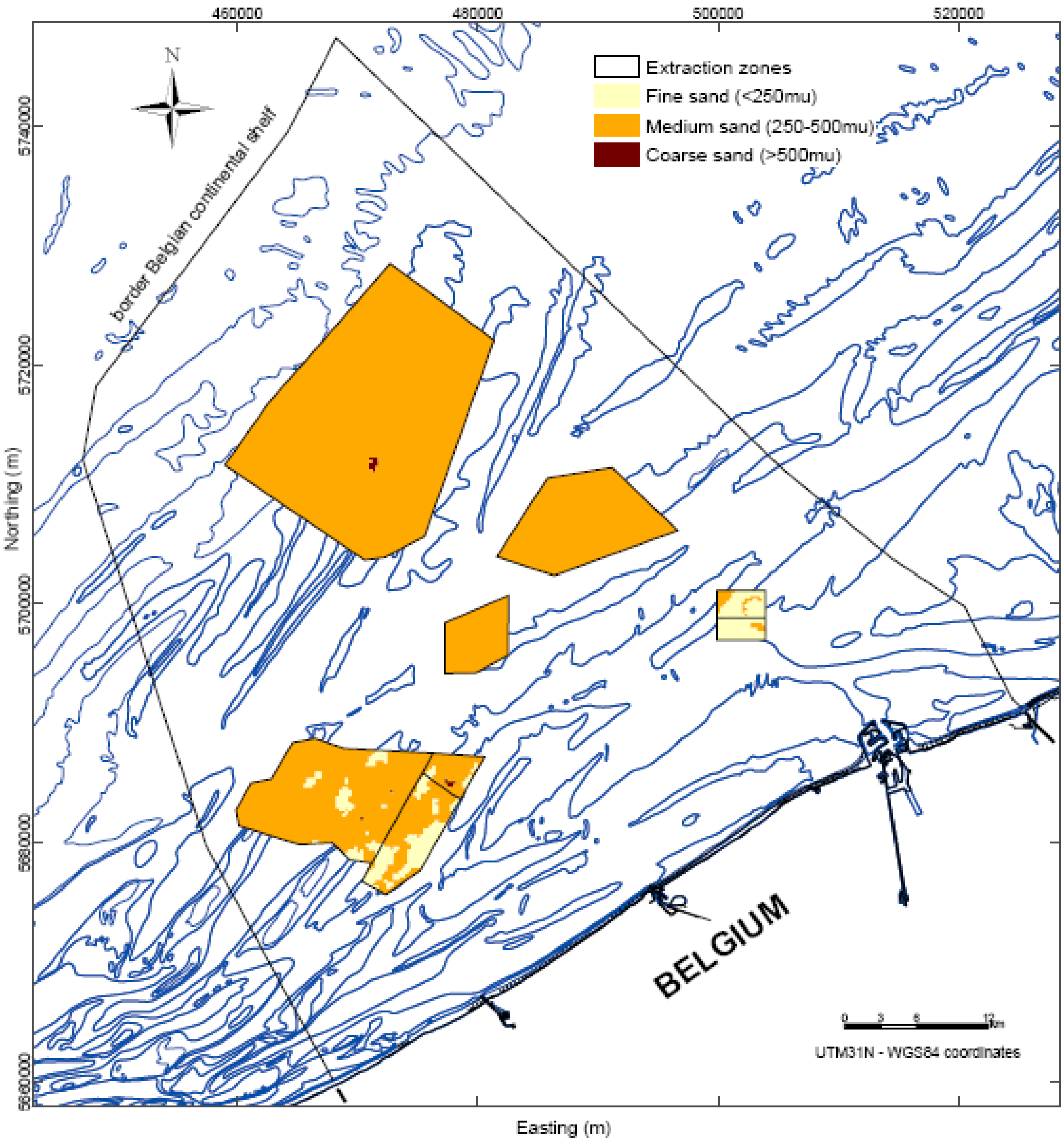


Fig. 1. Surface of the grain pockets within extraction zones according to d50 classification. Displayed are the fine sand (<250mu) , medium sand (250-500mu) and coarse sand (>500mu) classes. Source: Renard Center of Marine Geology, Ghent University 2006

DATA:

- Source: Renard Center of Marine Geology, University of Gent
- Dataset: Surface area (m²) of 24 pockets; classified by Folk Classification

ZONE	gmS+mS	gS+S	sG
1A	1773229	76247515	330305
1B	0	26365623	0
2A	0	11565844	0
2B	0	36355728	0
2C	0	104244079	0
3A	359517	7150628	0
3B	3968809	5421994	0
4	0	307318017	62500

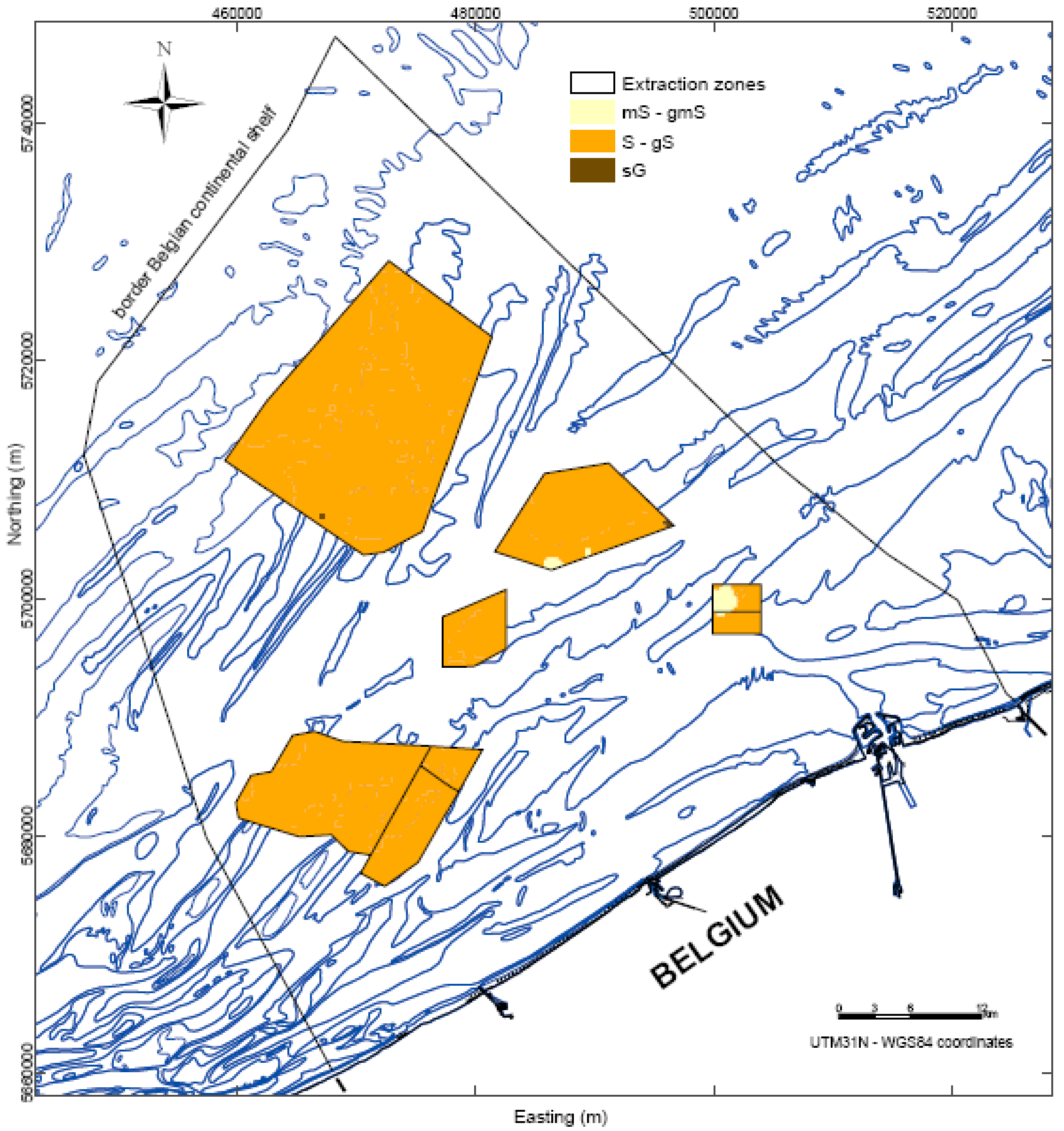


Fig. 2. Surface of the grain pockets within extraction zones according to Folk classification. Displayed are the mS-gmS, S-gS and sG classes. Source: Renard Center of Marine Geology, Ghent University 2006

3.8 extraction depth of gear

DATA:

- Source: Reimerswaal, personal communication
- Dataset: available as one set value = 0.5m

3.9 sum of surfaces

DATA:

- Source: Renard Center of Marine Geology, University of Gent
- Dataset: see annex section 3.7

3.11 surface to be extracted per zone and type

DEFINITION: With this variable, we distribute the monthly demand for a given grain size over the zones. When the first zone is closed (either by policy or because the critical depth is reached) we go to the next one, in order of increasing distance of the zones to the shore. It is a "virtual" surface as it does not take into account the actual extraction depth.

EQUATION:

Surface_to_be_extracted_per_zone_and_type[Zone1a,Fine_Sand] = IF
((Critical_depth_flag[Zone3a,Fine_Sand]+
Critical_depth_flag[Zone3b,Fine_Sand]+
Critical_depth_flag[Zone2a,Fine_Sand]+
Critical_depth_flag[Zone2b,Fine_Sand]+
Critical_depth_flag[Zone1b,Fine_Sand])=0 AND
Critical_depth_flag[Zone1a,Fine_Sand]=1)
THEN
To_be_extracted_nominal_surface_per_type[Fine_Sand]
ELSE
(0)

Surface_to_be_extracted_per_zone_and_type[Zone1a,Medium_Coarse_Sand] = IF
((Critical_depth_flag[Zone3a,Medium_Coarse_Sand]+
Critical_depth_flag[Zone3b,Medium_Coarse_Sand]+
Critical_depth_flag[Zone2a,Medium_Coarse_Sand]+
Critical_depth_flag[Zone2b,Medium_Coarse_Sand]+
Critical_depth_flag[Zone1b,Medium_Coarse_Sand])=0 AND
Critical_depth_flag[Zone1a,Medium_Coarse_Sand]=1)
THEN
To_be_extracted_nominal_surface_per_type[Medium_Coarse_Sand]
ELSE
(0)

Surface_to_be_extracted_per_zone_and_type[Zone1a,Gravel] = IF
((Critical_depth_flag[Zone3a,Gravel]+
Critical_depth_flag[Zone3b,Gravel]+
Critical_depth_flag[Zone2a,Gravel]+
Critical_depth_flag[Zone2b,Gravel]+
Critical_depth_flag[Zone1b,Gravel])=0 AND
Critical_depth_flag[Zone1a,Gravel]=1)
THEN

```
  To_be_extracted_nominal_surface_per_type[Gravel]
ELSE
 (0)

Surface_to_be_extracted_per_zone_and_type[Zone1b,Fine_Sand]  =  IF
((Critical_depth_flag[Zone3a,Fine_Sand]+
Critical_depth_flag[Zone3b,Fine_Sand]+
Critical_depth_flag[Zone2a,Fine_Sand]+
Critical_depth_flag[Zone2b,Fine_Sand])=0 AND
Critical_depth_flag[Zone1b,Fine_Sand]=1)
THEN
  To_be_extracted_nominal_surface_per_type[Fine_Sand]
ELSE
 (0)

Surface_to_be_extracted_per_zone_and_type[Zone1b,Medium_Coarse_Sand]  =  IF
((Critical_depth_flag[Zone3a,Medium_Coarse_Sand]+
Critical_depth_flag[Zone3b,Medium_Coarse_Sand]+
Critical_depth_flag[Zone2a,Medium_Coarse_Sand]+
Critical_depth_flag[Zone2b,Medium_Coarse_Sand])=0 AND
Critical_depth_flag[Zone1b,Medium_Coarse_Sand]=1)
THEN
  To_be_extracted_nominal_surface_per_type[Medium_Coarse_Sand]
ELSE
 (0)

Surface_to_be_extracted_per_zone_and_type[Zone1b,Gravel]  =  IF
((Critical_depth_flag[Zone3a,Gravel]+
Critical_depth_flag[Zone3b,Gravel]+
Critical_depth_flag[Zone2a,Gravel]+
Critical_depth_flag[Zone2b,Gravel])=0 AND
Critical_depth_flag[Zone1b,Gravel]=1)
THEN
  To_be_extracted_nominal_surface_per_type[Gravel]
ELSE
 (0)

Surface_to_be_extracted_per_zone_and_type[Zone2a,Fine_Sand]  =  IF
((Critical_depth_flag[Zone3a,Fine_Sand]+
Critical_depth_flag[Zone3b,Fine_Sand])=0 AND
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Critical_depth_flag[Zone2a,Fine_Sand]=1)
THEN
 To_be_extracted_nominal_surface_per_type[Fine_Sand]
ELSE
 (0)

Surface_to_be_extracted_per_zone_and_type[Zone2a,Medium_Coarse_Sand] = IF
((Critical_depth_flag[Zone3a,Medium_Coarse_Sand]+
Critical_depth_flag[Zone3b,Medium_Coarse_Sand])=0 AND
Critical_depth_flag[Zone2a,Medium_Coarse_Sand]=1)
THEN
 To_be_extracted_nominal_surface_per_type[Medium_Coarse_Sand]
ELSE
 (0)

Surface_to_be_extracted_per_zone_and_type[Zone2a,Gravel] = IF
((Critical_depth_flag[Zone3a,Gravel]+
Critical_depth_flag[Zone3b,Gravel])=0 AND
Critical_depth_flag[Zone2a,Gravel]=1)
THEN
 To_be_extracted_nominal_surface_per_type[Gravel]
ELSE
 (0)

Surface_to_be_extracted_per_zone_and_type[Zone2b,Fine_Sand] = IF
((Critical_depth_flag[Zone3a,Fine_Sand]+
Critical_depth_flag[Zone3b,Fine_Sand]+
Critical_depth_flag[Zone2a,Fine_Sand])=0 AND
Critical_depth_flag[Zone2b,Fine_Sand]=1)
THEN
 To_be_extracted_nominal_surface_per_type[Fine_Sand]
ELSE
 (0)

Surface_to_be_extracted_per_zone_and_type[Zone2b,Medium_Coarse_Sand] = IF
((Critical_depth_flag[Zone3a,Medium_Coarse_Sand]+
Critical_depth_flag[Zone3b,Medium_Coarse_Sand]+
Critical_depth_flag[Zone2a,Medium_Coarse_Sand])=0 AND
Critical_depth_flag[Zone2b,Medium_Coarse_Sand]=1)
THEN

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  To_be_extracted_nominal_surface_per_type[Medium_Coarse_Sand]
ELSE
 (0)

Surface_to_be_extracted_per_zone_and_type[Zone2b,Gravel] = IF
((Critical_depth_flag[Zone3a,Gravel]+
Critical_depth_flag[Zone3b,Gravel]+
Critical_depth_flag[Zone2a,Gravel])=0 AND
Critical_depth_flag[Zone2b,Gravel]=1)
THEN
  To_be_extracted_nominal_surface_per_type[Gravel]
ELSE
 (0)

Surface_to_be_extracted_per_zone_and_type[Zone2c,Fine_Sand] = IF
((Critical_depth_flag[Zone3a,Fine_Sand]+
Critical_depth_flag[Zone3b,Fine_Sand]+
Critical_depth_flag[Zone2a,Fine_Sand]+
Critical_depth_flag[Zone2b,Fine_Sand]+
Critical_depth_flag[Zone1b,Fine_Sand]+
Critical_depth_flag[Zone1a,Fine_Sand])=0 AND
Critical_depth_flag[Zone2c,Fine_Sand]=1)
THEN
  To_be_extracted_nominal_surface_per_type[Fine_Sand]
ELSE
 (0)

Surface_to_be_extracted_per_zone_and_type[Zone2c,Medium_Coarse_Sand] = IF
((Critical_depth_flag[Zone3a,Medium_Coarse_Sand]+
Critical_depth_flag[Zone3b,Medium_Coarse_Sand]+
Critical_depth_flag[Zone2a,Medium_Coarse_Sand]+
Critical_depth_flag[Zone2b,Medium_Coarse_Sand]+
Critical_depth_flag[Zone1b,Medium_Coarse_Sand]+
Critical_depth_flag[Zone1a,Medium_Coarse_Sand])=0 AND
Critical_depth_flag[Zone2c,Medium_Coarse_Sand]=1)
THEN
  To_be_extracted_nominal_surface_per_type[Medium_Coarse_Sand]
ELSE
 (0)
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Surface_to_be_extracted_per_zone_and_type[Zone2c,Gravel] = IF ((Critical_depth_flag[Zone3a,Gravel]+
Critical_depth_flag[Zone3b,Gravel]+
Critical_depth_flag[Zone2a,Gravel]+
Critical_depth_flag[Zone2b,Gravel]+
Critical_depth_flag[Zone1b,Gravel]+
Critical_depth_flag[Zone1a,Gravel])=0 AND
Critical_depth_flag[Zone2c,Gravel]=1)
THEN
To_be_extracted_nominal_surface_per_type[Gravel]
ELSE
(0)

Surface_to_be_extracted_per_zone_and_type[Zone3a,Fine_Sand] = IF (Critical_Depth_flag[Zone3a,Fine_Sand]=1)
THEN
To_be_extracted_nominal_surface_per_type[Fine_Sand]
ELSE (0)

Surface_to_be_extracted_per_zone_and_type[Zone3a,Medium_Coarse_Sand] = IF (Critical_Depth_flag[Zone3a,Medium_Coarse_Sand]=1)
THEN
To_be_extracted_nominal_surface_per_type[Medium_Coarse_Sand]
ELSE (0)

Surface_to_be_extracted_per_zone_and_type[Zone3a,Gravel] = IF (Critical_Depth_flag[Zone3a,Gravel]=1)
THEN
To_be_extracted_nominal_surface_per_type[Gravel]
ELSE (0)

Surface_to_be_extracted_per_zone_and_type[Zone3b,Fine_Sand] = IF (Critical_depth_flag[Zone3a,Fine_Sand]=0 AND
Critical_depth_flag[Zone3b,Fine_Sand]=1)
THEN
To_be_extracted_nominal_surface_per_type[Fine_Sand]
ELSE
(0)

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Surface_to_be_extracted_per_zone_and_type[Zone3b,Medium_Coarse_Sand] = IF
(Critical_depth_flag[Zone3a,Medium_Coarse_Sand]=0 AND
Critical_depth_flag[Zone3b,Medium_Coarse_Sand]=1)
THEN
  To_be_extracted_nominal_surface_per_type[Medium_Coarse_Sand]
ELSE
 (0)

Surface_to_be_extracted_per_zone_and_type[Zone3b,Gravel] = IF
(Critical_depth_flag[Zone3a,Gravel]=0 AND
Critical_depth_flag[Zone3b,Gravel]=1)
THEN
  To_be_extracted_nominal_surface_per_type[Gravel]
ELSE
 (0)

Surface_to_be_extracted_per_zone_and_type[Zone4,Fine_Sand] = IF
((Critical_depth_flag[Zone3a,Fine_Sand]+
Critical_depth_flag[Zone3b,Fine_Sand]+
Critical_depth_flag[Zone2a,Fine_Sand]+
Critical_depth_flag[Zone2b,Fine_Sand]+
Critical_depth_flag[Zone1b,Fine_Sand]+
Critical_depth_flag[Zone1a,Fine_Sand]+
Critical_depth_flag[Zone2c,Fine_Sand])=0 AND
Critical_depth_flag[Zone4,Fine_Sand]=1)
THEN
  To_be_extracted_nominal_surface_per_type[Fine_Sand]
ELSE
 (0)

Surface_to_be_extracted_per_zone_and_type[Zone4,Medium_Coarse_Sand] = IF
((Critical_depth_flag[Zone3a,Medium_Coarse_Sand]+
Critical_depth_flag[Zone3b,Medium_Coarse_Sand]+
Critical_depth_flag[Zone2a,Medium_Coarse_Sand]+
Critical_depth_flag[Zone2b,Medium_Coarse_Sand]+
Critical_depth_flag[Zone1b,Medium_Coarse_Sand]+
Critical_depth_flag[Zone1a,Medium_Coarse_Sand]+
Critical_depth_flag[Zone2c,Medium_Coarse_Sand])=0 AND
Critical_depth_flag[Zone4,Medium_Coarse_Sand]=1)
THEN
```

To_be_extracted_nominal_surface_per_type[Medium_Coarse_Sand]
ELSE
(0)

Surface_to_be_extracted_per_zone_and_type[Zone4,Gravel] = IF
((Critical_depth_flag[Zone3a,Gravel]+
Critical_depth_flag[Zone3b,Gravel]+
Critical_depth_flag[Zone2a,Gravel]+
Critical_depth_flag[Zone2b,Gravel]+
Critical_depth_flag[Zone1b,Gravel]+
Critical_depth_flag[Zone1a,Gravel]+
Critical_depth_flag[Zone2c,Gravel])=0 AND
Critical_depth_flag[Zone4,Gravel]=1)
THEN
To_be_extracted_nominal_surface_per_type[Gravel]
ELSE
(0)

4 FLEET AND TRIPS

4.1 average loading capacity of fleet A

DATA:

- Source: Ecolas nv. (2006): Environmental Impact Assessment for the extraction of marine aggregates on the BPNS. 194 pp. + Annexes
- Dataset: Maximum loading capacity of each fleet A vessel with an average as one set value)

Vessels of fleet A	Loading capacity in m³
Banjaard	1320
Reimerswaal	1600
Saeftinge	877
Average for fleet A vessels	1266

4.2 number of fleet A vessels

DATA:

- Source: Reimerswaal, personal communication (2004)
- Dataset: 3 (see dataset in section 4.1 of annex for vessel names)

4.3 maximum number of trips per day and per vessel

DATA:

- Source: Reimerswaal, personal communication (2004)
- Dataset: 2

4.4 maximum number of extraction days per month

DATA: available as one set value = 30

4.5 number of fleet B vessels

DATA:

- Source: Ecolas nv. (2006): Environmental Impact Assessment for the extraction of marine aggregates on the BPNS. 194 pp. + Annexes
- Dataset: 9 (see dataset in section 4.6 of annex for vessel names)

4.6 average loading capacity of fleet B

DATA:

- Source: Ecolas nv. (2006): Environmental Impact Assessment for the extraction of marine aggregates on the BPNS. 194 pp. + Annexes
- Dataset: Maximum loading capacity of each Fleet B vessel with an average as one set value

Vessels of fleet B	**Loading capacity in m³**
Arco Beck	2739
Arco Bourne	2600
Charlemagne	5000
Delta	1235
Orisant	2600
Swalinge	1800
Scelveringhe	3933
Schotsman	1523
Ulienspiegel	13700
Average for Fleet B	3903

4.9 extraction by fleet A

DEFINITION: The total sediment extracted by Fleet A over one month and not exceeding the maximum loading capacity of this fleet for 'fine sand', 'medium-coarse sand' and 'gravel'.

EQUATION:

Extraction_by_fleet_A[Zone1a,Fine_Sand] =
if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Fine_Sand]
-Extraction_per_zone_and_type[Zone3b,Fine_Sand]
-Extraction_per_zone_and_type[Zone2a,Fine_Sand]
-Extraction_per_zone_and_type[Zone2b,Fine_Sand]
-Extraction_per_zone_and_type[Zone1b,Fine_Sand])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone1a,Fine_Sand],Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Fine_Sand]
-Extraction_per_zone_and_type[Zone3b,Fine_Sand]
-Extraction_per_zone_and_type[Zone2a,Fine_Sand]
-Extraction_per_zone_and_type[Zone2b,Fine_Sand]
-Extraction_per_zone_and_type[Zone1b,Fine_Sand]))
ELSE (0)

Extraction_by_fleet_A[Zone1a,Medium_Coarse_Sand] =
if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone3b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone1b,Medium_Coarse_Sand])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone1a,Medium_Coarse_Sand],Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone3b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone1b,Medium_Coarse_Sand]))
ELSE (0)
Extraction_by_fleet_A[Zone1a,Gravel] = if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Gravel]
-Extraction_per_zone_and_type[Zone3b,Gravel]
-Extraction_per_zone_and_type[Zone2a,Gravel]
-Extraction_per_zone_and_type[Zone2b,Gravel]

-Extraction_per_zone_and_type[Zone1b,Gravel])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone1a,Gravel],Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Gravel]
-Extraction_per_zone_and_type[Zone3b,Gravel]
-Extraction_per_zone_and_type[Zone2a,Gravel]
-Extraction_per_zone_and_type[Zone2b,Gravel]
-Extraction_per_zone_and_type[Zone1b,Gravel]))
ELSE (0)

Extraction_by_fleet_A[Zone1b,Fine_Sand] =
if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Fine_Sand]
-Extraction_per_zone_and_type[Zone3b,Fine_Sand]
-Extraction_per_zone_and_type[Zone2a,Fine_Sand]
-Extraction_per_zone_and_type[Zone2b,Fine_Sand])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone1b,Fine_Sand],Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Fine_Sand]
-Extraction_per_zone_and_type[Zone3b,Fine_Sand]
-Extraction_per_zone_and_type[Zone2a,Fine_Sand]
-Extraction_per_zone_and_type[Zone2b,Fine_Sand]))
ELSE (0)

Extraction_by_fleet_A[Zone1b,Medium_Coarse_Sand] =
if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone3b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2b,Medium_Coarse_Sand])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone1b,Medium_Coarse_Sand],Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone3b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2b,Medium_Coarse_Sand]))
ELSE (0)

Extraction_by_fleet_A[Zone1b,Gravel] = if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Gravel]
-Extraction_per_zone_and_type[Zone3b,Gravel]
-Extraction_per_zone_and_type[Zone2a,Gravel]
-Extraction_per_zone_and_type[Zone2b,Gravel])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone1b,Gravel],Maximum_monthly_capacity_o
f_fleet_A
-Extraction_per_zone_and_type[Zone3a,Gravel]
-Extraction_per_zone_and_type[Zone3b,Gravel]
-Extraction_per_zone_and_type[Zone2a,Gravel]
-Extraction_per_zone_and_type[Zone2b,Gravel]))
ELSE (0)

Extraction_by_fleet_A[Zone2a,Fine_Sand] =
if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Fine_Sand]
-Extraction_per_zone_and_type[Zone3b,Fine_Sand])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone2a,Fine_Sand],Maximum_monthly_capaci
ty_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Fine_Sand]
-Extraction_per_zone_and_type[Zone3b,Fine_Sand]))
ELSE (0)

Extraction_by_fleet_A[Zone2a,Medium_Coarse_Sand] =
if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone3b,Medium_Coarse_Sand])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone2a,Medium_Coarse_Sand],Maximum_mo
nthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone3b,Medium_Coarse_Sand]))
ELSE (0)

Extraction_by_fleet_A[Zone2a,Gravel] = if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Gravel]
-Extraction_per_zone_and_type[Zone3b,Gravel])> 0
THEN

(MIN(Extraction_per_zone_and_type[Zone2a,Gravel],Maximum_monthly_capacity_o
f_fleet_A
-Extraction_per_zone_and_type[Zone3a,Gravel]
-Extraction_per_zone_and_type[Zone3b,Gravel]))
ELSE (0)

Extraction_by_fleet_A[Zone2b,Fine_Sand] =
if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Fine_Sand]
-Extraction_per_zone_and_type[Zone3b,Fine_Sand]
-Extraction_per_zone_and_type[Zone2a,Fine_Sand])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone2b,Fine_Sand],Maximum_monthly_capaci
ty_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Fine_Sand]
-Extraction_per_zone_and_type[Zone3b,Fine_Sand]
-Extraction_per_zone_and_type[Zone2a,Fine_Sand]))
ELSE (0)

Extraction_by_fleet_A[Zone2b,Medium_Coarse_Sand] =
if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone3b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2a,Medium_Coarse_Sand])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone2b,Medium_Coarse_Sand],Maximum_mo
nthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone3b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2a,Medium_Coarse_Sand]))
ELSE (0)

Extraction_by_fleet_A[Zone2b,Gravel] = if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Gravel]
-Extraction_per_zone_and_type[Zone3b,Gravel]
-Extraction_per_zone_and_type[Zone2a,Gravel])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone2b,Gravel],Maximum_monthly_capacity_o
f_fleet_A
-Extraction_per_zone_and_type[Zone3a,Gravel]

-Extraction_per_zone_and_type[Zone3b,Gravel]
-Extraction_per_zone_and_type[Zone2a,Gravel]))
ELSE (0)

Extraction_by_fleet_A[Zone2c,Fine_Sand] =
if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Fine_Sand]
-Extraction_per_zone_and_type[Zone3b,Fine_Sand]
-Extraction_per_zone_and_type[Zone2a,Fine_Sand]
-Extraction_per_zone_and_type[Zone2b,Fine_Sand]
-Extraction_per_zone_and_type[Zone1b,Fine_Sand]
-Extraction_per_zone_and_type[Zone1a,Fine_Sand])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone2c,Fine_Sand],Maximum_monthly_capacit
y_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Fine_Sand]
-Extraction_per_zone_and_type[Zone3b,Fine_Sand]
-Extraction_per_zone_and_type[Zone2a,Fine_Sand]
-Extraction_per_zone_and_type[Zone2b,Fine_Sand]
-Extraction_per_zone_and_type[Zone1b,Fine_Sand]
-Extraction_per_zone_and_type[Zone1a,Fine_Sand]))
ELSE (0)

Extraction_by_fleet_A[Zone2c,Medium_Coarse_Sand] =
if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone3b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone1b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone1a,Medium_Coarse_Sand])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone2c,Medium_Coarse_Sand],Maximum_mo
nthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone3b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone1b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone1a,Medium_Coarse_Sand]))

ELSE (0)

Extraction_by_fleet_A[Zone2c,Gravel] = if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Gravel]
-Extraction_per_zone_and_type[Zone3b,Gravel]
-Extraction_per_zone_and_type[Zone2a,Gravel]
-Extraction_per_zone_and_type[Zone2b,Gravel]
-Extraction_per_zone_and_type[Zone1b,Gravel]
-Extraction_per_zone_and_type[Zone1a,Gravel])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone2c,Gravel],Maximum_monthly_capacity_of
_fleet_A
-Extraction_per_zone_and_type[Zone3a,Gravel]
-Extraction_per_zone_and_type[Zone3b,Gravel]
-Extraction_per_zone_and_type[Zone2a,Gravel]
-Extraction_per_zone_and_type[Zone2b,Gravel]
-Extraction_per_zone_and_type[Zone1b,Gravel]
-Extraction_per_zone_and_type[Zone1a,Gravel]))
ELSE (0)

Extraction_by_fleet_A[Zone3a,Fine_Sand] =
MIN(Extraction_per_zone_and_type[Zone3a,Fine_Sand],Maximum_monthly_capacit
y_of_fleet_A)

Extraction_by_fleet_A[Zone3a,Medium_Coarse_Sand] =
MIN(Extraction_per_zone_and_type[Zone3a,Medium_Coarse_Sand],Maximum_mon
thly_capacity_of_fleet_A)
Extraction_by_fleet_A[Zone3a,Gravel] =
MIN(Extraction_per_zone_and_type[Zone3a,Gravel],Maximum_monthly_capacity_of
_fleet_A)

Extraction_by_fleet_A[Zone3b,Fine_Sand] =
if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Fine_Sand])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone3b,Fine_Sand],Maximum_monthly_capaci
ty_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Fine_Sand]))
ELSE (0)

Extraction_by_fleet_A[Zone3b,Medium_Coarse_Sand] = if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Medium_Coarse_Sand])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone3b,Medium_Coarse_Sand],Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Medium_Coarse_Sand]))
ELSE (0)

Extraction_by_fleet_A[Zone3b,Gravel] = if(Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Gravel])> 0
THEN
(MIN(Extraction_per_zone_and_type[Zone3b,Gravel],Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Gravel]))
ELSE (0)

Extraction_by_fleet_A[Zone4,Fine_Sand] = IF ((Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Fine_Sand]
-Extraction_per_zone_and_type[Zone3b,Fine_Sand]
-Extraction_per_zone_and_type[Zone2a,Fine_Sand]
-Extraction_per_zone_and_type[Zone2b,Fine_Sand]
-Extraction_per_zone_and_type[Zone1b,Fine_Sand]
-Extraction_per_zone_and_type[Zone1a,Fine_Sand]
-Extraction_per_zone_and_type[Zone2c,Fine_Sand])> 0)
THEN
(MIN(Extraction_per_zone_and_type[Zone4,Fine_Sand],Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Fine_Sand]
-Extraction_per_zone_and_type[Zone3b,Fine_Sand]
-Extraction_per_zone_and_type[Zone2a,Fine_Sand]
-Extraction_per_zone_and_type[Zone2b,Fine_Sand]
-Extraction_per_zone_and_type[Zone1b,Fine_Sand]
-Extraction_per_zone_and_type[Zone1a,Fine_Sand]
-Extraction_per_zone_and_type[Zone2c,Fine_Sand]))
ELSE (0)

Extraction_by_fleet_A[Zone4,Medium_Coarse_Sand] = IF ((Maximum_monthly_capacity_of_fleet_A

-Extraction_per_zone_and_type[Zone3a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone3b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone1b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone1a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2c,Medium_Coarse_Sand])> 0)
THEN
(MIN(Extraction_per_zone_and_type[Zone4,Medium_Coarse_Sand],Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone3b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone1b,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone1a,Medium_Coarse_Sand]
-Extraction_per_zone_and_type[Zone2c,Medium_Coarse_Sand]))
ELSE (0)

Extraction_by_fleet_A[Zone4,Gravel] = IF ((Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Gravel]
-Extraction_per_zone_and_type[Zone3b,Gravel]
-Extraction_per_zone_and_type[Zone2a,Gravel]
-Extraction_per_zone_and_type[Zone2b,Gravel]
-Extraction_per_zone_and_type[Zone1b,Gravel]
-Extraction_per_zone_and_type[Zone1a,Gravel]
-Extraction_per_zone_and_type[Zone2c,Gravel])> 0)
THEN
(MIN(Extraction_per_zone_and_type[Zone4,Gravel],Maximum_monthly_capacity_of_fleet_A
-Extraction_per_zone_and_type[Zone3a,Gravel]
-Extraction_per_zone_and_type[Zone3b,Gravel]
-Extraction_per_zone_and_type[Zone2a,Gravel]
-Extraction_per_zone_and_type[Zone2b,Gravel]
-Extraction_per_zone_and_type[Zone1b,Gravel]
-Extraction_per_zone_and_type[Zone1a,Gravel]
-Extraction_per_zone_and_type[Zone2c,Gravel]))
ELSE (0)

5 DISTANCES TRAVELLED

5.2 distance between zone and port

DATA:

- Source: Management Unit of the North Sea Mathematical Models, Royal Belgian Institute of Natural Sciences (BMDC, S. Jans 20050919)
- Dataset: Distances between center of concession zones and the 4 different ports with an average as 8 set values for the 8 zones

Distance to center of zone	Average distance (m)
1a	41,900
1b	40,400
2a	36,500
2b	38,000
2c	43,500
3a	32,800
3b	34,000
4	57,800

SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY
(SPSD II)

Part 2:
Global change, Ecosystems and Biodiversity

Annex 2

BALANS

BALANCING IMPACTS OF HUMAN ACTIVITIES
IN THE NORTH SEA

EV/21

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February 2007

ANNEX 2:
SAND AND GRAVEL EXTRACTION ENVIRONMENT

CONTENTS

1 MACROBENTHIC DENSITY AT EXTRACTION SITE: STOCK AND FLOWS

1.1 density extraction site

DATA:

- Source: MACRODAT database (Section Marine Biology), Van Hoey et al. (2004)
- Dataset: available at Section Marine Biology, University of Ghent

TABLE 1: Characterization of the species assemblages of the Belgian Continental Shelf (adapted from Van Hoey et al., 2004)

Species assemblage	**SA1**	**SA2**	**SA3**	**SA4**	**SA5**	**SA6**	**SA7**	**SA8**	**SA9**	**SA10**
Sediment type	FS	FS	MS	MS	MS	MS	FS	FS	FS	FS
Median grain size (µm)	219	208	268	274	333	409	219	243	230	248
Mud content (%)	5.8	4.3	1.9	0.4	0.2	0.3	<0.1	0.1	<0.1	<0.1
Depth (m)	-13	-8	-14	-12	-16	-15	-2	2	2	4
Species richness (#/m²)	30	18	13	7	8	5	5	8	5	5
Density	6432	2746	2017	402	304	190	135	482	101	983
Name	Type I SA *Abra alba-Mysella bidentata* community	Type II SA	Type II SA	Type I SA *Nepthys cirrosa* community	Type II SA	Type I SA *Ophelia limacina-Glycera lapidum* community	Type II SA	Type II SA	Type II SA	Type I SA Eurydice pulcra-Scolelepis squamata community

1.3 mortality rate

DATA:

- Source: Blackford (1997); Duplisea (1998)
- Dataset: Although several data for mortality rate of macrobenthos are circulating in literature, we chose the value of Blackford (1997) for deposit feeders and suspension feeders because these functional groups dominate in continental shelf ecosystems according to Silvert (1991). The value of Blackford (1997) is also determined for environmental conditions similar to the ones valid for the BPNS.

TABLE 2: Data on mortality rate found in literature

Source		Mortality rate
Blackford (1997)	- deposit feeders/suspension feeders - predators	0.001/d 0.003/d
Duplisea (1998)		0.0014/d
Chosen value (Blackford, 1997)		0.001/d or 0.05/month

1.5 density for competition

DATA:

- Source: MACRODAT database (Section Marine Biology)
- Dataset: available at Section Marine Biology, University of Ghent

1.8 birth rate

DATA:

- Source: Sohma et al. (2001); Duplisea (1998); Ortiz & Wolff (2002)
- Dataset: Although several data for birth rate of macrobenthos are circulating in literature, we chose the value of Ortiz & Wolff (2002) because this value is also determined for environmental conditions similar to the ones valid for the BPNS (i.e. sandy habitats).

TABLE 3: Data on birth rate found in literature

Source	Birth rate
Sohma et al. (2001)	0.053/d
Duplisea (1998)	0.185/d
Ortiz & Wolff (2002)	0.012/d
Chosen value (Ortiz & Wolff, 2002)	0.012/d or 0.36/month

2 EFFECT OF AMOUNT OF EXTRACTION

2.1 effect of amount on density

DATA: Calculated in meta-analysis

EXPLANATION OF METHODOLOGY OF META-ANALYSIS

Because a large amount of literature on the impact of aggregate extraction and shrimp fisheries is available it is difficult to deduct general trends in these impacts (because the different studies were carried out in different habitats, with different regimes, sampling times, intensities of extraction,…).

Besides that, the effects of aggregate extraction or bottom fisheries on macrobenthos or sediment composition are not easily extracted from literature, because most articles give conflicting conclusions (ranging from a negligible effect to a huge effect). This problem can be solved by doing a meta-analysis.

Meta-analysis is the summary of multiple, independent studies to detect general relationships (Normand, 1999; Collie et al., 2000). It is a summary term for all quantitative methods that are used to combine evidence across studies (Myers & Mertz, 1998). Every treatment described in an article is treated as an independent replicate. Using this methodology on the available literature on the effects of extraction and fisheries on macrobenthos and sediment composition will allow the prediction of the "mean effects" (general trends).

Therefore, a compilation database of all available impact studies has been made and from these compiled data it will be possible to deduct consistent patterns in the responses of benthic organisms and sediment composition to these disturbances.

The magnitude of the response of a variable A (macrobenthic density/fraction of a certain grain size fraction) can then be calculated as follows:

% difference = $((A_{after} – A_{before})/A_{before})*100$

or % difference = $((A_{impact} – A_{control})/A_{control})*100$

with A_{after}/A_{impact} the value of the variable after the disturbance/at the impacted site and $A_{before}/A_{control}$ the value of the variable before the disturbance/at the control site

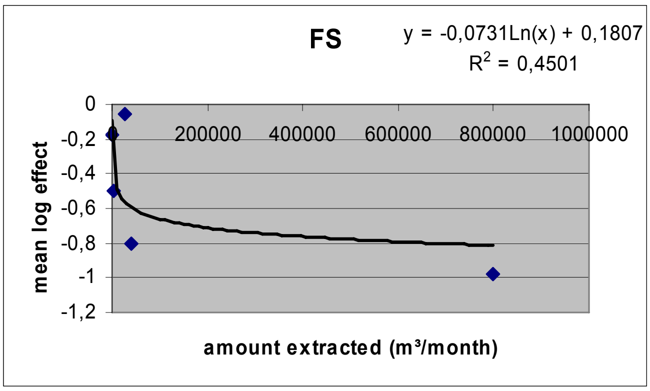
The resulting values of % difference are then log-transformed to get a normal distribution of the values. The meta-analysis investigates the following effects:

- The impact of aggregate extraction (effect of amount of sand extracted and effect of surface area extracted) on the macrobenthos
- The subsequent recolonisation rate after cessation of extraction (with respect to regime of extraction).
- The effect of aggregate extraction on the sediment composition (for different regimes of extraction)
- The impact of shrimp fisheries (effect of effort of fishing and effect of surface area fished) on the macrobenthic density
- The subsequent recolonisation rate after cessation of fishing (with respect to regime of extraction)
- The effect of shrimp fisheries on the sediment composition

The trends that merge from this analysis will be used to determine the equation which fits the trend best.

The document only gave the equations for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.

GRAPH 1: Mean (logarithmic) effect of the extraction of a certain amount of sediment in fine sand habitats on the macrobenthic density at the extraction site

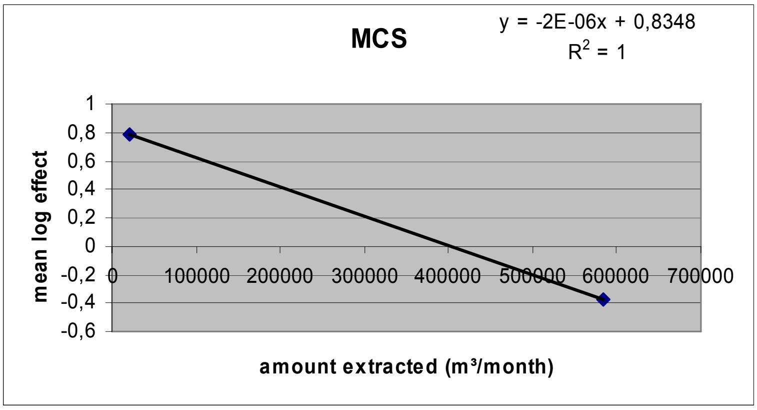


effect_of_amount__on_density[Zone*,Fine_Sand] = IF (Extraction_per_zone_and_type[Zone*,Fine_Sand]<10) THEN 0 ELSE ((10^(((-

0.0731*LOGN(Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000))+0.1807) +2.004))-101)/100

Note: same equation for all zones for fine sand.

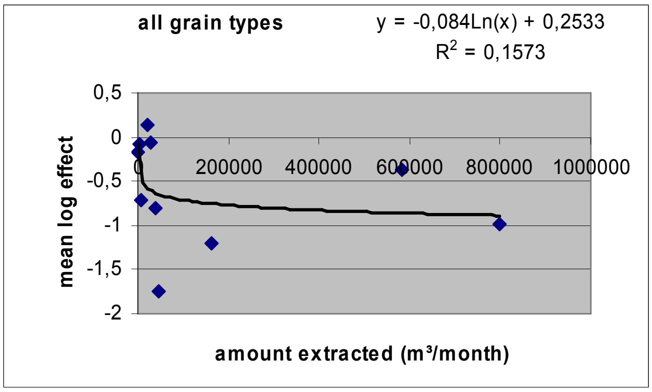
<u>GRAPH 2:</u> Mean (logarithmic) effect of the extraction of a certain amount of sediment in medium-coarse sand habitats on the macrobenthic density at the extraction site



effect_of_amount_on_density [Zone*, Medium_Coarse_Sand] = IF (Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]=0) THEN 0 ELSE ((10^(((-2*10^(-6)*(Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand] /1000000))+0.8348)+2.004))-101)/100

Note: same equation for all zones for medium-coarse sand.

<u>GRAPH 3:</u> Mean (logarithmic) effect of the extraction of a certain amount of sediment in all habitats on the macrobenthic density at the extraction site. Since there were not enough data available to detect a trend for gravel habitats, the general equation found for all habitats was used.



effect_of_amount_on_density [Zone*,Gravel] = IF (Extraction_per_zone_and_type[Zone*,Gravel]<10) THEN 0 ELSE ((10^(((-

0.084*LOGN(Extraction_per_zone_and_type[Zone*,Gravel]/1000000))+0.2533)+2.004))-101)/100

Note: same equation for all zones for gravel.

3 EFFECT OF SURFACE AREA OF EXTRACTION

3.1 r1

DATA: calculated from meta-analysis
For more information on the methodology of the meta-analysis see subsection 2.1.

TABLE 4: The amount of days between two consequent extraction events were classified into 4 regimes (continuous regime, regime 1, regime 2 and regime 3) following the evaluation of trends of mean effect of density against amount of days between two events.

Grain type	Continuous regime	Regime 1	Regime 2	Regime 3
Gravel	0-15	15-200	201-750	>750
Medium-coarse sand	0-15	15-200	201-600	>600
Fine sand	0-15	15-100	101-600	>600

The document only gave the equations for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.
R1[Zone*,Fine_Sand] = IF (regime[Zone*,Fine_Sand]>15) AND (regime[Zone*,Fine_Sand]<101) THEN 1 ELSE 0

Note: same equation for all zones for fine sand.

R1[Zone*,Medium_Coarse_Sand] = IF (regime[Zone*,Medium_Coarse_Sand]>15) AND (regime[Zone*,Medium_Coarse_Sand]<201) THEN 1 ELSE 0

Note: same equation for all zones for medium-coarse sand.

R1[Zone*,Gravel] = IF (regime[Zone*,Gravel]>15) AND (regime[Zone*,Gravel]<201) THEN 1 ELSE 0

Note: same equation for all zones for gravel.

3.2 r2

DATA: calculated from meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

Data: see TABLE 4 above (subsection 3.1)

The document only gave the equations for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.

R2[Zone*,Fine_Sand] = IF (regime[Zone*,Fine_Sand]>100) AND (regime[Zone*, Fine_Sand]<601) THEN 1 ELSE 0

Note: same equation for all zones for fine sand.

R2[Zone*,Medium_Coarse_Sand] = IF (regime[Zone*,Medium_Coarse_Sand]>200) AND (regime[Zone*,Medium_Coarse_Sand]<601) THEN 1 ELSE 0

Note: same equation for all zones for medium-coarse sand.

R2[Zone*,Gravel] = IF (regime[Zone*,Gravel]>200) AND (regime[Zone*,Gravel]<751) THEN 1 ELSE 0

Note: same equation for all zones for gravel.

3.3 r3

DATA: calculated from meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

Data: see TABLE 4 above (subsection 3.1)

The document only gave the equations for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.

R3[Zone*,Fine_Sand] = IF (regime[Zone*,Fine_Sand]>600) THEN 1 ELSE 0

Note: same equation for all zones for fine sand.

R3[Zone*,Medium_Coarse_Sand] = IF (regime[Zone*,Medium_Coarse_Sand]>600) THEN 1 ELSE 0

Note: same equation for all zones for medium-coarse sand.

R3[Zone*,Gravel] = IF (regime[Zone*,Gravel]>750) THEN 1 ELSE 0

Note: same equation for all zones for gravel.

3.4 r continuous

DATA: calculated from meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

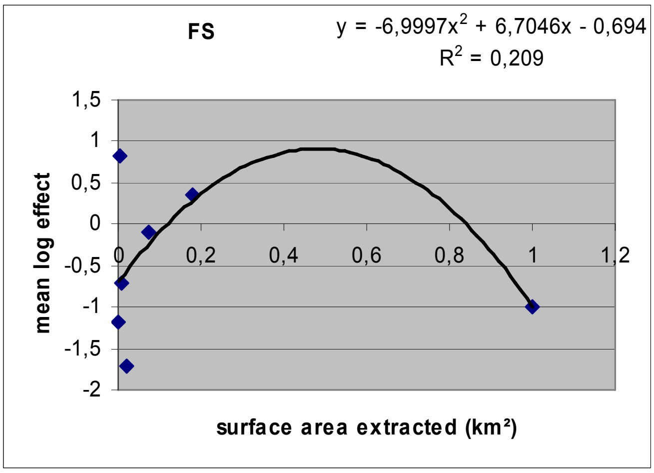
Data: see TABLE 4 above (subsection 3.1)

3.5 effect surface 1

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

GRAPH 4: Mean (logarithmic) effect of the extraction of a certain surface area in fine sand habitats on the macrobenthic density at the extraction site (when regime 1 is valid).

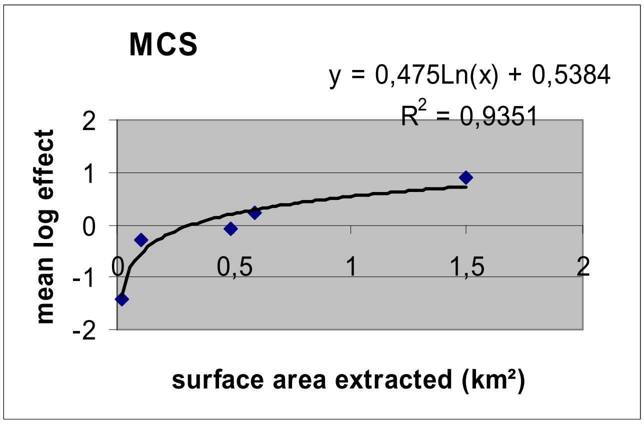


The document only gave the equations for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.

Effect_surface_1 [Zone*, Fine_sand] = IF(R1[Zone*,Fine_Sand]=1)THEN(((10^(((-6.9997*((Effectively_extracted_surface_perzone_and_type[Zone*,Fine_Sand] / 1000000)^2))+(6.7046*(Effectively_extracted_surface per_zone_and_type[Zone*,Fine_Sand] /1000000))-0.694)+2.004))-101)/100)ELSE0

Note: same equation for all zones for fine sand.

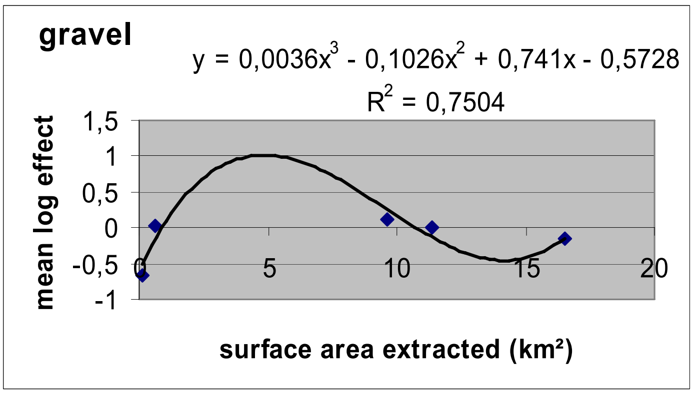
GRAPH 5: Mean (logarithmic) effect of the extraction of a certain surface area in medium-coarse sand habitats on the macrobenthic density at the extraction site (when regime 1 is valid).



effect_surface_1 [Zone*, Medium_Coarse_Sand] = IF(R1[Zone*,Medium_Coarse _Sand]=1 AND Effectively_extracted_surface_per_zone_and_type [Zone*,Medium_Coarse_Sand]>100) THEN (((10^((0.475*LOGN((Effectively_extracted_surface_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000))+0.5384)+2.004))-101)/100) ELSE 0

Note: same equation for all zones for medium-coarse sand.

GRAPH 6: Mean (logarithmic) effect of the extraction of a certain surface area in gravel habitats on the macrobenthic density at the extraction site (when regime 1 is valid).



effect_surface_1[Zone*,Gravel] = IF(R1[Zone1a,Gravel]=1)THEN(((10^(((0.0036*

((Effectively_extracted_surface_per_zone_and_type[Zone*,Gravel]/1000000)^3))-(0.1026*((Effectively_extracted_surface_per_zone_and_type[Zone*,Gravel]/1000000)^2))+(0.741*(Effectively_extracted_surface_per_zone_and_type[Zone*,Gravel]/1000000))-0.5728)+2.004))-101)/100) ELSE 0

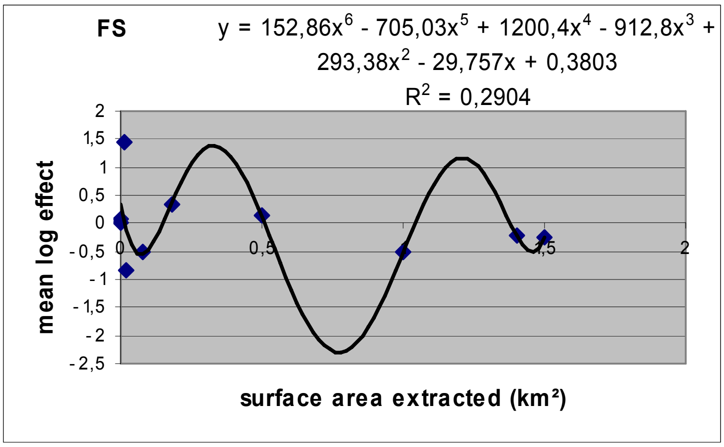
Note: same equation for all zones for gravel.

3.6 effect surface 2

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

GRAPH 7: Mean (logarithmic) effect of the extraction of a certain surface area in fine sand habitats on the macrobenthic density at the extraction site (when regime 2 is valid).

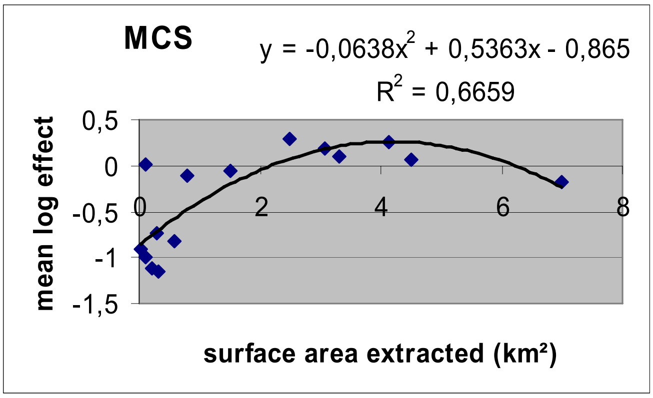


The document only gave the equations for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.

effect_surface_2[Zone*,Fine_Sand] = IF(R2[Zone*,Fine_Sand]=1)THEN(((10^(((-152.86*((Effectively_extracted_surface_per_zone_and_type[Zone*,Fine_Sand]/1000000)^6))-(705.03*((Effectively_extracted_surface_per_zone_and_type[Zone*,Fine_Sand]/1000000)^5))+(1200.4*((Effectively_extracted_surface_per_zone_and_type[Zone*,Fine_Sand]/1000000)^4))-(912.8*((Effectively_extracted_surface_per_zone_and_type[Zone*,Fine_Sand]/1000000)^3))+(293.38*((Effectively_extracted_surface_per_zone_and_type[Zone*,Fine_Sand]/1000000)^2))-(29.757*((Effectively_extracted_surface_per_zone_and_type[Zone*,Fine_Sand]/1000000))+0.3803)+2.004))-101)/100)) ELSE 0

Note: Equations for all other zones and fine sand are the same.

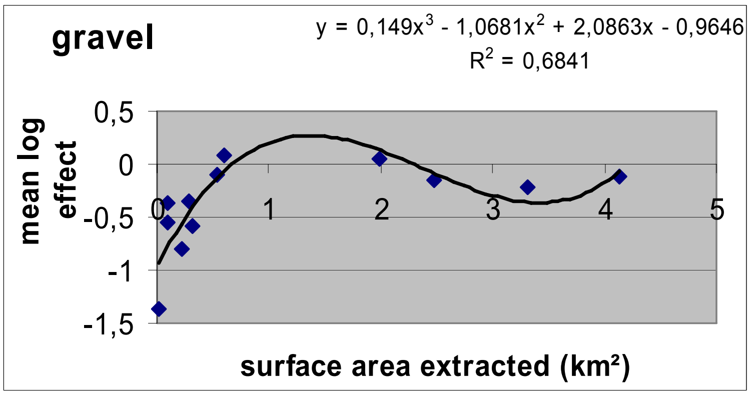
GRAPH 8: Mean (logarithmic) effect of the extraction of a certain surface area in medium-coarse sand habitats on the macrobenthic density at the extraction site (when regime 2 is valid).



effect_surface_2[Zone*,Medium_Coarse_Sand] = IF(R2[Zone*,Medium_Coarse _Sand]=1)THEN(((10^(((-0.0638*((Effectively_extracted_surface_per_zone_ and_type[Zone*,Medium_Coarse_Sand]/1000000)^2))+(0.5363*(Effectively_extracte d_surface_per_zone_and_type[Zone*,Medium_Coarse_Sand]/10000000))- 0.865)+2.004))-101)/100)ELSE 0

Note: Equations for all other zones and medium-coarse sand are the same.

GRAPH 9: Mean (logarithmic) effect of the extraction of a certain surface area in gravel habitats on the macrobenthic density at the extraction site (when regime 2 is valid).



effect_surface_2(Zone*,Gravel] = IF(R2[Zone*,Gravel]=1)THEN(((10^((((0.149*

((Effectively_extracted_surface_per_zone_and_type[Zone*,Gravel]/1000000)^3))-(1.0681*((Effectively_extracted_surface_per_zone_and_type[Zone*,Gravel]/1000000)^2))+(2.0863*((Effectively_extracted_surface_per_zone_and_type[Zone*,Gravel]/1000000))-0.9646)))+2.004))-101)/100) ELSE 0

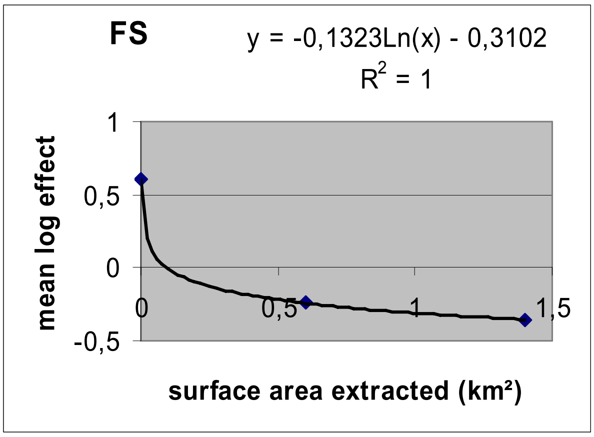
Note: Equations for all other zones and gravel are the same.

3.7 effect surface 3

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

GRAPH 10: Mean (logarithmic) effect of the extraction of a certain surface area in fine sand habitats on the macrobenthic density at the extraction site (when regime 3 is valid).

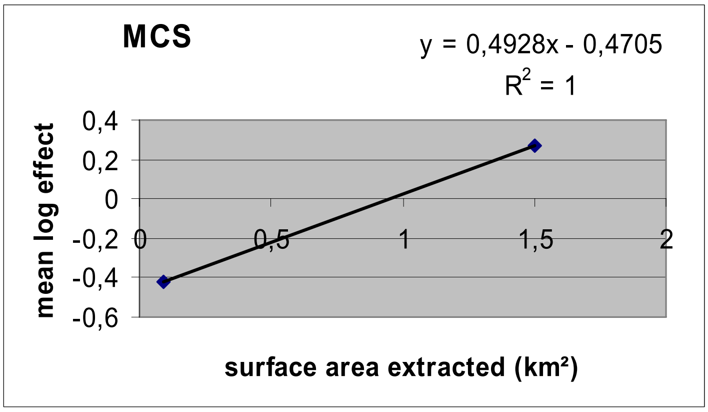


The document only gave the equations for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.

effect_surface_3[Zone*,Fine_Sand] = IF(R3[Zone*,Fine_Sand]=1 AND Effectively_extracted_surface_per_zone_and_type[Zone*,Fine_Sand]>100) THEN(((10^((-0.1323*LOGN((Effectively_extracted_surface_per_zone_and_type[Zone*,Fine_Sand]/1000000))-0.3102)+2.004))-101)/100)ELSE 0

Note: Equations for all other zones and fine sand are the same.

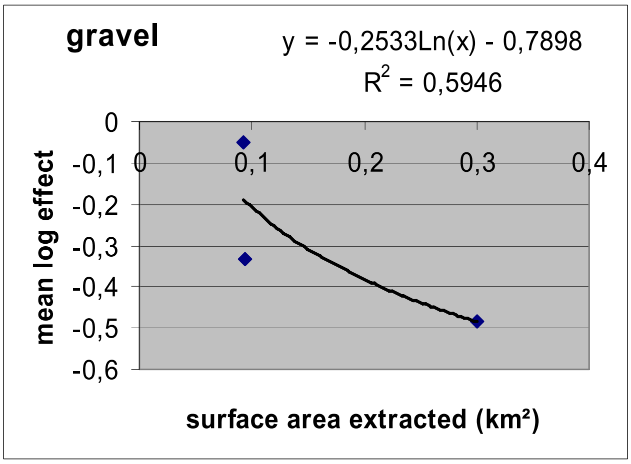
GRAPH 11: Mean (logarithmic) effect of the extraction of a certain surface area in medium-coarse sand habitats on the macrobenthic density at the extraction site (when regime 3 is valid).



effect_surface_3[Zone*,Medium_Coarse_Sand] = IF(R3[Zone*,Medium_Coarse_Sand]=1)THEN(((10^((0.4928*(Effectively_extracted_surface_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)-0.4705)+2.004))-101)/100)ELSE 0

Note: Equations for all other zones and medium-coarse sand are the same.

GRAPH 12: Mean (logarithmic) effect of the extraction of a certain surface area in gravel habitats on the macrobenthic density at the extraction site (when regime 3 is valid).



effect_surface_3[Zone*,Gravel] = IF(R3[Zone*,Gravel]=1 AND Effectively_extracted_surface_per_zone_and_type[Zone*,Gravel]>100)

THEN(((10^((-0.2533*LOGN((Effectively_extracted_surface_per
_zone_and_type[Zone*,Gravel]/1000000))-0.7898)+2.004))-101)/100)ELSE 0

Note: Equations for all other zones and gravel are the same.

4 MACROBENTHIC DENSITY AT DEPOSITION SITE: STOCK AND FLOWS

4.1 density deposition site

DATA:

- Source: MACRODAT database (Section Marine Biology), Van Hoey et al. (2004)
- Dataset: available at Section Marine Biology, University of Ghent

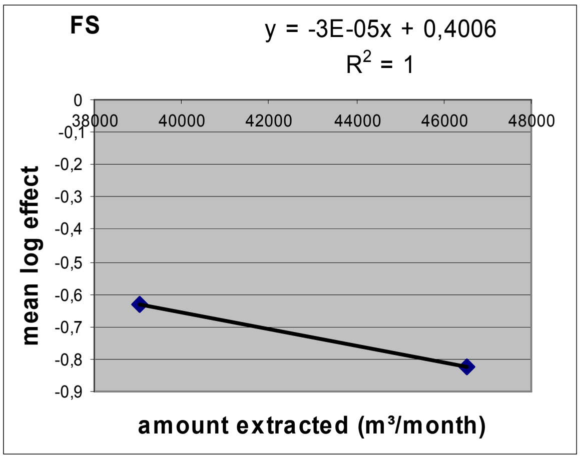
See subsection 1.1 above.

4.3 effect of amount on smothering

DATA: calculated from meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

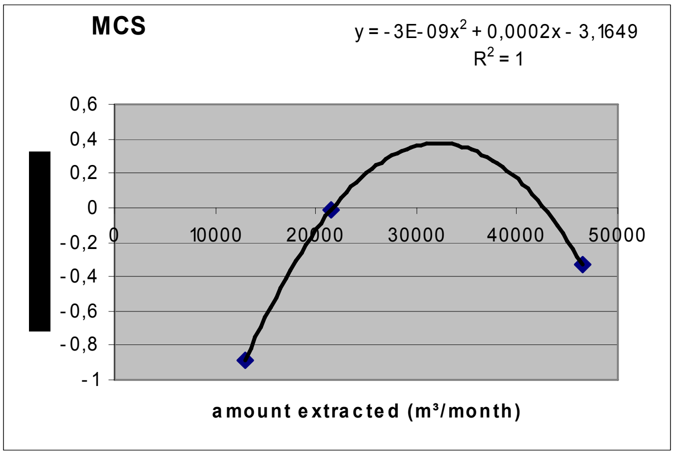
GRAPH 13: Mean (logarithmic) effect of the extraction of a certain amount of sediment in fine sand habitats on the macrobenthic density at the deposition site (effect on smothering of macrobenthos).



effect_of_amount_on_smothering[Zone*,Fine_Sand] = ((10^(((-3*(10^(-5))*Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000)+0.4006)+2.004))-101)/100

Note: The equations for all other zones for fine sand is the same.

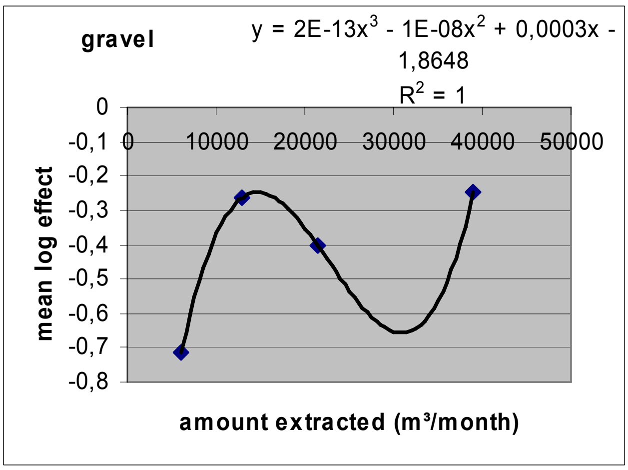
GRAPH 14: Mean (logarithmic) effect of the extraction of a certain amount of sediment in medium-coarse sand habitats on the macrobenthic density at the deposition site (effect on smothering of macrobenthos).



effect_of_amount_on_smothering[Zone*,Medium_Coarse_Sand] = (10^((((-3*(10^(-9))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^2))+(0.0002*(Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)))-3.1649)+2.004)-101)/100

Note: The equations for all zones for medium-coarse sand are the same.

GRAPH 15: Mean (logarithmic) effect of the extraction of a certain amount of sediment in gravel habitats on the macrobenthic density at the deposition site (effect on smothering of macrobenthos).



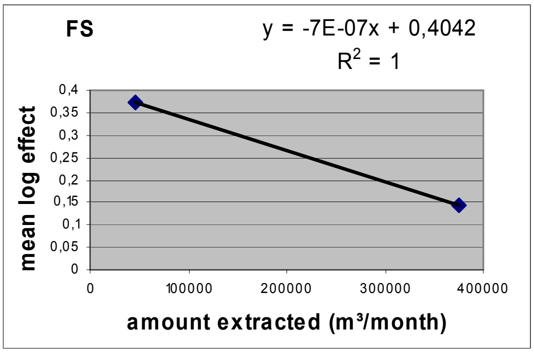
effect_of_amount_on_smothering[Zone*,Gravel] = ((10^((((2*(10^(-13))*((Extraction_per_zone_and_type[Zone*,Gravel]/1000000)^3))-(1*(10^(-8))*((Extraction_per_zone_and_type[Zone*,Gravel])/1000000)^2))+(0.0003*Extraction_per_zone_and_type[Zone*,Gravel]/1000000)-1.8648)+2.004))-101)/100

Note: The equations for all zones for gravel are the same.

4.5 effect of amount on depositing

DATA: calculated from meta-analysis
For more information on the methodology of the meta-analysis see subsection 2.1.

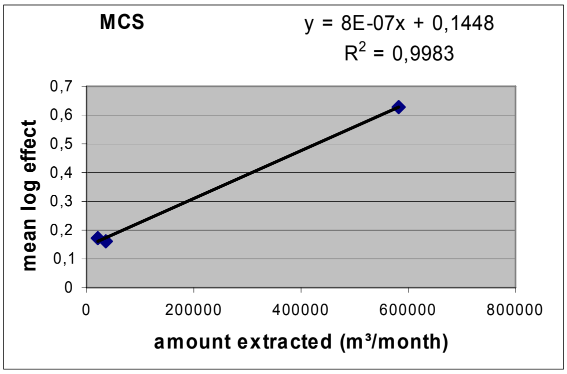
GRAPH 16: Mean (logarithmic) effect of the extraction of a certain amount of sediment in fine sand habitats on the macrobenthic density at the deposition site (effect on depositing macrobenthic individuals).



effect_of_amount__on_depositing[Zone*,Fine_Sand] = ((10^(((-7*(10^(-7))*Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000)+0.4042)+2.004))-101)/100

Note: The equations for all zones for fine sand are the same.

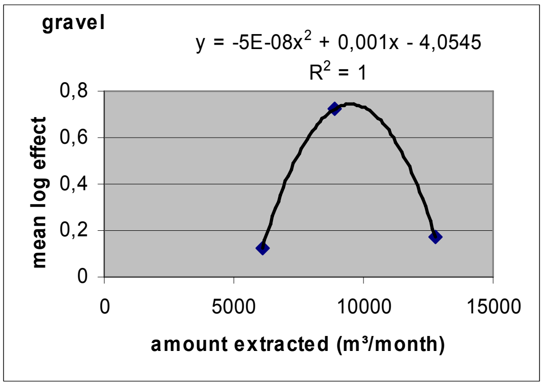
GRAPH 17: Mean (logarithmic) effect of the extraction of a certain amount of sediment in medium-coarse sand habitats on the macrobenthic density at the deposition site (effect on depositing macrobenthic individuals).



effect_of_amount__on_depositing[Zone*,Medium_Coarse_Sand] = ((10^(((8*(10^(-7))*Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)+0.1448)+2.004))-101)/100

Note: The equations for all other zones for medium-coarse sand are the same.

<u>GRAPH 18:</u> Mean (logarithmic) effect of the extraction of a certain amount of sediment in gravel habitats on the macrobenthic density at the deposition site (effect on depositing macrobenthic individuals).



effect_of_amount__on_depositing[Zone*,Gravel] = ((10^(((-5*(10^(-8))*((Extraction_per_zone_and_type[Zone*,Gravel]/1000000)^2))+(0.001*Extraction_per_zone_and_type[Zone*,Gravel]/1000000)-4.0545)+2.004))-101)/100

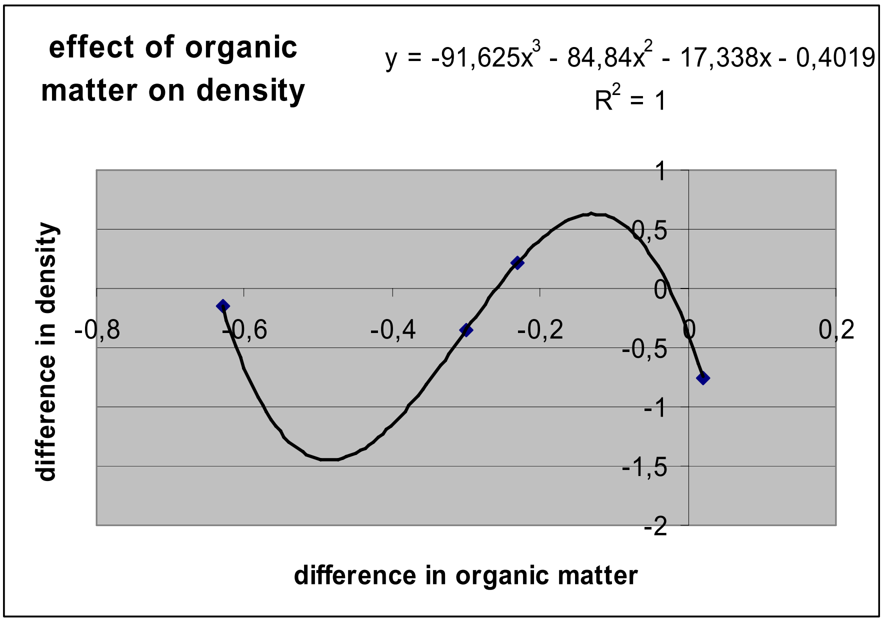
Note: The equations for all other zones and gravel are the same.

4.7 effect of organic matter on density

DATA: calculated from meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

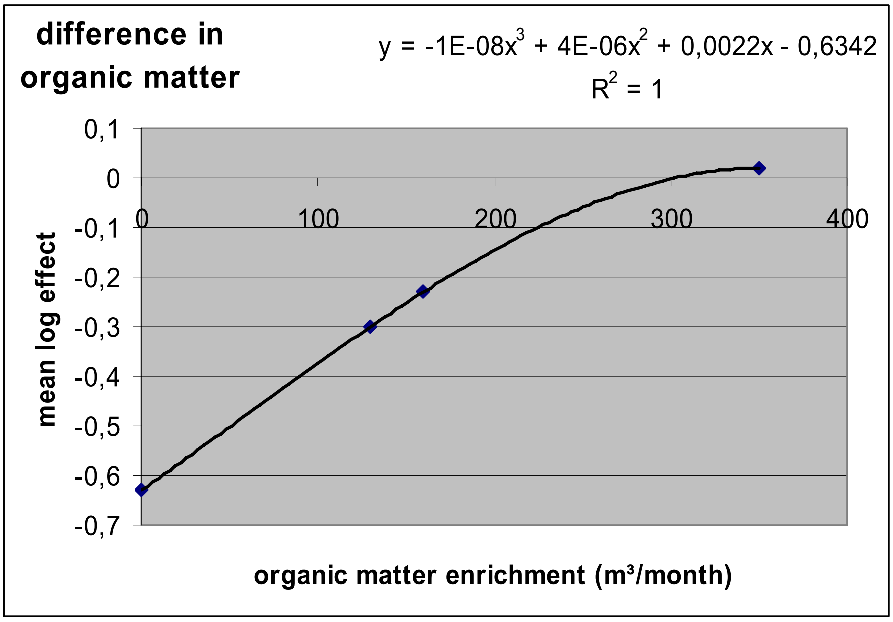
GRAPH 19: Effect of the difference in organic matter on the macrobenthic density at the deposition site.



4.8 difference in organic matter

DATA: calculated from meta-analysis
For more information on the methodology of the meta-analysis see subsection 2.1.

GRAPH 20: Mean (logarithmic) effect of the organic enrichment (due to extraction and deposition of sediment) on the difference in organic matter in the sediment before and after the extraction.



4.9 organic matter enrichment

DATA:

- Source: Newell et al. (1999)
- Dataset:

TABLE 5: Data on organic matter release after aggregate extraction found in literature.

Source	Mean amount of organic matter released (during normal loading operations of a hopper dredger with a capacity of 4500 t/trip)
Newell et al. (1999)	1.98089 t/trip
Fraction of total amount of sediment removed	0.0004402 (0.044 %)

4.11 dying off 2

DEFINITION: The amount of macrobenthic individuals that die off naturally

EQUATION: density_deposition_site[*,*]*mortality_rate

ARRAY: zone vs. grain type

UNITS: ind/m²

VALUE: range between 0 and unlimited; only +

TYPE: flow

FUNCTION: calculation
LINKS:

- Input: Density deposition site; Mortality rate

DATA: calculated but not verifiable

4.12 competition 2
DEFINITION: The amount of macrobenthic individuals that die off or leave due to competition effects
EQUATION:IF(density__deposition_site[Zone,Grain]>density_for_competition[Zone, Grain])THEN(density__deposition_site[Zone,Grain]-density_for_competition[Zone,Gr ain])/DTELSE 0
ARRAY: zone vs. grain type
UNITS: ind/m²
VALUE: range between 0 and unlimited, only +
TYPE: flow
FUNCTION: calculation
LINKS:

- Input: Density deposition site; Density for competition

DATA: calculated but not verifiable

4.13 recruiting 2
DEFINITION: The amount of macrobenthic individuals that are being born
EQUATION: density__deposition_site[Zone,Grain]*birth_rate
ARRAY: zone vs. grain type
UNITS: ind/m²
VALUE: range between 0 and unlimited; only +
TYPE: flow
FUNCTION: calculation
LINKS:

- Input: Density deposition site; Birth rate

DATA: calculated but not verifiable

4.14 density for competition
DEFINITION: The maximum macrobenthic density which can be sustained in a zone of the BCS
EQUATION: constant
ARRAY: none
UNITS: ind/m²

VALUE: 1000 (maximum macrobenthic density found on sandbank tops of BCS)
TYPE: flow
FUNCTION: scenario
LINKS:

- Output: Competition 2

DATA:

- Source: MACRODAT database (Section Marine Biology)
- Dataset: available at Section Marine Biology, University of Ghent

4.15 birth rate
DEFINITION: The rate with which macrobenthic individuals are being born
EQUATION: constant
ARRAY: none
UNITS: numerical
VALUE: 0.36
TYPE: parameter
FUNCTION: scenario
LINKS:

- Output: Recruiting 2

DATA:

- Source: Sohma et al. (2001); Duplisea (1998); Ortiz & Wolff (2002)
- Dataset: see subsection 1.8 above

4.16 mortality rate
DEFINITION: The rate with which macrobenthic individuals die off
EQUATION: constant
ARRAY: none
UNITS: numerical
VALUE: 0.0505
TYPE: parameter
FUNCTION: scenario
LINKS:

- Output: Dying off 2

DATA:

- Source: Blackford (1997); Duplisea (1998)
- Dataset: see subsection 1.3 above

5 SEDIMENT COMPOSITION AT THE EXTRACTION SITE

5.1 sediment extraction site fs

DATA: Calculated from meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

TABLE 6: The initial values of the different grain size fractions of each grain type (as determined in the meta-analysis).

Grain type	Grain size fraction		
	Gravel	MCS	FS
Gravel	61.84	29.64	8.43
Medium-coarse sand	11.69	76.68	11.94
Fine sand	8.40	31.22	60.37

The document only gave the equations for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.

sediment_extraction_site_FS[Zone*,Fine_Sand](t) = sediment_extraction_site_FS[Zone*,Fine_Sand](t - dt) + (natural_input_FS[Zone1b,Fine_Sand] + infilling_FS[Zone*,Fine_Sand] - decrease_by_extraction_FS[Zone*,Fine_Sand] - natural_decrease_by_transport_FS[Zone*,Fine_Sand]) * dt

Note: The equations for all other zones of fine sand are the same.

sediment_extraction_site_FS[Zone*,Medium_Coarse_Sand](t) = sediment_extraction_site_FS[Zone*,Medium_Coarse_Sand](t - dt) + (natural_input_FS[Zone*,Medium_Coarse_Sand] + infilling_FS[Zone*,Medium_Coarse_Sand] - decrease_by_extraction_FS[Zone*,Medium_Coarse_Sand] - natural_decrease_by_transport_FS[Zone*,Medium_Coarse_Sand]) * dt

Note: The equations for all other zones of medium-coarse sand are the same.

sediment_extraction_site_FS[Zone*,Gravel](t) = sediment_extraction_site_FS[Zone1a,Gravel](t - dt) + (natural_input_FS[Zone*,Gravel] + infilling_FS[Zone*,Gravel] – decrease_by_extraction_FS[Zone*,Gravel] - natural_decrease_by_transport_FS[Zone*,Gravel]) * dt

Note: The equations for all other zones of gravel are the same.

5.3 infilling rate fs

DATA: Calculated from meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

TABLE 7: The infilling rates of the different grain size fractions of each grain type (as determined in the meta-analysis).

Grain type	Infilling rate of the grain size fractions		
	Gravel	MCS	FS
Gravel	1.0102	1.0101	1.0106
Medium-coarse sand	1.049	1.0168	1.0104
Fine sand	1.0215	1.028	1.0129

5.6 sand transport fs

DATA: Calculated from meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

TABLE 8: The natural sand transport rates of the different grain size fractions of each grain type (as determined in the meta-analysis).

Grain type	Natural sand transport rate of the grain size fractions		
	Gravel	MCS	FS
Gravel	1.01	1.0077	1.0095
Medium-coarse sand	1.0056	1.0063	1.0084
Fine sand	1.00084	1.0015	1.0071

5.8 sediment extraction site mcs

DEFINITION: The percentage of the medium-coarse sand grain size fraction that is present in a zone (different for all grain types)

EQUATION: sediment__extraction_site_MCS[Zone1a,Fine_Sand](t - dt) + (natural_i nput_MSC[Zone1a,Fine_Sand] + infilling_MSC[Zone1a,Fine_Sand] - decrease_by_extractio n_MSC[Zone1a,Fine_Sand] - natural_decrease_by_ transport_MSC
[Zone1a,Fine_Sand])*dt

ARRAY: zone vs. grain type

UNITS: %

VALUE: initial value = 31.22; range between 0 and unlimited
TYPE: stock
FUNCTION: objective
LINKS:

- Input: Sediment extraction site MCS; Natural input 2; Infilling 2
- Output: Decrease by extraction 2; Decrease by natural transport 2

DATA: Calculated from meta-analysis

For initial values, see subsection 5.1 above. The description of the stocks of the other grain size types and zones are identical and only the equations are given:

sediment_extraction_site_MCS[Zone*,Fine_Sand](t)=sediment_extraction_site_MCS [Zone*,Fine_Sand](t-dt)+(natural_input_MSC[Zone*,Fine_Sand]+infilling_MSC [Zone*, Fine_Sand]-decrease_by_extraction_MSC[Zone*,Fine_Sand]-natural_decrease_by_transport_MSC[Zone*,Fine_Sand])*dt

Note: The equations for all other zones of fine sand are the same.

sediment_extraction_site_MCS[Zone*,Medium_Coarse_Sand](t)=sediment_extraction_site_MCS[Zone1a,Medium_Coarse_Sand](t-dt)+(natural_input_MSC[Zone*,Medium_Coarse_Sand]+infilling_MSC[Zone*,Medium_Coarse_Sand]-decrease_by_extraction_MSC[Zone*,Medium_Coarse_Sand]-natural_decrease_by_transport_MSC[Zone*,Medium_Coarse_Sand])*dt

Note: The equations for all other zones of medium-coarse sand are the same.

sediment_extraction_site_MCS[Zone*,Gravel](t)=sediment_extraction_site_MCS[Zone*,Gravel](t-dt)+(natural_input_MSC[Zone*,Gravel]+infilling_MSC[Zone*,Gravel]-decrease_by_extraction_MSC[Zone*,Gravel]-natural_decrease_by_transport_MSC [Zone*,Gravel])*dt

Note: The equations for all other zones of gravel are the same.

5.9 sediment extraction site gravel

DEFINITION: The percentage of the gravel grain size fraction that is present in a zone (different for all grain types)
EQUATION: sediment_extraction_site_gravel[Zone1a,Fine_Sand](t-dt)+(natural_input_Gravel[Zone1a,Fine_Sand]+infilling_Gravel [Zone1a,Fine_Sand]-

decrease_by_extraction_Gravel [Zone1a, Fine_Sand]- natural_decrease_by_transport_Gravel [Zone1a,Fine_Sand])*dt
ARRAY: zone vs. grain type
UNITS: %
VALUE: initial value = 8.40; range between 0 and unlimited
TYPE: stock
FUNCTION: objective
LINKS:

- Input: Sediment extraction site gravel; Natural input; Infilling
- Output: Decrease by extraction; Decrease by natural transport

DATA: Calculated from meta-analysis

For initial values, see subsection 5.1 above. The description of the stocks of the other grain size types and zones are identical and only the equations are given:

sediment_extraction_site_gravel[Zone*,Fine_Sand](t) = sediment_extraction_site_gravel[Zone*,Fine_Sand](t - dt) + (natural_input_Gravel [Zone1b,Fine_Sand] + infilling_Gravel [Zone*,Fine_Sand] - decrease_by_extraction_Gravel [Zone*,Fine_Sand] - natural_decrease_by_transport_Gravel [Zone*,Fine_Sand]) * dt

Note: The equations for all other zones of fine sand are the same.

sediment_extraction_site_gravel[Zone*,Medium_Coarse_Sand](t) = sediment_extraction_site_gravel[Zone*,Medium_Coarse_Sand](t - dt) + (natural_input_Gravel[Zone*,Medium_Coarse_Sand] + infilling_Gravel[Zone*,Medium_Coarse_Sand] – decrease_by_extraction_Gravel[Zone*,Medium_Coarse_Sand] - natural_decrease_by_transport_Gravel[Zone*,Medium_Coarse_Sand]) * dt

Note: The equations for all other zones of medium-coarse sand are the same.

sediment_extraction_site_gravel[Zone*,Gravel](t)=sediment_extraction_site_gravel[Zone1a,Gravel](t-dt)+(natural_input_Gravel[Zone*,Gravel]+infilling_Gravel[Zone*,Gravel]–decrease_by_extraction_Gravel[Zone*,Gravel]-natural_decrease_by_transport_Gravel[Zone*,Gravel])*dt

Note: The equations for all other zones of gravel are the same.

5.10 natural imput MCS

DEFINITION: The percentage of the medium-coarse sand grain size fraction that is coming in the zone due to natural sediment transport processes

EQUATION: infilling_rate_MCS[zone,gr]*sediment_extraction_site_MCS[zone,gr]

ARRAY: zone vs. grain type

UNITS: %

VALUE: range from 0 to unlimited; only +

TYPE: flow

FUNCTION: calculation

LINKS:

- Input: Infilling rate MCS; sediment extraction site MCS
- Output: Sediment extraction site MCS

DATA: calculated but not verifiable

5.11 natural input gravel

DEFINITION: The percentage of the gravel grain size fraction that is coming in the zone due to natural sediment transport processes

EQUATION: infilling_rate_Gravel[zone,gr]*sediment_extraction_site_gravel[zone,gr]

ARRAY: zone vs. grain type

UNITS: %

VALUE: range from 0 to unlimited; only +

TYPE: flow

FUNCTION: calculation

LINKS:

- Input: Infilling rate Gravel; sediment extraction site gravel
- Output: Sediment extraction site gravel

DATA: calculated but not verifiable

5.12 infilling rate MCS

DEFINITION: The rate at which the medium-coarse sand grain size fraction is transported to an area

EQUATION: Constant

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: 1.028 (for gr=Fine Sand), 1.0168 (for gr= Medium Coarse Sand), 1.0101 (for gr=gravel) for zone 1A

TYPE: parameter

FUNCTION: scenario

LINKS:

- Output: Natural input MCS

DATA: Calculated from meta-analysis

See TABLE 7 above for data.

5.13 infilling rate gravel

DEFINITION: The rate at which the fine sand grain size fraction is transported to an area

EQUATION: Constant

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: 1.0215 (for gr=Fine Sand), 1.049 (for gr= Medium Coarse Sand), 1.0102 (for gr=gravel) for zone 1A

TYPE: parameter

FUNCTION: scenario

LINKS:

- Output: Natural input Gravel

DATA: Calculated from meta-analysis

See TABLE 7 above for data.

5.14 infilling MCS

DEFINITION: The percentage of the medium-coarse sand grain size fraction that fills in the extraction tracks

EQUATION:IF(sum_of_effects_surface_MCS[zone,gr]=0)THEN(0)ELSE((sum_of_effects_surface_MCS[zone,gr]+1)*sediment_extraction_site_MCS[zone,gr])-((sum_of_effects_ surface_MCS[zone,gr]+1)*sediment_extraction_site_MCS[zone,gr])

ARRAY: zone vs. grain type

UNITS: %

VALUE: range from 0 to unlimited; only +

TYPE: flow

FUNCTION: calculation

LINKS:

- Input: Sum of effects surface MCS; Sediment extraction site MCS
- Output: Sediment extraction site MCS

DATA: calculated but not verifiable

5.15 infilling gravel

DEFINITION: The percentage of the gravel grain size fraction that fills in the extraction tracks

EQUATION:IF(sum_of_effects_surface_gravel[zone,gr]=0)THEN(0)ELSE((sum_of_effects_surface_gravel[zone,gr]+1)*sediment_extraction_site_gravel[zone,gr])-((sum_of_effects_ surface_gravel[zone,gr]+1)*sediment_extraction_site_gravel[zone,gr])

ARRAY: zone vs. grain type

UNITS: %

VALUE: range from 0 to unlimited; only +

TYPE: flow

FUNCTION: calculation

LINKS:

- Input: Sum of effects surface gravel; Sediment extraction site gravel
- Output: Sediment extraction site gravel

DATA: calculated but not verifiable

5.16 natural decrease by transport MCS

DEFINITION: The percentage of the medium-coarse sand grain size fraction that leaves the zone due to natural sediment transport processes

EQUATION: sand_transport_MCS[zone,gr]*sediment_extraction_site_MCS[zone,gr]

ARRAY: zone vs. grain type

UNITS: %

VALUE: range from 0 to unlimited; only +

TYPE: flow

FUNCTION: calculation

LINKS:

- Input: Sand transport MCS; Sediment extraction site MCS

DATA: calculated but not verifiable

5.17 natural decrease by transport gravel

DEFINITION: The percentage of the gravel grain size fraction that leaves the zone due to natural sediment transport processes

EQUATION: sand_transport_gravel [zone,gr]*sediment_extraction_site_gravel[zone,gr]

ARRAY: zone vs. grain type

UNITS: %

VALUE: range from 0 to unlimited; only +

TYPE: flow

FUNCTION: calculation
LINKS:

- Input: Sand transport Gravel; Sediment extraction site gravel

DATA: calculated but not verifiable

5.18 sand transport MCS

DEFINITION: The rate at which the medium-coarse sand grain size fraction is transported away from an area
EQUATION: constant
ARRAY: zone vs. grain type
UNITS: numerical
VALUE: 1.0015 (for gr=Fine Sand), 1.0063 (for gr= Medium Coarse Sand), 1.0077 (for gr=gravel) for zone 1A
TYPE: parameter
FUNCTION: scenario
LINKS:

- Output: Natural decrease by transport MCS

DATA: Calculated from meta-analysis

See TABLE 8 above for data.

5.19 sand transport gravel

DEFINITION: The rate at which the gravel grain size fraction is transported away from an area
EQUATION: constant
ARRAY: zone vs. grain type
UNITS: numerical
VALUE: 1.00084 (for gr=Fine Sand), 1.0056 (for gr= Medium Coarse Sand), 1.01 (for gr=gravel) for zone 1A
TYPE: parameter
FUNCTION: scenario
LINKS:

- Output: Natural decrease by transport Gravel

DATA: Calculated from meta-analysis
See TABLE 8 above for data.

5.20 decrease by extraction MCS

DEFINITION: The percentage of the medium-coarse sand grain size fraction that is removed from the zone due to the extraction activities

EQUATION:IF(sum_of_effects_amount_MCS[zone,gr]<0)THEN(sediment_extraction _site_MCS[zone,gr]-(sum_of_effects_amount_MCS[zone,gr]+1)*sediment__extracti on_site _MCS[zone,gr])ELSE0

ARRAY: zone vs. grain type

UNITS: %

VALUE: range from 0 to unlimited; only +

TYPE: flow

FUNCTION: calculation

LINKS:

- Input: Sum of effects amount MCS; Sediment extraction site MCS

DATA: calculated but not verifiable

5.21 decrease by extraction gravel

DEFINITION: The percentage of the gravel grain size fraction that is removed from the zone due to the extraction activities

EQUATION:IF(sum_of_effects_amount_gravel[zone,gr]<0)THEN(sediment_extractio n_site_gravel[zone,gr]-(sum_of_effects_amount_gravel[zone,gr]+1)*sediment__extra ction_site _gravel[zone,gr])ELSE0

ARRAY: zone vs. grain type

UNITS: %

VALUE: range from 0 to unlimited; only +

TYPE: flow

FUNCTION: calculation

LINKS:

- Input: Sum of effects amount gravel; Sediment extraction site gravel

DATA: calculated but not verifiable

6 EFFECT OF SURFACE AREA EXTRACTED ON SEDIMENT COMPOSITION

These variables are described in the decision process diamond "Effect surface sediment".

6.1 R1_2

DEFINITION: Regime 1, which is different for the different grain size types

EQUATION:IF(regime[Zone1a,Fine_Sand]>15)AND(regime[Zone1a,Fine_Sand]<

101)THEN1ELSE0
ARRAY: zone vs. grain type
UNITS: numerical
VALUE: range between 0 and 1; only +
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: Regime
- Output: Effect surface gravel 1; Effect surface MCS 1; Effect surface FS 1

DATA: calculated from meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

The regimes are equal to the ones described in TABLE 4.

The description above only gives the equation for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.

R1_2[Zone*,Fine_Sand] = IF (regime[Zone*,Fine_Sand]>15) AND (regime[Zone*, Fine_Sand]<101) THEN 1 ELSE 0
Note: The equations for all other zones of fine sand are the same.

R1_2[Zone*,Medium_Coarse_Sand] = IF (regime[Zone*,Medium_Coarse_Sand]> 15) AND (regime[Zone*,Medium_Coarse_Sand]<201) THEN 1 ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

R1_2[Zone*,Gravel] = IF (regime[Zone*,Gravel]>15) AND (regime[Zone*,Gravel] <201) THEN 1 ELSE 0

Note: The equations for all other zones of gravel are the same.

6.2 R2_2

DEFINITION: Regime 2, which is different for the different grain size types
EQUATION:IF(regime[Zone1a,Fine_Sand]>100)AND(regime[Zone1a,Fine_Sand]<6 01) THEN 1 ELSE 0
ARRAY: zone vs. grain type

UNITS: numerical
VALUE: range between 0 and 1; only +
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: Regime
- Output: Effect surface gravel 2; Effect surface MCS 2; Effect surface FS 2

DATA: calculated from meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

The regimes are equal to the ones described in TABLE 4.

The description above only gives the equation for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.

R2_2[Zone*,Fine_Sand] = IF (regime[Zone*,Fine_Sand]>100) AND (regime[Zone *,Fine_Sand]<601) THEN 1 ELSE 0

Note: The equations for all other zones of fine sand are the same.
R2_2[Zone*,Fine_Sand] R2_2[Zone*,Medium_Coarse_Sand] =IF(regime[Zone*, Medium_Coarse_Sand]>200)AND(regime[Zone*,Medium_Coarse_Sand]<601)THEN 1ELSE0

Note: The equations for all other zones of medium-coarse sand are the same.

R2_2[Zone*,Gravel] = IF (regime[Zone*,Gravel]>200) AND (regime[Zone*,Grave l]<751) THEN 1 ELSE 0

Note: The equations for all other zones of gravel are the same.

6.3 R3_2

DEFINITION: Regime 3, which is different for the different grain size types
EQUATION: IF (regime[Zone1a,Fine_Sand]>600) THEN 1 ELSE 0
ARRAY: zone vs. grain type
UNITS: numerical
VALUE: range between 0 and 1; only +

TYPE: variable
FUNCTION: calculation
LINKS:

- Input: Regime
- Output: Effect surface gravel 3; Effect surface MCS 3; Effect surface FS 3

DATA: calculated from meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

The regimes are equal to the ones described in TABLE 4.

The description above only gives the equation for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.

R3_2[Zone*,Fine_Sand] = IF (regime[Zone*,Fine_Sand]>600) THEN 1 ELSE 0

Note: The equations for all other zones of fine sand are the same.

R3_2[Zone*,Medium_Coarse_Sand] = IF (regime[Zone*,Medium_Coarse_Sand]> 600) THEN 1 ELSE 0
Note: The equations for all other zones of medium-coarse sand are the same.

R3_2[Zone*,Gravel] = IF (regime[Zone*,Gravel]>750) THEN 1 ELSE 0

Note: The equations for all other zones of gravel are the same.

6.4 r continuous

DEFINITION: Continuous regime (when the mean number of days between two trips is less than 15), which is similar for all grain size types
EQUATION: IF (Mean_number_of_days_between_2_trips[Zone1a,Fine_Sand]<15) OR (regime[Zone1a,Fine_Sand]=0) THEN 1 ELSE 0
ARRAY: zone vs. grain type
UNITS: numerical
VALUE: range between 0 and 1; only +
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: Regime; Mean number of days between 2 trips
- Output: Sum of effects surface gravel; Sum of effects surface MCS; Sum of effects surface FS

DATA: calculated from meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

The regimes are equal to the ones described in TABLE 4.

The description above only gives the equation for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.

R_continuous_2[Zone*,Fine_Sand] = IF (Mean_number_of_days_between_2_trips[Zone*,Fine_Sand]<15) OR (regime[Zone*,Fine_Sand]=0) THEN 1 ELSE 0

Note: The equations for all other zones of fine sand are the same.

R_continuous_2[Zone*,Medium_Coarse_Sand] = IF (Mean_number_of_days_between_2_trips[Zone*,Medium_Coarse_Sand]<15) OR (regime[Zone*,Medium_Coarse_Sand]=0) THEN 1 ELSE 0
Note: The equations for all other zones of medium-coarse sand are the same.

R_continuous_2[Zone*,Gravel] = IF (Mean_number_of_days_between_2_trips[Zone1a,Gravel]<15) OR (regime[Zone*,Gravel]=0) THEN 1 ELSE 0

Note: The equations for all other zones of gravel are the same.

6.5 effect surface gravel 1

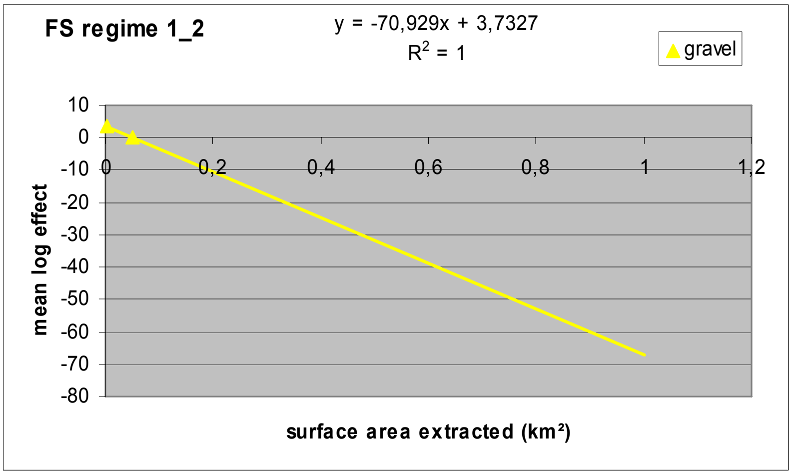
DEFINITION: Effect of the extraction of a certain surface area on the gravel grain size fraction when regime 1_2 is valid
EQUATION: IF(R1_2[Zone1a,Fine_Sand]=1)THEN(((10^(((-70.929*(Effectively_extracted_surface_per_zone_and_type[Zone1a,Fine_Sand]/1000000))+3.7327)+2.004))-101)/100) ELSE 0
ARRAY: zone vs. grain type
UNITS: numerical
VALUE: range between 0 and unlimited; +/-
TYPE: variable

FUNCTION: calculation
LINKS:
- Input: R1_2; Effectively extracted surface per zone and type
- Output: Sum of effects surface gravel

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

GRAPH 21: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in fine sand habitats on the gravel grain size fraction of the sediment (when regime 1_2 is valid).

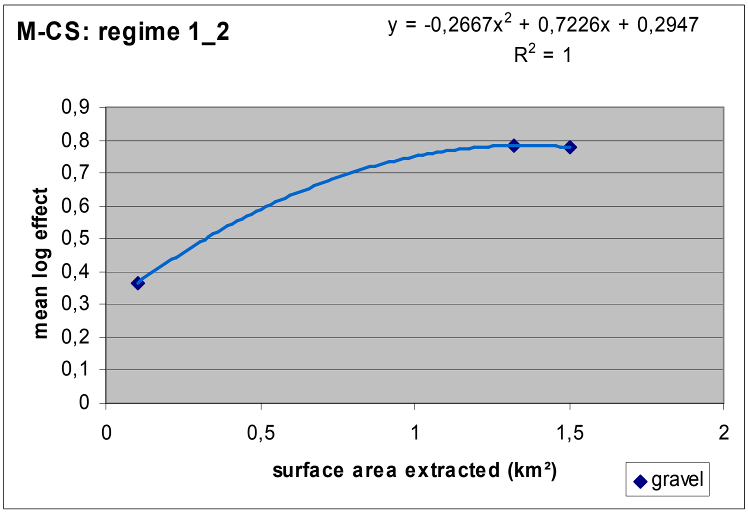


The description above only gives the equation for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.

effect_surface_gravel_1[Zone*,Fine_Sand] = IF(R1_2[Zone*,Fine_Sand]=1)THEN (((10^(((-70.929*(Effectively_extracted_surface_per_zone_and _type[Zone*,Fine_Sand]/10000 00))+3.7327)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of fine sand are the same.

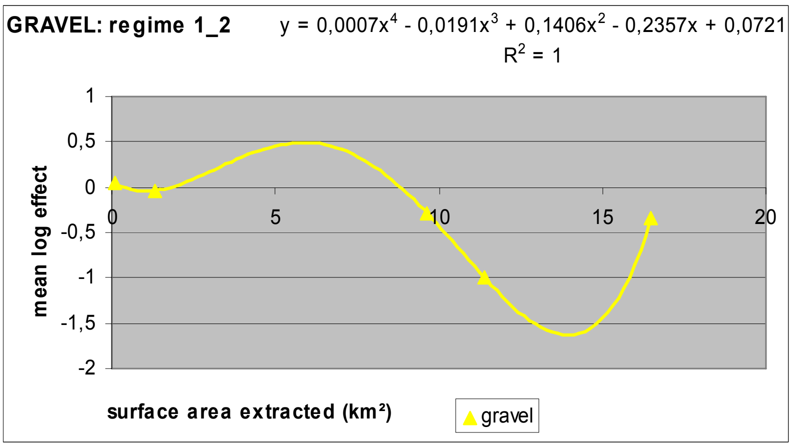
GRAPH 22: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in medium-coarse sand habitats on the gravel grain size fraction of the sediment (when regime 1_2 is valid).



effect_surface_gravel_1[Zone*,Medium_Coarse_Sand] = IF(R1_2[Zone*,Medium _Coarse_Sand]=1)THEN(((10^(((-0.2667*((Effectively_extracted_surface_per_zone _and _type[Zone*,Medium_Coarse_Sand]/1000000)^2))+(0.7226*(Effectively_extrac ted_surface_per_zone_and _type[Zone*,Medium_Coarse_Sand]/1000000))+0.2947) +2.004))-101)/100)ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

GRAPH 23: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in gravel habitats on the gravel grain size fraction of the sediment (when regime 1_2 is valid).



effect_surface_gravel_1[Zone*,Gravel] = IF(R1_2[Zone*,Gravel]=1)THEN(((10^((((0.0007*((Effectively_extracted_surface_per_zone_and _type[Zone*,Gravel]/1000000)^4))-(0.0 191*((Effectively_extracted_surface_per_zone_and _type[Zone*,Gravel]/

1000000)^3)))+(0.1406*((Effectively_extracted_surface_per_zone_and _type[Zone*,Gravel]/1000000)^2))-(0.2357*(Extracted_surface_per_zone_and_type[Zone*,Gravel]/1000000))+0.0721)+2.004))-101)/100) ELSE 0

Note: The equations for all other zones of gravel are the same.

6.6 effect surface MCS 1

DEFINITION: Effect of the extraction of a certain surface area on the medium-coarse sand grain size fraction when regime 1_2 is valid

EQUATION: IF(R1_2[Zone1a,Fine_Sand]=1)THEN(((10^(((-26.678*(Effectively_extracted_surface_per_zone_and_type[Zone1a,Fine_Sand]/1000000))+1.4842)+2.004))-101)/100) ELSE 0

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

TYPE: variable

FUNCTION: calculation

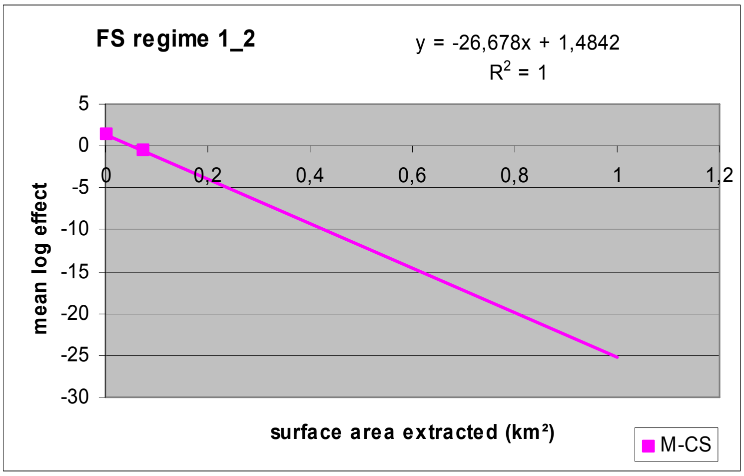
LINKS:

- Input: R1_2; Effectively extracted surface per zone and type
- Output: Sum of effects surface MCS

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

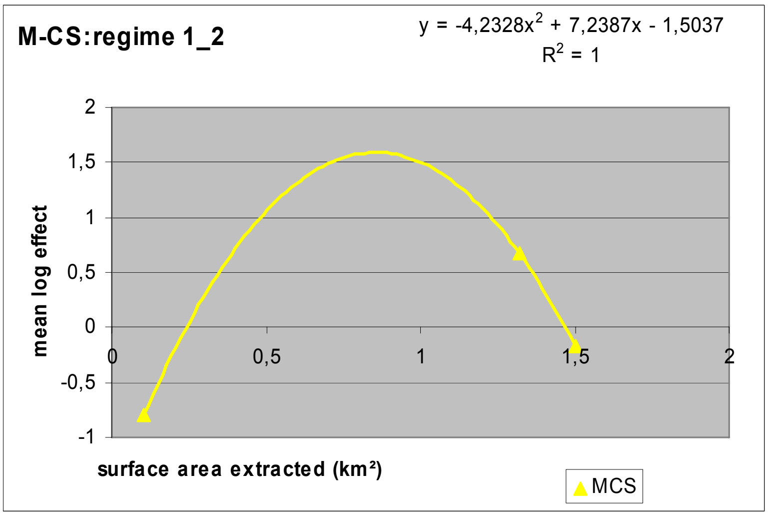
GRAPH 24: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in fine sand habitats on the medium-coarse sand grain size fraction of the sediment (when regime 1_2 is valid).



effect_surface_MCS_1[Zone*,Fine_Sand] = IF(R1_2[Zone*,Fine_Sand]=1)THEN(((10^(((-26.678*(Effectively_extracted_surface_per_zone_and _type[Zone*,Fine _Sand]/10000 00))+1.4842)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of fine sand are the same.

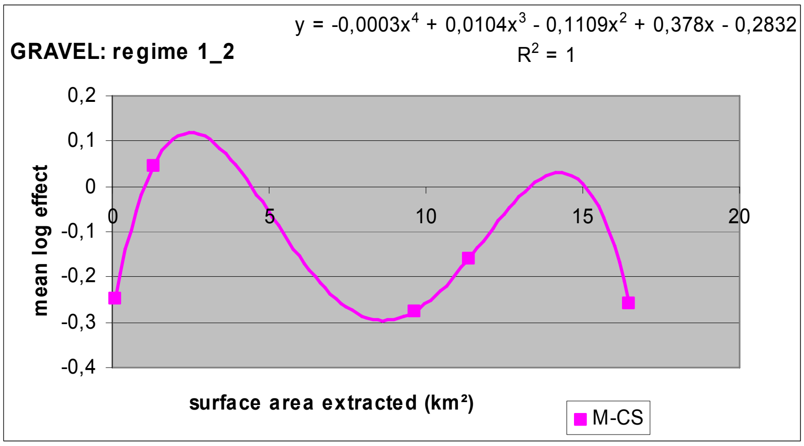
<u>GRAPH 25:</u> Mean (logarithmic) effect of the extraction of a certain surface area of sediment in medium-coarse sand habitats on the medium-coarse sand grain size fraction of the sediment (when regime 1_2 is valid).



effect_surface_MCS_1[Zone*,Medium_Coarse_Sand]=IF(R1_2[Zone*,Medium_Coarse_Sand]=1)THEN(((10^(((-4.2328*((Effectively_extracted_surface_per_zone_and _type[Zone*,Medium_Coarse_Sand]/1000000)^2))+(7.2387*(Effectively_extracted_ surface_per_zone_and _type[Zone*,Medium_Coarse_Sand]/1000000))-1.5037)+2.004))-101)/100)ELSE0

Note: The equations for all other zones of medium-coarse sand are the same.

GRAPH 26: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in gravel habitats on the medium-coarse sand grain size fraction of the sediment (when regime 1_2 is valid).



effect_surface_MCS_1[Zone*,Gravel] = IF(R1_2[Zone*,Gravel]=1)THEN(((10^(((-0.0003*((Effectively_extracted_surface_per_zone_and _type[Zone*,Gravel]/1000000)^4))+(0.0104*((Effectively_extracted_surface_per_zone_and _type[Zone*,Gravel]/1000000)^3))-(0.1109*((Effectively_extracted_surface_per_zone_and _type[Zone*,Gravel]/1000000)^2))+(0.378*(Effectively_extracted_surface_per_zone_and _type[Zone*,Gravel]/1000000))-0.2832)+2.004))-101)/1 00) ELSE 0

Note: The equations for all other zones of gravel are the same.

6.7 effect surface FS 1

DEFINITION: Effect of the extraction of a certain surface area on the fine sand grain size fraction when regime 1_2 is valid

EQUATION:IF(R1_2[Zone1a,Fine_Sand]=1)THEN(((10^(((-4.8656*((Effectively_extracted_surface_per_zone_and_type[Zone1a,Fine_Sand]/1000000)^2))+(5.2302*(Effectively_extracted_surface_per_zone_and_type[Zone1a,Fine_Sand]/1000000))-0.2861)+2.004))-101)/100)E LSE 0

ARRAY: zone vs. grain type

UNITS: numerical

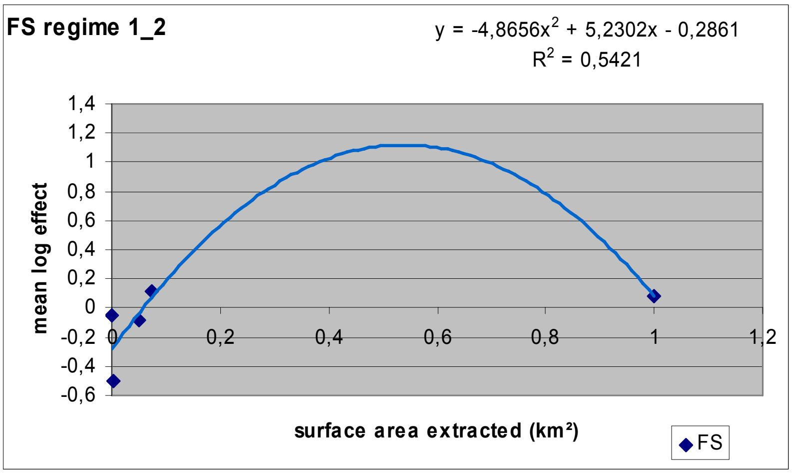
VALUE: range between 0 and unlimited; +/-
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: R1_2; Effectively extracted surface per zone and type
- Output: Sum of effects surface FS

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

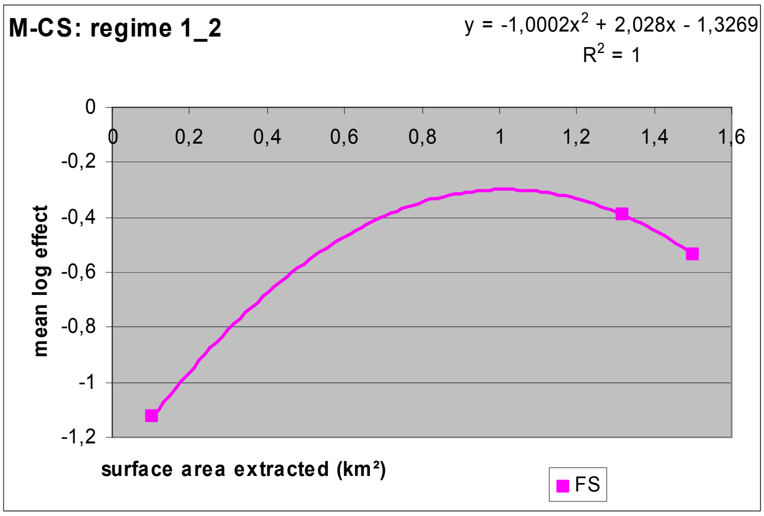
GRAPH 27: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in fine sand habitats on the fine sand grain size fraction of the sediment (when regime 1_2 is valid).



effect_surface_FS_1[Zone*,Fine_Sand] = IF(R1_2[Zone*,Fine_Sand]=1)THEN(((10^(((- 4.8656*((Effectively_extracted_surface_per_zone_and _type[Zone*,Fine _Sand]/10000 00)^2))+(5.2302*(Effectively_extracted_surface_per_zone_and _type[Zone*,Fine_Sand]/1000000))-0.2861)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of fine sand are the same.

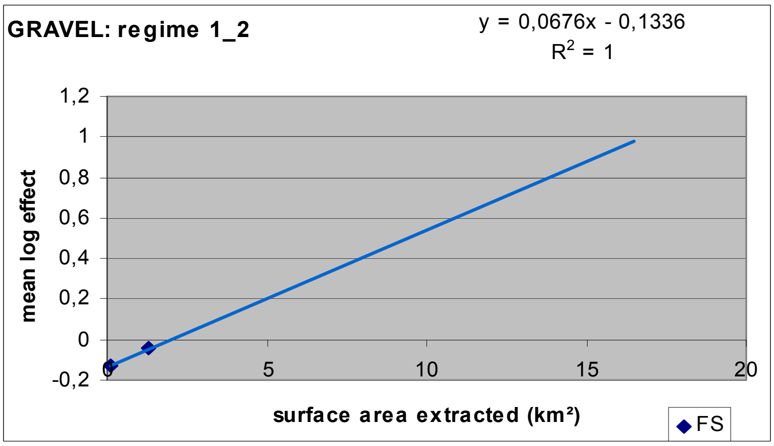
GRAPH 28: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in medium-coarse sand habitats on the fine sand grain size fraction of the sediment (when regime 1_2 is valid).



effect_surface_FS_1[Zone*,Medium_Coarse_Sand] = IF(R1_2[Zone*,Medium_Coarse_Sand]=1)THEN(((10^(((-1.0002*((Effectively_extracted_surface_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^2))+(2.028*(Effectively_extracted_surface_per_zone_and _type[Zone*,Medium_Coarse_Sand]/1000000))-1.3269)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of medium-coarse are the same.

GRAPH 29: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in gravel habitats on the fine sand grain size fraction of the sediment (when regime 1_2 is valid).



effect_surface_FS_1[Zone*,Gravel] = IF(R1_2[Zone*,Gravel]=1)THEN(((10^(((0.0676*(Effectively_extracted_surface_per_zone_and _type[Zone*,Gravel]/1000000))-0.1336)+2. 004))-101)/100) ELSE 0

Note: The equations for all other zones of gravel are the same.

6.8 effect surface gravel 2

DEFINITION: Effect of the extraction of a certain surface area on the gravel grain size fraction when regime 2_2 is valid

EQUATION: IF(R2_2[Zone1a,Fine_Sand]=1)THEN(((10^(((-1.6326*(Effectively_extracted_surface_per_zone_and_type[Zone1a,Fine_Sand]/1000000)+2.1952)+2.004))-101)/100)) ELSE 0

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

TYPE: variable

FUNCTION: calculation

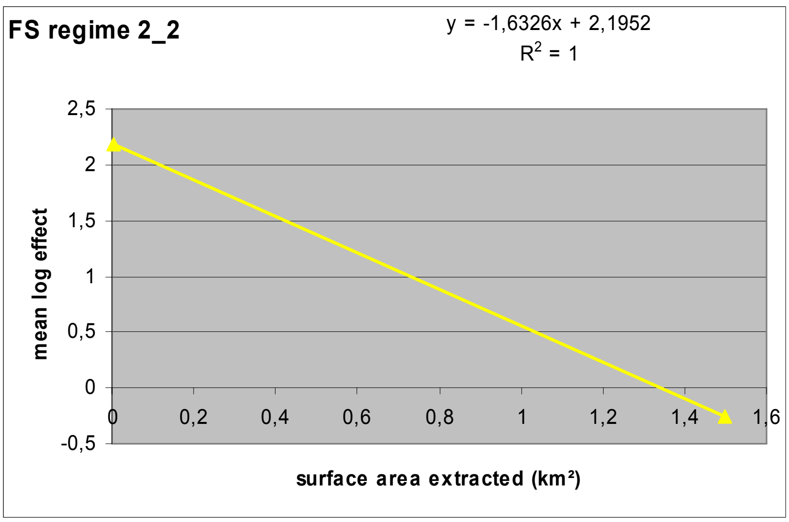
LINKS:

- Input: R2_2; Effectively Extracted surface per zone and type
- Output: Sum of effects surface gravel

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

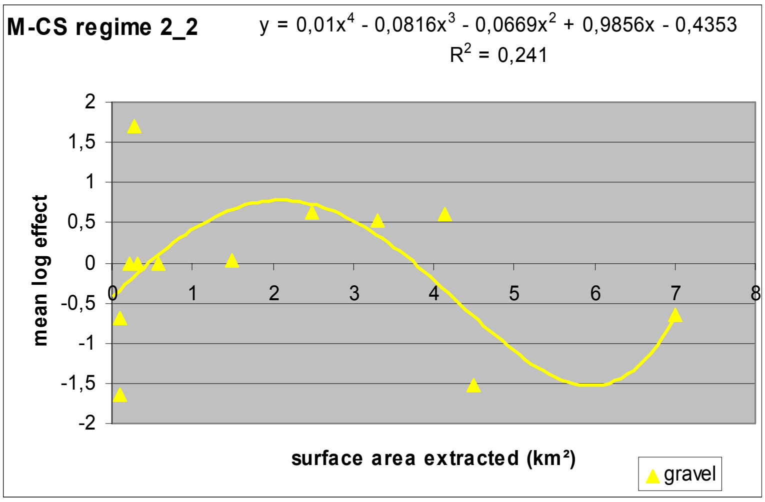
GRAPH 30: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in fine sand habitats on the gravel grain size fraction of the sediment (when regime 2_2 is valid).



effect_surface__gravel_2[Zone*,Fine_Sand] = IF(R2_2[Zone*,Fine_Sand]=1)THEN (((10^(((-1.6326*(Effectively_extracted_surface_per_zone_and_type[Zone*,Fine_Sand]/100 0000)+2.1952)+2.004))-101)/100)) ELSE 0

Note: The equations for all other zones of fine sand are the same.

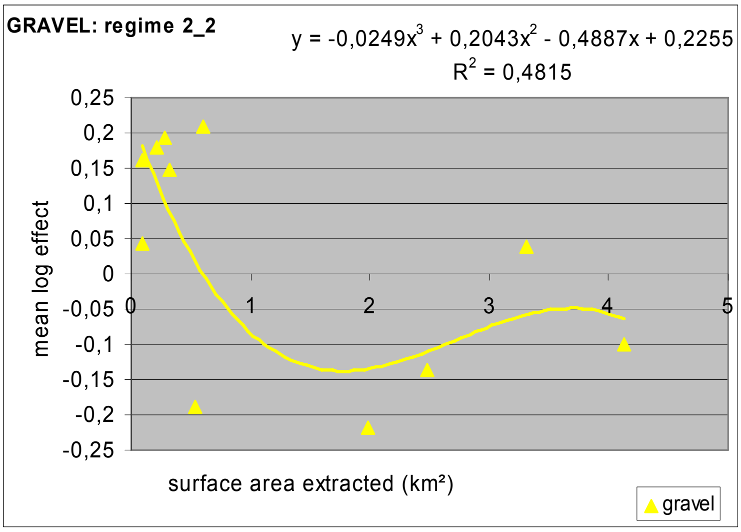
GRAPH 31: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in medium-coarse sand habitats on the gravel grain size fraction of the sediment (when regime 2_2 is valid).



effect_surface__gravel_2[Zone1a,Medium_Coarse_Sand] = IF(R2_2[Zone*,Medium_Coarse_Sand]=1)THEN(((10^(((0.01*((Effectively_extracted_surface_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^4))-(0.0816*((Effectively_extracted_surface_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^3))-(0.0669*((Extracted_surface_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^2))+(0.9856*(Effectively_extracted_surface_per_zone_and_type[Zone*,Medium_Coarse_Sand]/10000000))-0.43 53)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

GRAPH 32: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in gravel habitats on the gravel grain size fraction of the sediment (when regime 2_2 is valid).



effect_surface__gravel_2[Zone*,Gravel] = IF(R2_2[Zone*,Gravel]=1)THEN(((10^ ((((-0.0249*((Effectively_extracted_surface_per_zone_and_type[Zone*,Gravel]/1000000) ^3))+(0.2043*((Effectively_extracted_surface_per_zone_and_type[Zone*,Gravel] /1000000)^2))-(0.4887*((Effectively_extracted_surface_per_zone_and_type[Zone* ,Gravel]/1000000))+0.2255)))+2.004))-101)/100) ELSE 0

Note: The equations for all other zones of gravel are the same.

6.9 effect surface MCS 2

DEFINITION: Effect of the extraction of a certain surface area on the medium-coarse sand grain size fraction when regime 2_2 is valid

EQUATION: IF(R2_2[Zone1a,Fine_Sand]=1)THEN(((10^(((-0.2441*LOGN(Effectively_extracted_surface_per_zone_and_type[Zone1a,Fine_Sand]/1000000))-0.7414)+2.004))-101)/ 100) ELSE 0

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

TYPE: variable

FUNCTION: calculation

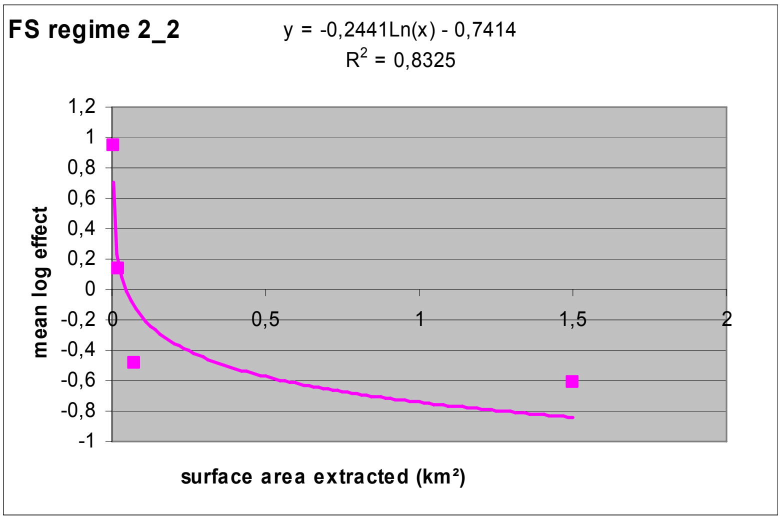
LINKS:

- Input: R2_2; Effectively_extracted surface per zone and type
- Output: Sum of effects surface MCS

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

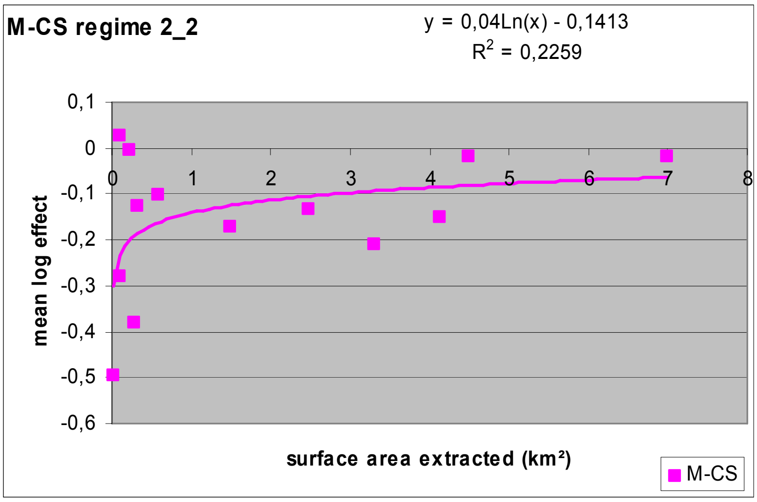
GRAPH 33: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in fine sand habitats on the medium-coarse sand grain size fraction of the sediment (when regime 2_2 is valid).



effect_surface__MCS_2[Zone*,Fine_Sand] = IF(R2_2[Zone*,Fine_Sand]=1)THEN (((10^(((-0.2441*LOGN(Effectively_extracted_surface_per_zone_and_type[Zone*, Fine_Sand]/ 1000000))-0.7414)+2.004))-101)/100) ELSE 0

Note: The equations for all other zones fine sand are the same.

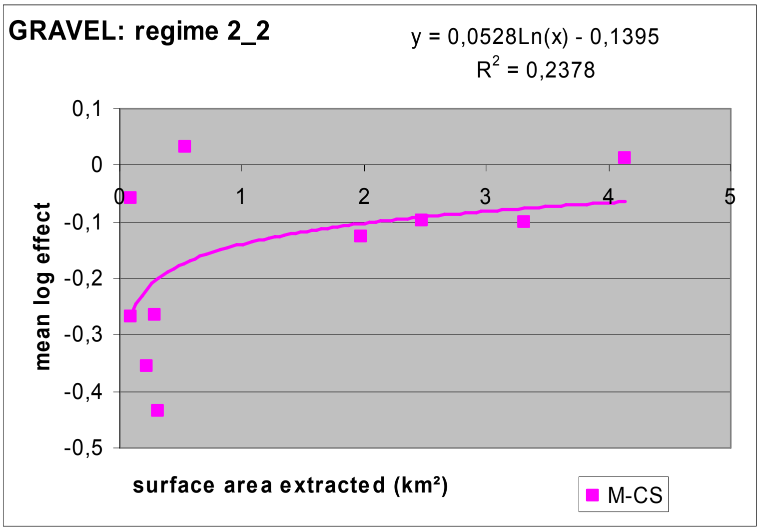
GRAPH 34: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in medium-coarse sand habitats on the medium-coarse sand grain size fraction of the sediment (when regime 2_2 is valid).



effect_surface__MCS_2[Zone*,Medium_Coarse_Sand] = IF(R2_2[Zone*,Medium_Coarse_Sand]=1)THEN(((10^(((0.04*LOGN(Effectively_extracted_surface_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000))-0.1413)+2.004))-101)/100) ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

<u>GRAPH 35:</u> Mean (logarithmic) effect of the extraction of a certain surface area of sediment in gravel habitats on the medium-coarse sand grain size fraction of the sediment (when regime 2_2 is valid).



effect_surface__MCS_2[Zone*,Gravel] = IF(R2_2[Zone*,Gravel]=1)THEN(((10^(((0.0528*LOGN(Effectively_extracted_surface_per_zone_and_type[Zone*,Gravel]/1000000))-0. 1395)+2.004))-101)/100) ELSE 0

Note: The equations for all other zones of gravel are the same.

6.10 effect surface FS 2

DEFINITION: Effect of the extraction of a certain surface area on the fine sand grain size fraction when regime 2_2 is valid

EQUATION:IF(R2_2[Zone1a,Fine_Sand]=1)THEN(((10^((((8.0265*((Effectively_extracted_surface_per_zone_and_type[Zone1a,Fine_Sand]/1000000)^3))-(14.337*((Effectively_extracted_surface_per_zone_and_type[Zone1a,Fine_Sand]/1000000)^2))+(4.5428*(Effectively_extr acted_surface_per_zone_and_type[Zone1a,Fine_Sand]/1000000))-0.1432)+2.004))-101)/100)) ELSE 0

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

TYPE: variable

FUNCTION: calculation

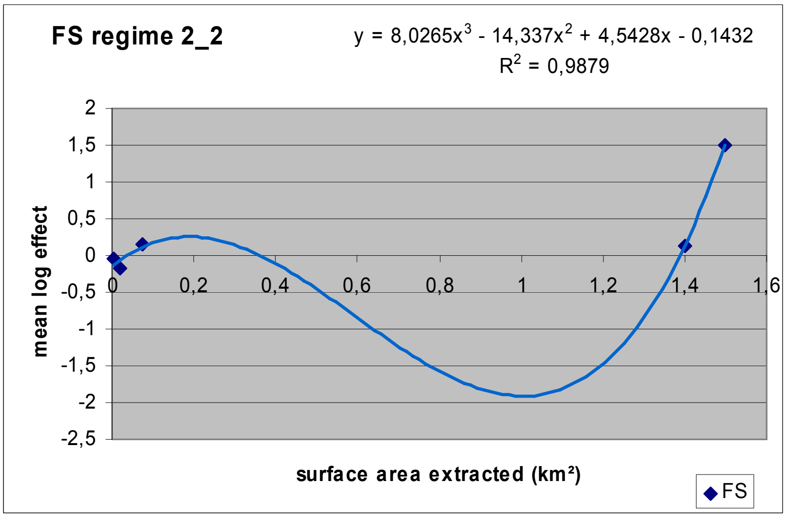
LINKS:

- Input: R2_2; Effectively_extracted surface per zone and type
- Output: Sum of effects surface FS

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

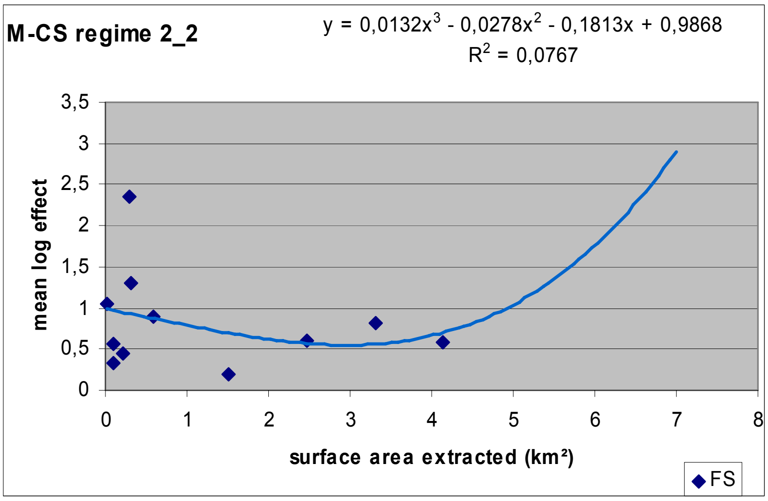
GRAPH 36: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in fine sand habitats on the fine sand grain size fraction of the sediment (when regime 2_2 is valid).



effect_surface__FS_2[Zone*,Fine_Sand] = IF(R2_2[Zone*,Fine_Sand]=1)THEN(((10^((((8.0265*((Effectively_extracted_surface_per_zone_and_type[Zone*,Fine_Sand]/1000000)^3))-(14.337*((Effectively_extracted_surface_per_zone_and_type[Zone*,Fine_Sand]/1000000)^2))+(4.5428*(Effectively_extracted_surface_per_zone_and_type[Zone*,Fine_Sand]/1000000))-0.1432)+2.004))-101)/100)) ELSE 0

Note: The equations for all other zones of fine sand are the same.

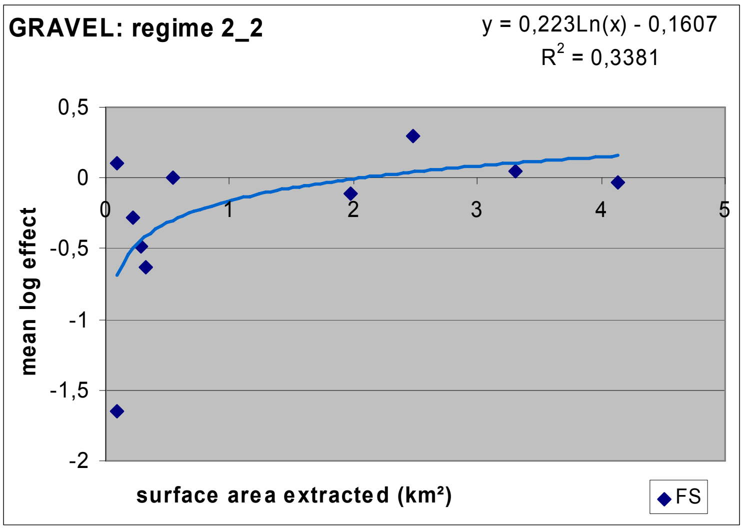
GRAPH 37: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in medium-coarse sand habitats on the fine sand grain size fraction of the sediment (when regime 2_2 is valid).



effect_surface__FS_2[Zone*,Medium_Coarse_Sand] = IF(R2_2[Zone*,Medium_Coarse_Sand]=1)THEN(((10^(((0.0132*((Effectively_extracted_surface_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^3))-(0.0278*((Effectively_extracted_surface_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^2))-(0.1813*(Effectively_extracted_surface_per_zone_and_type[Zone*,Medium_Coarse_Sand]/10000000))+0.9868)+2.004))-1 01)/100)ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

GRAPH 38: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in gravel habitats on the fine sand grain size fraction of the sediment (when regime 2_2 is valid).



effect_surface__FS_2[Zone*,Gravel] = IF(R2_2[Zone*,Gravel]=1)THEN(((10^(((0.223*LOGN(Effectively_extracted_surface_per_zone_and_type[Zone*,Gravel]/1000000))-0.16 07)+2.004))-101)/100) ELSE 0

Note: The equations for all other zones of gravel are the same.

6.11 effect surface gravel 3

DEFINITION: Effect of the extraction of a certain surface area on the gravel grain size fraction when regime 3_2 is valid

EQUATION:IF(R3_2[Zone1a,Fine_Sand]=1)THEN(((10^(((0.76*LOGN(Effectively_extracted_surface_per_zone_and_type[Zone1a,Fine_Sand]/1000000))-0.148)+2.004))-101)/100) ELSE 0

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

TYPE: variable

FUNCTION: calculation

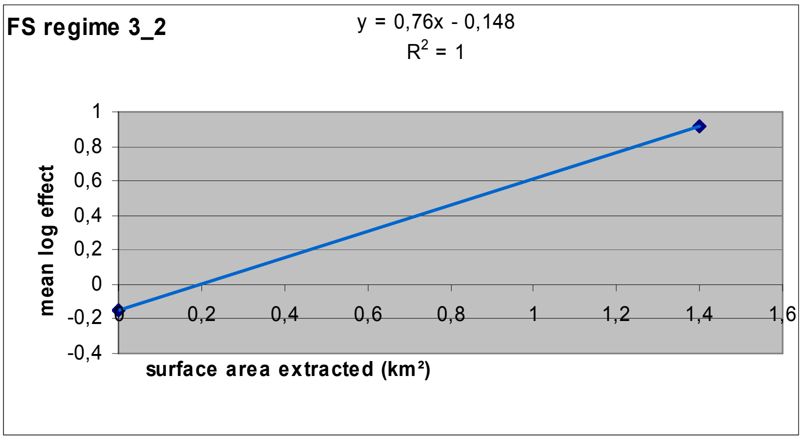
LINKS:

- Input: R3_2; Effectively_extracted surface per zone and type
- Output: Sum of effects surface gravel

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

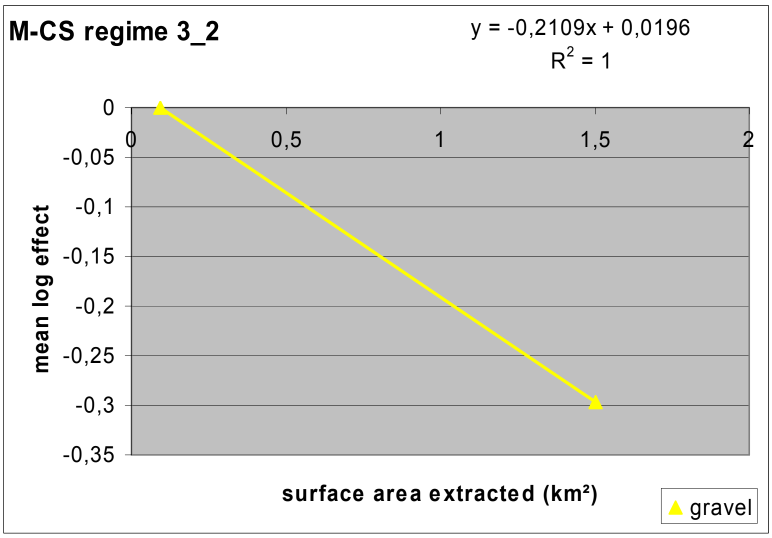
GRAPH 39: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in fine sand habitats on the gravel grain size fraction of the sediment (when regime 3_2 is valid).



effect_surface_gravel_3[Zone*,Fine_Sand] = IF(R3_2[Zone*,Fine_Sand]=1)THEN (((10^(((0.76*LOGN(Effectively_extracted_surface_per_zone_and_type[Zone*,Fine_Sand]/1000000))-0.148)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of fine sand are the same.

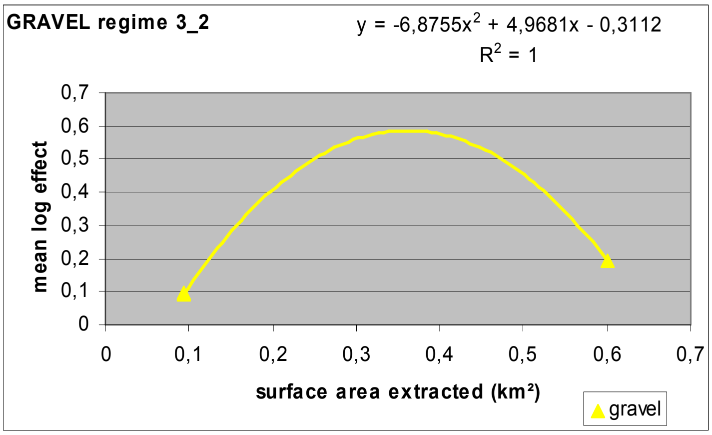
GRAPH 40: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in medium-coarse sand habitats on the gravel grain size fraction of the sediment (when regime 3_2 is valid).



effect_surface_gravel_3[Zone*,Medium_Coarse_Sand] = IF(R3_2[Zone*,Medium_Coarse_Sand]=1)THEN(((10^(((-0.2109*(Effectively_extracted_surface_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000))+0.0196)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

GRAPH 41: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in gravel habitats on the gravel grain size fraction of the sediment (when regime 3_2 is valid).



effect_surface_gravel_3[Zone*,Gravel] = IF(R3_2[Zone*,Gravel]=1)THEN(((10^(((-6.8755*((Effectively_extracted_surface_per_zone_and_type[Zone*,Gravel]/1000000)^2))+(4. 9681*(Effectively_extracted_surface_per_zone_and_type[Zone*,Gravel]/1000000))-0.3112)+2. 004))-101)/100)ELSE 0

Note: The equations for all other zones of gravel are the same.

6.12 effect surface MCS 3

DEFINITION: Effect of the extraction of a certain surface area on the medium-coarse sand grain size fraction when regime 3_2 is valid

EQUATION:IF(R3_2[Zone1a,Fine_Sand]=1)THEN(((10^(((0.76*LOGN(Effectively_extracted_surface_per_zone_and_type[Zone1a,Fine_Sand]/1000000))-0.148)+2.004))-101)/100) ELSE 0

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

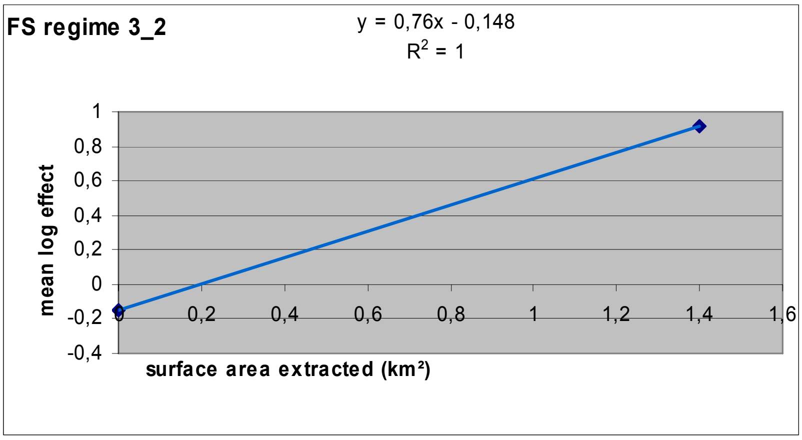
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: R3_2; Effectively_extracted surface per zone and type
- Output: Sum of effects surface MCS

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

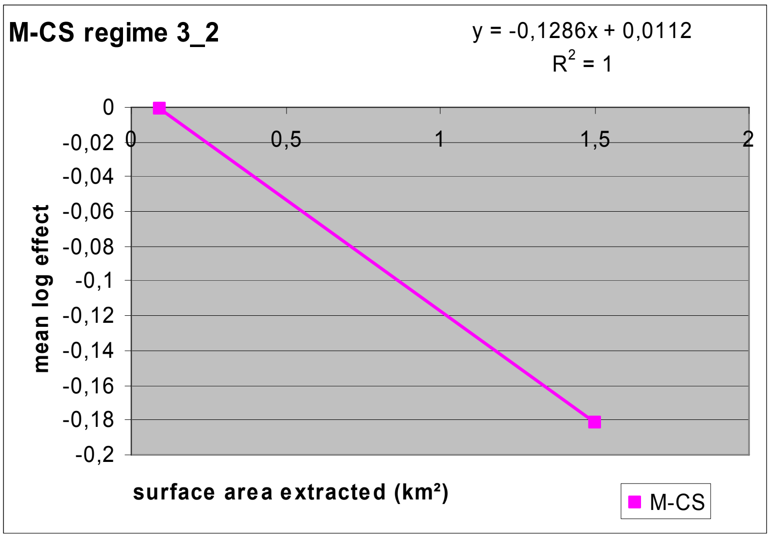
GRAPH 42: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in fine sand habitats on the medium-coarse grain size fraction of the sediment (when regime 3_2 is valid).



effect_surface_MCS_3[Zone*,Fine_Sand] = IF(R3_2[Zone*,Fine_Sand]=1)THEN(((10^(((0.76*LOGN(Effectively_extracted_surface_per_zone_and_type[Zone*,Fine_Sand]/1000000))-0.148)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of fine sand are the same.

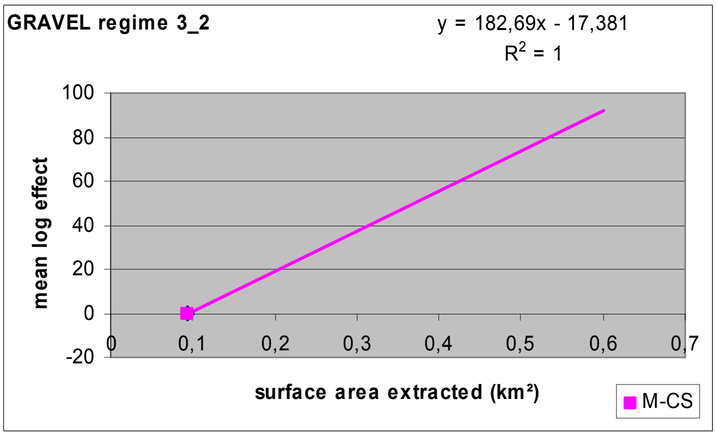
GRAPH 43: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in medium-coarse sand habitats on the medium-coarse grain size fraction of the sediment (when regime 3_2 is valid).



effect_surface_MCS_3[Zone*,Medium_Coarse_Sand] = IF(R3_2[Zone*,Medium_Coarse_Sand]=1)THEN(((10^((-0.1286*(Effectively_extracted_surface_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)+0.0112)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

GRAPH 44: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in gravel habitats on the medium-coarse grain size fraction of the sediment (when regime 3_2 is valid).



effect_surface_MCS_3[Zone*,Gravel] = IF(R3_2[Zone*,Gravel]=1)THEN(((10^(((182.69*(Effectively_extracted_surface_per_zone_and_type[Zone*,Gravel]/1000000))-17.381)+ 2.004))-101)/100)ELSE 0

Note: The equations for all other zones of gravel are the same.

6.13 effect surface FS 3

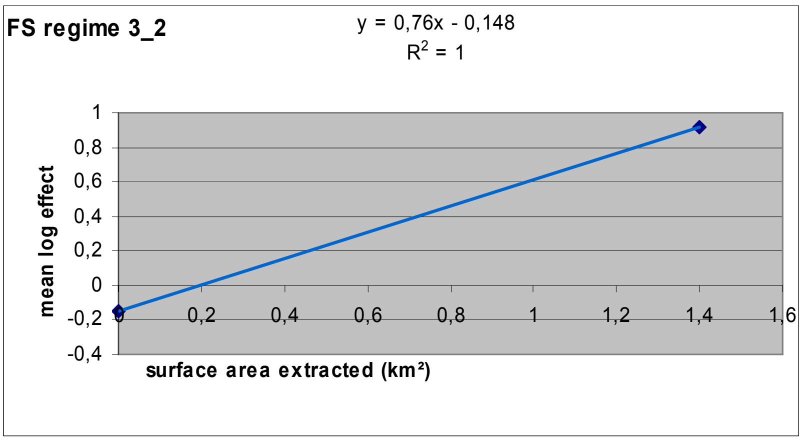
DEFINITION: Effect of the extraction of a certain surface area on the fine sand grain size fraction when regime 3_2 is valid
EQUATION:IF(R3_2[Zone1a,Fine_Sand]=1)THEN(((10^(((0.76*LOGN(Effectively_extracted_surface_per_zone_and_type[Zone1a,Fine_Sand]/1000000))-0.148)+2.004))-101)/100) ELSE 0
ARRAY: zone vs. grain type
UNITS: numerical
VALUE: range between 0 and unlimited; +/-
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: R3_2; Effectively_extracted surface per zone and type
- Output: Sum of effects surface FS

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

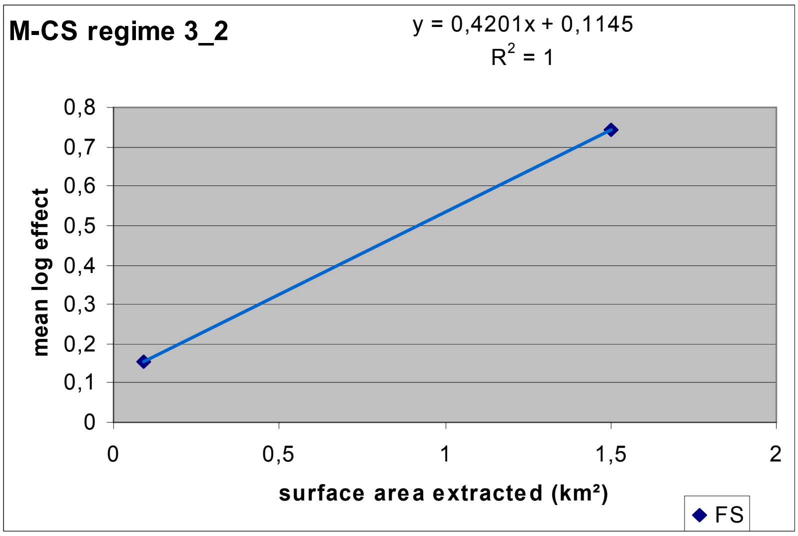
GRAPH 45: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in fine sand habitats on the fine sand grain size fraction of the sediment (when regime 3_2 is valid).



effect_surface_FS_3[Zone*,Fine_Sand] = IF(R3_2[Zone*,Fine_Sand]=1)THEN(((10^(((0.76*LOGN(Effectively_extracted_surface_per_zone_and_type[Zone*,Fine_Sand]/1000000))-0.148)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of fine sand are the same.

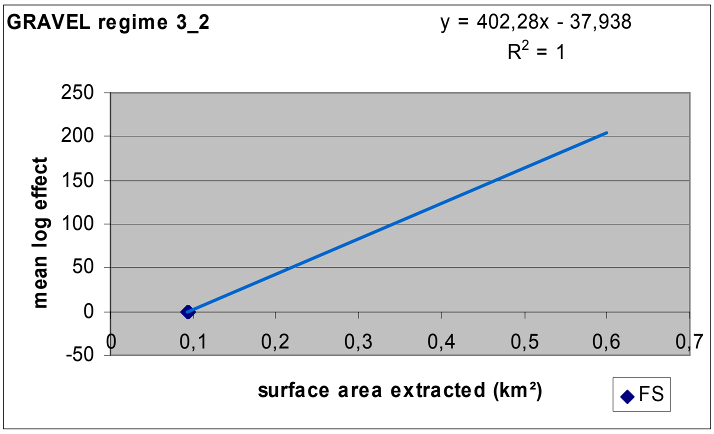
GRAPH 46: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in medium-coarse sand habitats on the fine sand grain size fraction of the sediment (when regime 3_2 is valid).



effect_surface_FS_3[Zone*,Medium_Coarse_Sand] = IF(R3_2[Zone*,Medium_Coarse_Sand]=1)THEN(((10^((0.4201*(Effectively_extracted_surface_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)+0.1145)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

GRAPH 47: Mean (logarithmic) effect of the extraction of a certain surface area of sediment in gravel habitats on the fine sand grain size fraction of the sediment (when regime 3_2 is valid).



effect_surface_FS_3[Zone*,Gravel] = IF(R3_2[Zone*,Gravel]=1)THEN(((10^(((402.28*(Effectively_extracted_surface_per_zone_and_type[Zone*,Gravel]/1000000))-37.938)+2. 004))-101)/100)ELSE 0

Note: The equations for all other zones of gravel are the same.

6.14 sum of effects of surface gravel

DEFINITION: Sum of the effects of the extraction of a certain surface area for all regimes on the gravel grain size fraction

EQUATION: IF(R_continuous_2[Zone,Grain]=1)THEN 0 ELSE (SUM(effect_surface_gravel_1[Zone,Grain]+effect_surface_gravel_3[Zone,Grain]+effect_surface__gravel_2[Zone,Grain]))

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

TYPE: variable

FUNCTION: calculation

LINKS:

- Input: R continuous 2; Effect surface gravel 1; Effect surface gravel 2; Effect surface gravel 3
- Output: Infilling

DATA: calculated but not verifiable

6.15 sum of effects of surface MCS

DEFINITION: Sum of the effects of the extraction of a certain surface area for all regimes on the medium-coarse sand grain size fraction

EQUATION:IF(R_continuous_2[Zone,Grain]=1)THEN 0 ELSE (SUM(effect_surface_MCS_1[Zone,Grain]+effect_surface_MCS_3[Zone,Grain]+effect_surface__MCS_2[Zone,Grain]))
ARRAY: zone vs. grain type
UNITS: numerical
VALUE: range between 0 and unlimited; +/-
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: R continuous 2; Effect surface MCS 1; Effect surface MCS 2; Effect surface MCS 3
- Output: Infilling 2

DATA: calculated but not verifiable

6.16 sum of effects of surface FS

DEFINITION: Sum of the effects of the extraction of a certain surface area for all regimes on the gravel grain size fraction
EQUATION:IF(R_continuous_2[Zone,Grain]=1)THEN0ELSE(SUM(effect_surface_FS_1[Zone,Grain]+effect_surface_FS_3[Zone,Grain]+effect_surface__FS_2[Zone,Grain]))
ARRAY: zone vs. grain type
UNITS: numerical
VALUE: range between 0 and unlimited; +/-
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: R continuous 2; Effect surface FS 1; Effect surface FS 2; Effect surface FS 3
- Output: Infilling 3

DATA: calculated but not verifiable

7 EFFECT OF AMOUNT OF AGGREGATES EXTRACTED ON SEDIMENT COMPOSITION

These variables are described in the decision process diamond "Effect amount sediment".

7.1 R1_3

DEFINITION: Regime 1, which is different for the different grain size types
EQUATION: = IF(regime[Zone1a,Fine_Sand]>15) AND (regime[Zone1a,Fine_Sand]<101) THEN 1 ELSE 0
ARRAY: zone vs. grain type
UNITS: numerical
VALUE: range between 0 and 1; only +
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: Regime
- Output: Effect amount gravel 1; Effect amount MCS 1; Effect amount FS 1

DATA: calculated from meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

The regimes are equal to the ones described in TABLE 4.

The description above only gives the equation for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.

R1_3[Zone*,Fine_Sand] = IF (regime[Zone*,Fine_Sand]>15) AND (regime[Zone*, Fine_Sand]<101) THEN 1 ELSE 0

Note: The equations for all other zones of fine sand are the same.

R1_3[Zone*,Medium_Coarse_Sand] = IF (regime[Zone*,Medium_Coarse_Sand]> 15) AND (regime[Zone*,Medium_Coarse_Sand]<201) THEN 1 ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

R1_3[Zone*,Gravel] = IF (regime[Zone*,Gravel]>15) AND (regime[Zone*,Gravel]<201) THEN 1 ELSE 0

Note: The equations for all other zones of gravel are the same.

7.2 R2_3

DEFINITION: Regime 2, which is different for the different grain size types
EQUATION:IF(regime[Zone1a,Fine_Sand]>100)AND(regime[Zone1a,Fine_Sand]<601) THEN 1 ELSE 0
ARRAY: zone vs. grain type
UNITS: numerical
VALUE: range between 0 and 1; only +
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: Regime
- Output: Effect amount gravel 2; Effect amount MCS 2; Effect amount FS 2

DATA: calculated from meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

The regimes are equal to the ones described in TABLE 4.

The description above only gives the equation for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.

R2_3[Zone*,Fine_Sand] = IF (regime[Zone*,Fine_Sand]>100) AND (regime[Zone*, Fine_Sand]<601) THEN 1 ELSE 0

Note: The equations for all other zones of fine sand are the same.

R2_3[Zone*,Medium_Coarse_Sand] = IF (regime[Zone*,Medium_Coarse_Sand]>200) AND (regime[Zone*,Medium_Coarse_Sand]<601) THEN 1 ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

R2_3[Zone*,Gravel] = IF (regime[Zone*,Gravel]>200) AND (regime[Zone*,Gravel]<751) THEN 1 ELSE 0

Note: The equations for all other zones of gravel are the same.

7.3 R3_3

DEFINITION: Regime 3, which is different for the different grain size types
EQUATION: IF (regime[Zone1a,Fine_Sand]>600) THEN 1 ELSE 0
ARRAY: zone vs. grain type
UNITS: numerical
VALUE: range between 0 and 1; only +
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: Regime
- Output: Effect amount gravel 3; Effect amount MCS 3; Effect amount FS 3

DATA: calculated from meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

The regimes are equal to the ones described in TABLE 4.

The description above only gives the equation for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.

R3_3[Zone*,Fine_Sand] = IF (regime[Zone*,Fine_Sand]>600) THEN 1 ELSE 0

Note: The equations for all other zones of fine sand are the same.

R3_3[Zone*,Medium_Coarse_Sand] = IF (regime[Zone*,Medium_Coarse_Sand]> 600) THEN 1 ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

R3_3[Zone*,Gravel] = IF (regime[Zone*,Gravel]>750) THEN 1 ELSE 0

Note: The equations for all other zones of gravel are the same.

7.4 r continuous 3

DEFINITION: Continuous regime (when the mean number of days between two trips is less than 15), which is similar for all grain size types
EQUATION: IF (Mean_number_of_days_between_2_trips[Zone1a,Fine_Sand]<15) OR (regime[Zone1a,Fine_Sand]=0) THEN 1 ELSE 0

ARRAY: zone vs. grain type
UNITS: numerical
VALUE: range between 0 and 1; only +
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: Regime; Mean number of days between 2 trips
- Output: Sum of effects amount gravel; Sum of effects amount MCS; Sum of effects amount FS

DATA: calculated from meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

The regimes are equal to the ones described in TABLE 4.

The description above only gives the equation for this variable for the fine sand grain type in Zone 1a. Here the equations for the other grain types and zones are described.

R_continuous_3[Zone*,Fine_Sand] = IF (Mean_number_of_days_between_2_trips[Zone*,Fine_Sand]<15) OR (regime[Zone*,Fine_Sand]=0) THEN 1 ELSE 0

Note: The equations for all other zones of fine sand are the same.

R_continuous_3[Zone*,Medium_Coarse_Sand] = IF (Mean_number_of_days_between_2_trips[Zone*,Medium_Coarse_Sand]<15) OR (regime[Zone*,Medium_Coarse_Sand]=0) THEN 1 ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

R_continuous_3[Zone*,Gravel] = IF (Mean_number_of_days_between_2_trips[Zone*,Gravel]<15) OR (regime[Zone*,Gravel]=0) THEN 1 ELSE 0

Note: The equations for all other zones of gravel are the same.

7.5 effect amount gravel 1

DEFINITION: Effect of the extraction of a certain amount of sediment on the gravel grain size fraction when regime 1_3 is valid

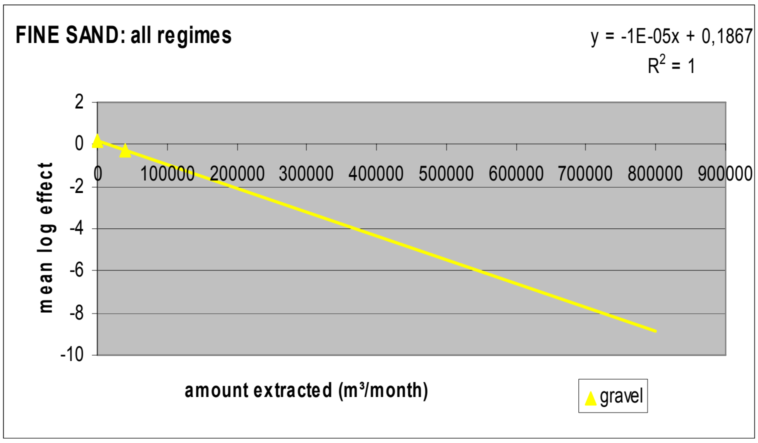
EQUATION: IF(R1_3[Zone1a,Fine_Sand]=1)THEN(((10^((-1*(10^(-5))*(Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000)+0.1867)+2.004))-101)/100)ELSE 0
ARRAY: zone vs. grain type
UNITS: numerical
VALUE: range between 0 and unlimited; +/-
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: R1_3; Extraction per zone and type
- Output: Sum of effects amount gravel

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

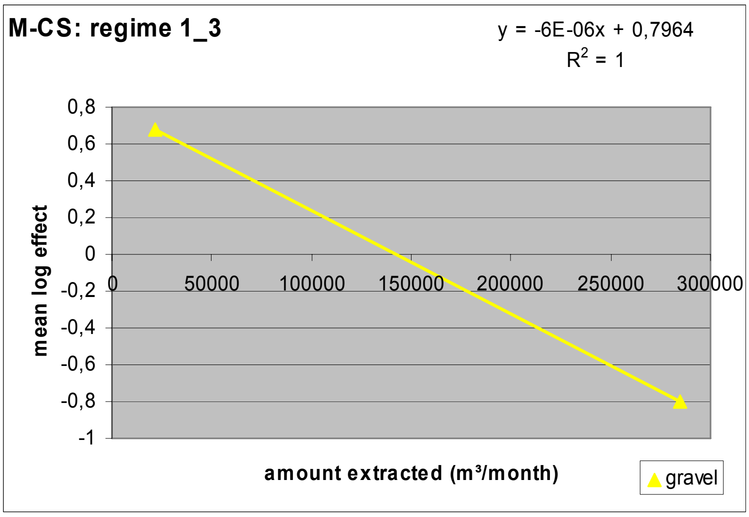
GRAPH 48: Mean (logarithmic) effect of the extraction of a certain amount of sediment in fine sand habitats on the gravel grain size fraction of the sediment (when regime 1_3 is valid).



effect_amount_gravel_1[Zone*,Fine_Sand] = IF(R1_3[Zone*,Fine_Sand]=1)THEN(((10^((-1*(10^(-5))*(Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000)+0.1867)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of fine sand are the same.

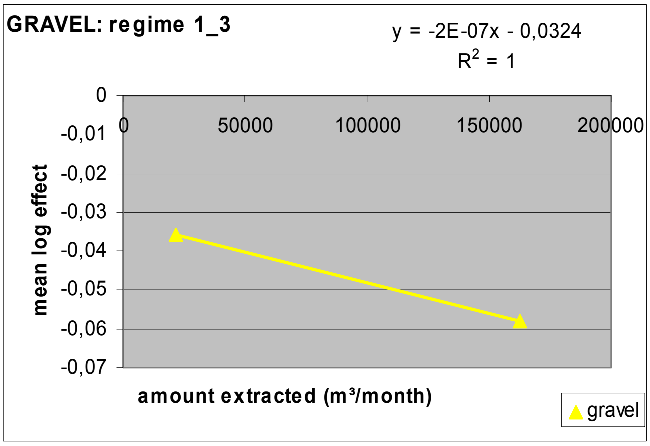
GRAPH 49: Mean (logarithmic) effect of the extraction of a certain amount of sediment in medium-coarse sand habitats on the gravel grain size fraction of the sediment (when regime 1_3 is valid).



effect_amount_gravel_1[Zone*,Medium_Coarse_Sand] = IF(R1_3[Zone*,Medium_Coarse_Sand]=1)THEN(((10^((-6*(10^(-6))*(Extraction_per_zone_and_type[Zone*, Medium_Coarse_Sand]/1000000)+0.7964)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

GRAPH 50: Mean (logarithmic) effect of the extraction of a certain amount of sediment in gravel habitats on the gravel grain size fraction of the sediment (when regime 1_3 is valid).



effect_amount_gravel_1[Zone*,Gravel] = IF(R1_3[Zone*,Gravel]=1)THEN(((10^((-2*(10^(-7))*(Extraction_per_zone_and_type[Zone*,Gravel]/1000000)-0.0324)+2.004))-101)/100) ELSE 0

Note: The equations for all other zones of gravel are the same.

7.6 effect amount MCS 1

DEFINITION: Effect of the extraction of a certain amount of sediment on the medium-coarse sand grain size fraction when regime 1_3 is valid

EQUATION: IF(R1_3[Zone1a,Fine_Sand]=1)THEN(((10^(((-2*(10^(-9))*((Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000)^2))-(0.0001*(Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000))-0.0097)+2.004))-101)/100)ELSE 0

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

TYPE: variable

FUNCTION: calculation

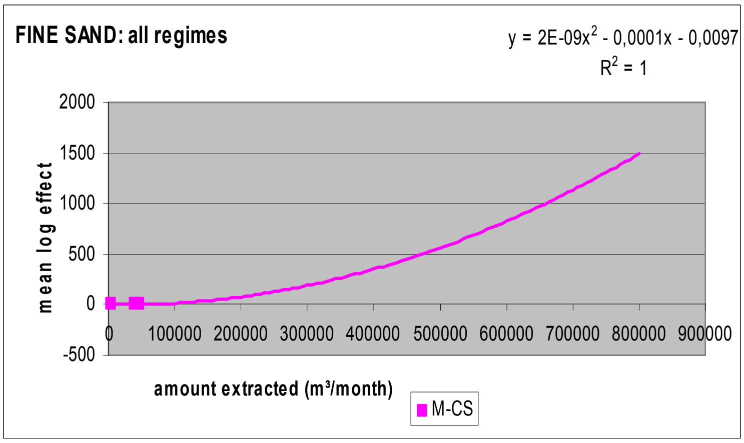
LINKS:

- Input: R1_3; Extraction per zone and type
- Output: Sum of effects amount MCS

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

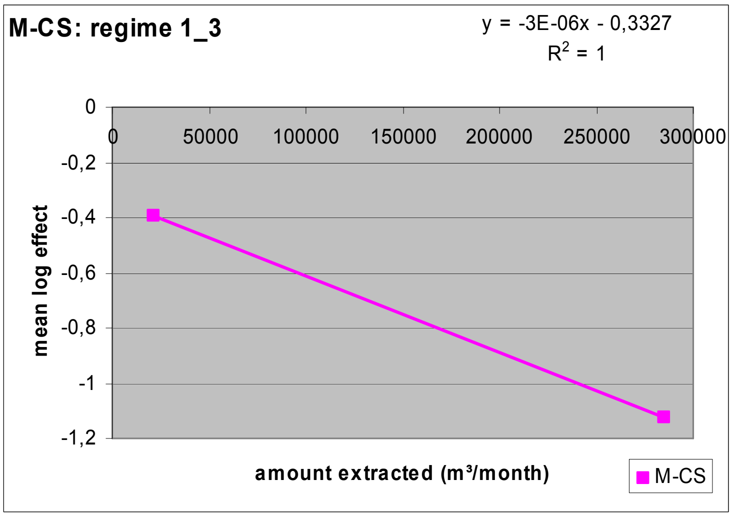
GRAPH 51: Mean (logarithmic) effect of the extraction of a certain amount of sediment in fine sand habitats on the medium-coarse sand grain size fraction of the sediment (when regime 1_3 is valid).



effect_amount_MCS_1[Zone*,Fine_Sand] = IF(R1_3[Zone*,Fine_Sand]=1)THEN(((10^(((-2*(10^(-9))*((Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000)^2))-(0.0001*(Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000))-0.0097)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of fine sand are the same.

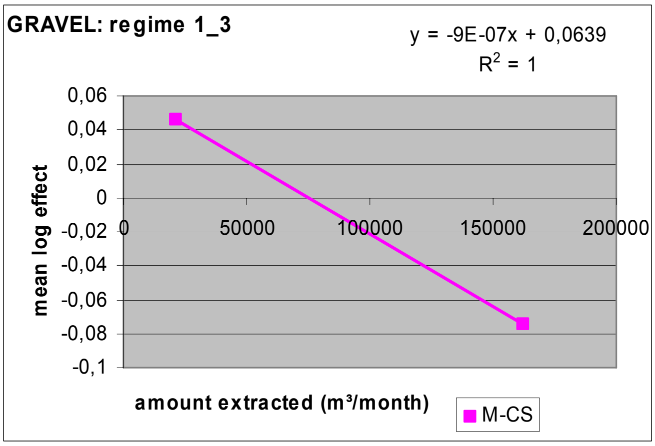
GRAPH 52: Mean (logarithmic) effect of the extraction of a certain amount of sediment in medium-coarse sand habitats on the medium-coarse sand grain size fraction of the sediment (when regime 1_3 is valid).



effect_amount_MCS_1[Zone*,Medium_Coarse_Sand] = IF(R1_3[Zone*,Medium_Coarse_Sand]=1)THEN(((10^((-3*(10^(-6))*(Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)-0.3327)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

GRAPH 53: Mean (logarithmic) effect of the extraction of a certain amount of sediment in gravel habitats on the medium-coarse sand grain size fraction of the sediment (when regime 1_3 is valid).



effect_amount_MCS_1[Zone*,Gravel] = IF(R1_3[Zone*,Gravel]=1)THEN(((10^((-9*(10^(-7))*(Extraction_per_zone_and_type[Zone*,Gravel]/1000000)+0.0639)+2.004))-101)/100) ELSE 0

Note: The equations for all other zones of gravel are the same.

7.7 effect amount FS 1

DEFINITION: Effect of the extraction of a certain amount of sediment on the fine sand grain size fraction when regime 1_3 is valid

EQUATION: IF(R1_3[Zone1a,Fine_Sand]=1)THEN(((10^(((-3*(10^(-21))*((Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000)^4))+(2*(10^(-15))*((Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000)^3))-(5*(10^(-10))*((Extraction_pe r_zone_and_type[Zone1a,Fine_Sand]/1000000)^2))+(3*(10^(-5))*(Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000))+0.3643)+2.004))-101)/100)ELSE 0

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

TYPE: variable

FUNCTION: calculation

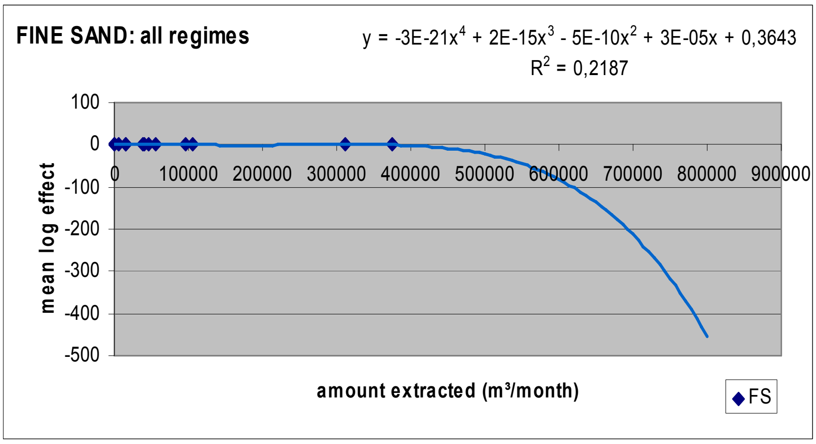
LINKS:

- Input: R1_3; Extraction per zone and type
- Output: Sum of effects amount FS

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

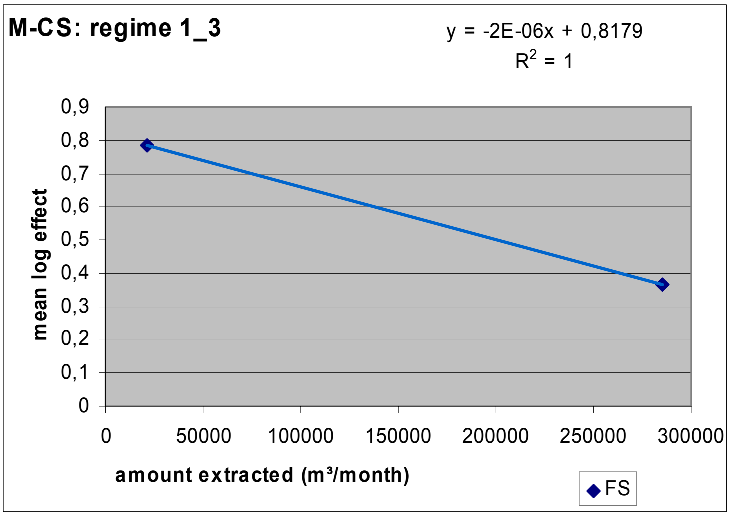
GRAPH 54: Mean (logarithmic) effect of the extraction of a certain amount of sediment in fine sand habitats on the fine sand grain size fraction of the sediment (when regime 1_3 is valid).



effect_amount_FS_1[Zone*,Fine_Sand] = IF(R1_3[Zone*,Fine_Sand]=1)THEN(((10^(((-3*(10^(-21))*((Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000)^ 4))+(2*(10^(-15))*((Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000)^3)) - (5*(10^(-10))*((Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000)^2))+(3 *(10^(-5))*(Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000))+0.3643)+2 .004))-101)/100)ELSE 0

Note: The equations for all other zones of fine sand are the same.

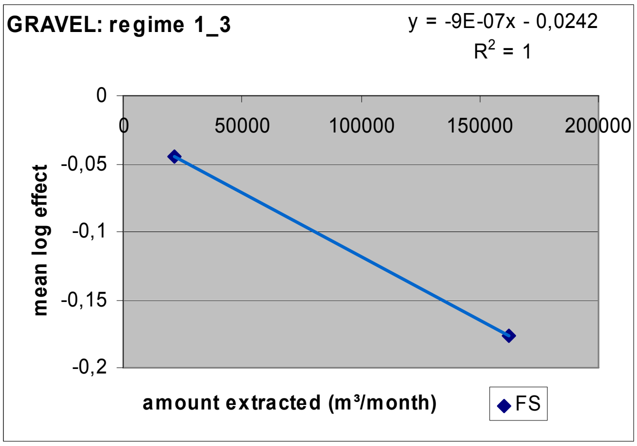
GRAPH 55: Mean (logarithmic) effect of the extraction of a certain amount of sediment in fine sand habitats on the medium-coarse sand grain size fraction of the sediment (when regime 1_3 is valid).



effect_amount_FS_1[Zone*,Medium_Coarse_Sand] = IF(R1_3[Zone*,Medium_Coarse_Sand]=1)THEN(((10^((-2*(10^(-6))*(Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)+0.8179)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

<u>GRAPH 56:</u> Mean (logarithmic) effect of the extraction of a certain amount of sediment in fine sand habitats on the gravel grain size fraction of the sediment (when regime 1_3 is valid).



effect_amount_FS_1[Zone*,Gravel] = IF(R1_3[Zone*,Gravel]=1)THEN(((10^(((-9*(10^(-7))*(Extraction_per_zone_and_type[Zone*,Gravel]/1000000))-0.0242)+2.004))-101)/100) ELSE 0

Note: The equations for all other zones of gravel are the same.

7.8 effect amount gravel 2

DEFINITION: Effect of the extraction of a certain amount of sediment on the gravel grain size fraction when regime 2_3 is valid

EQUATION: IF(R2_3[Zone1a,Fine_Sand]=1)THEN(((10^((-1*(10^(-5))*(Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000) +0.1867)+2.004))-101)/100)ELSE0

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

TYPE: variable

FUNCTION: calculation

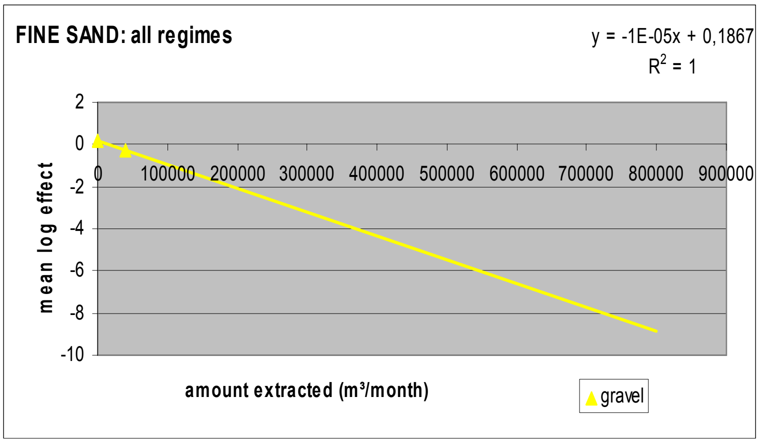
LINKS:

- Input: R2_3; Extraction per zone and type
- Output: Sum of effects amount gravel

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

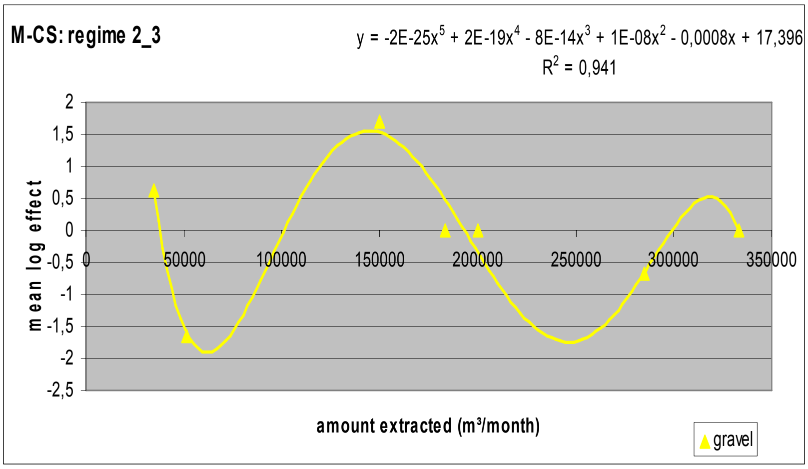
GRAPH 57: Mean (logarithmic) effect of the extraction of a certain amount of sediment in fine sand habitats on the gravel grain size fraction of the sediment (when regime 2_3 is valid).



effect_amount__gravel_2[Zone*,Fine_Sand] = IF(R2_3[Zone*,Fine_Sand]=1)THEN(((10^((-1*(10^(-5))*(Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000) +0.1867)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of fine sand are the same.

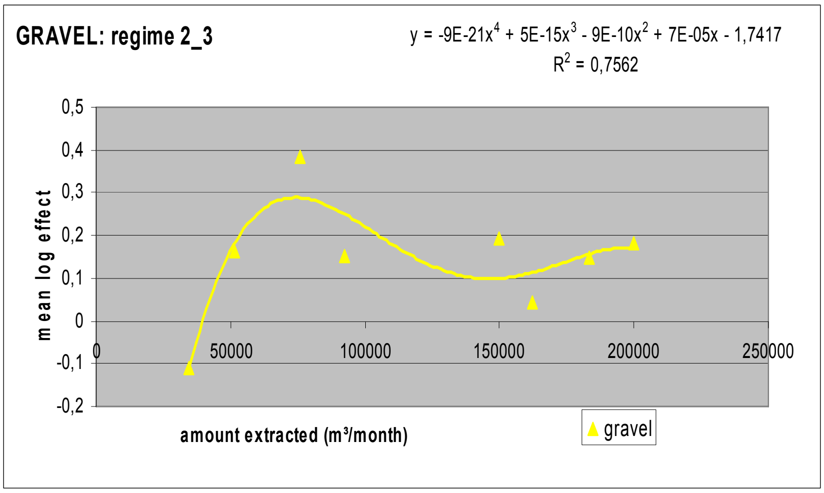
GRAPH 58: Mean (logarithmic) effect of the extraction of a certain amount of sediment in medium-coarse sand habitats on the gravel grain size fraction of the sediment (when regime 2_3 is valid).



effect_amount__gravel_2[Zone*,Medium_Coarse_Sand] = IF(R2_3[Zone*,Medium_Coarse_Sand]=1)THEN(((10^(((-2*(10^(-25))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^5))+(2*(10^(-19))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^4))-(8*(10^(-14))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^3))+(1*(10^(-8))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^2))-(0.0008*(Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/10000000))+17.396)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

GRAPH 59: Mean (logarithmic) effect of the extraction of a certain amount of sediment in gravel habitats on the gravel grain size fraction of the sediment (when regime 2_3 is valid).



effect_amount__gravel_2[Zone*,Gravel] = IF(R2_3[Zone*,Gravel]=1)THEN(((10^ (((-9*(10^(-21))*((Extraction_per_zone_and_type[Zone*,Gravel]/1000000)^4))+(5*(1 0^(-15))*((Extraction_per_zone_and_type[Zone*,Gravel]/1000000)^3))-(9*(10^(-10)) *((Extraction_per_zone_and_type[Zone*,Gravel]/1000000)^2))+(7*(10^(-5))*((Extraction_per_zone_and_type[Zone*,Gravel]/1000000))-1.7417))+2.004))-101)/100) ELSE 0

Note: The equations for all other zones of gravel are the same.

7.9 effect amount MCS 2

DEFINITION: Effect of the extraction of a certain amount of sediment on the medium-coarse sand grain size fraction when regime 2_3 is valid

EQUATION: IF(R2_3[Zone1a,Fine_Sand]=1)THEN(((10^(((2*(10^(-9))*((Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000)^2))-(0.0001*((Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000))-0.0097)+2.004))-101)/100)) ELSE 0

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

TYPE: variable

FUNCTION: calculation

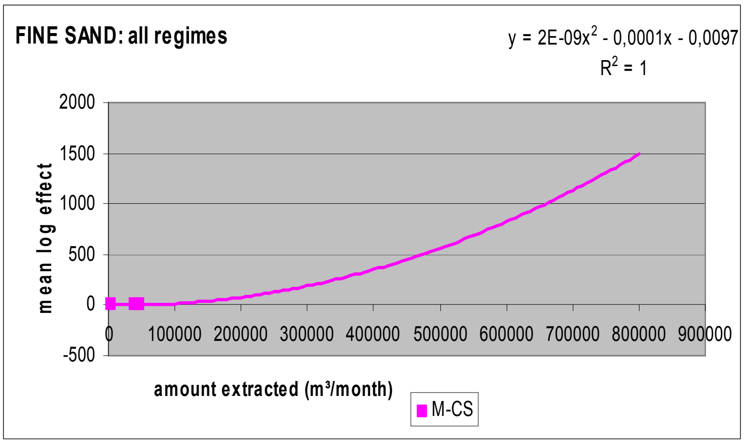
LINKS:

- Input: R2_3; Extraction per zone and type
- Output: Sum of effects amount MCS

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

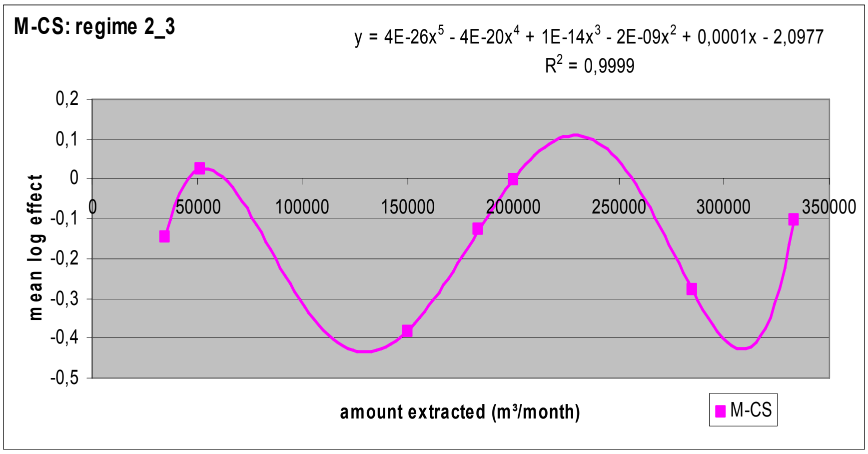
GRAPH 60: Mean (logarithmic) effect of the extraction of a certain amount of sediment in fine sand habitats on the medium-coarse sand grain size fraction of the sediment (when regime 2_3 is valid).



effect_amount__MCS_2[Zone*,Fine_Sand] = IF(R2_3[Zone*,Fine_Sand]=1)THEN(((10^(((2*(10^(-9))*((Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000)^2))-(0.0001*((Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000))-0.0097)+2.004))-101)/100)) ELSE 0

Note: The equations for all other zones of fine sand are the same.

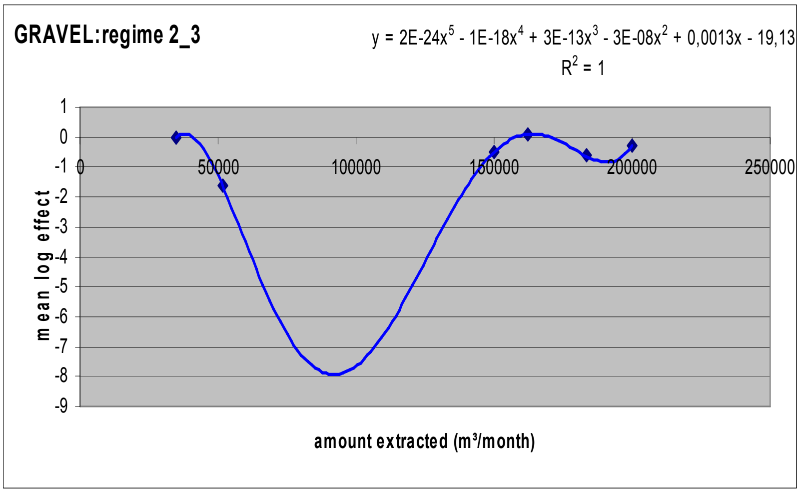
GRAPH 61: Mean (logarithmic) effect of the extraction of a certain amount of sediment in medium-coarse sand habitats on the medium-coarse sand grain size fraction of the sediment (when regime 2_3 is valid).



effect_amount__MCS_2[Zone*,Medium_Coarse_Sand] = IF(R2_3[Zone*,Medium_Coarse_Sand]=1)THEN(((10^(((4*(10^(-26))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^5))-(4*(10^(-20))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^4))+(1*(10^(-14))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^3))-(2*(10^(-9))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^2))+(0.0001*(Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/10000000))-2.0977)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

GRAPH 62: Mean (logarithmic) effect of the extraction of a certain amount of sediment in gravel habitats on the medium-coarse sand grain size fraction of the sediment (when regime 2_3 is valid).



effect_amount__MCS_2[Zone*,Gravel] = IF(R2_3[Zone*,Gravel]=1)THEN(((10^(((2*(10^(-24))*((Extraction_per_zone_and_type[Zone*,Gravel]/1000000)^5))-(1*(10^(-18))*((Extraction_per_zone_and_type[Zone*,Gravel]/1000000)^4))+(3*(10^(-13))*((Extraction_per_zone_and_type[Zone*,Gravel]/1000000)^3))-(3*(10^(-8))*((Extraction_per_zone_and_type[Zone*,Gravel]/1000000)^2))+(0.0013*(Extraction_per_zone_and_type[Zone*,Gravel]/1000000))-19.13)+2.004))-101)/100) ELSE 0

Note: The equations for all other zones of gravel are the same.

7.10 effect amount FS 2

DEFINITION: Effect of the extraction of a certain amount of sediment on the fine sand grain size fraction when regime 2_3 is valid

EQUATION: IF(R2_3[Zone1a,Fine_Sand]=1)THEN(((10^(((-3*(10^(-21))*((Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000)^4))+(2*(10^(-15))*((Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000)^3))-(5*(10^(-10))*((Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000)^2))+(3*(10^(-5))*((Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000))+0.3643)+2.004))-101)/100)) ELSE 0

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

TYPE: variable

FUNCTION: calculation

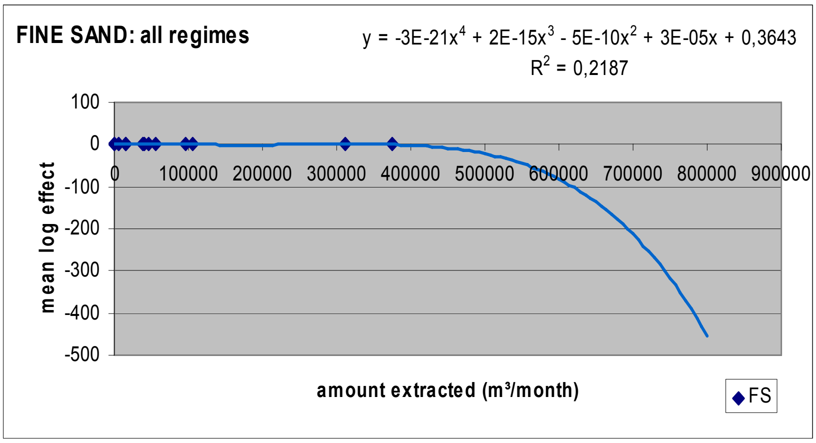
LINKS:

- Input: R2_3; Extraction per zone and type
- Output: Sum of effects amount FS

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

GRAPH 63: Mean (logarithmic) effect of the extraction of a certain amount of sediment in fine sand habitats on the fine sand grain size fraction of the sediment (when regime 2_3 is valid).

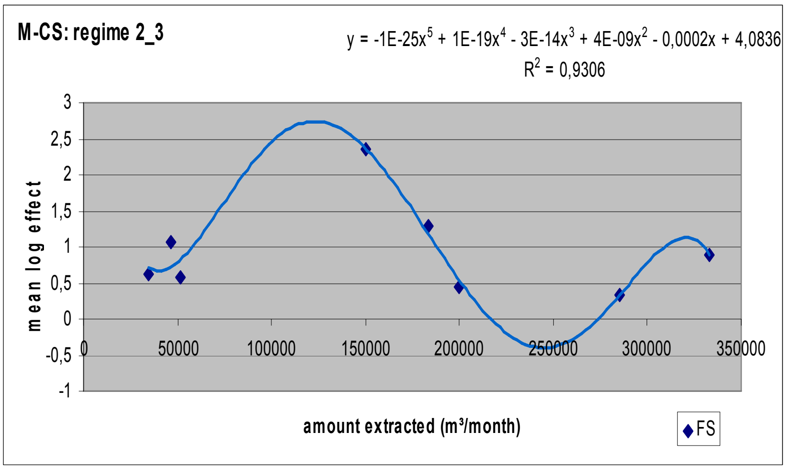


effect_amount__FS_2[Zone*,Fine_Sand] = IF(R2_3[Zone*,Fine_Sand]=1)THEN(((10^(((-3*(10^(-21))*((Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000)^4))+(2*(10^(-15))*((Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000)^3)

)-(5*(10^(-10))*((Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000)^2))+(3*(10^(-5))*((Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000))+0.3643) +2.004))-101)/100)) ELSE 0

Note: The equations for all other zones of fine sand are the same.

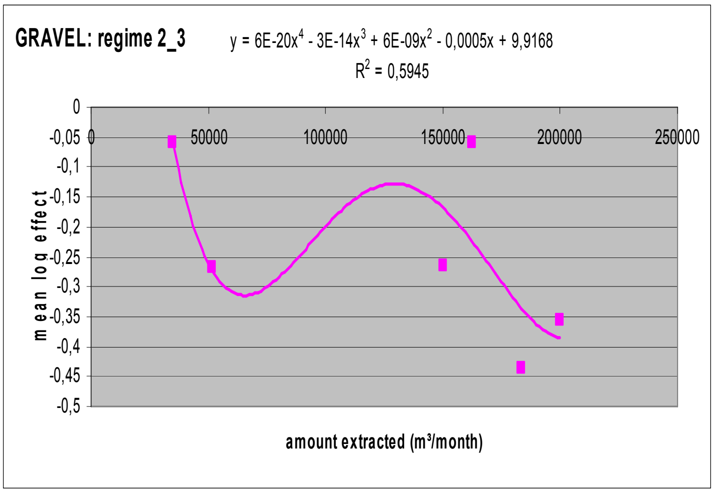
GRAPH 64: Mean (logarithmic) effect of the extraction of a certain amount of sediment in medium-coarse sand habitats on the fine sand grain size fraction of the sediment (when regime 2_3 is valid).



effect_amount__FS_2[Zone*,Medium_Coarse_Sand] = IF(R2_3[Zone*,Medium_Coarse_Sand]=1)THEN(((10^(((-1*(10^(-25))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^5))+(1*(10^(-19))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^4))-(3*(10^(-14))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^3))+(4*(10^(-9))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^2))-(0.0002*(Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/10000000))+4.0836)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

GRAPH 65: Mean (logarithmic) effect of the extraction of a certain amount of sediment in gravel habitats on the fine sand grain size fraction of the sediment (when regime 2_3 is valid).



effect_amount__FS_2[Zone*,Gravel] = IF(R2_3[Zone*,Gravel]=1)THEN(((10^((((6*(10^(-20))*((Extraction_per_zone_and_type[Zone*,Gravel]/1000000)^4))-(3*(10^(-14))*((Extraction_per_zone_and_type[Zone*,Gravel]/1000000)^3))+(6*(10^(-9))*((Extraction_per_zone_and_type[Zone*,Gravel]/1000000)^2))-(0.0005*((Extraction_per_zone_and_type[Zone*,Gravel]/1000000))+9.9168)))+2.004))-101)/100) ELSE 0

Note: The equations for all other zones of gravel are the same.

7.11 effect amount gravel 3

DEFINITION: Effect of the extraction of a certain amount of sediment on the gravel grain size fraction when regime 3_3 is valid

EQUATION: IF(R3_3[Zone1a,Fine_Sand]=1)THEN(((10^((-1*(10^(-5))*(Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000)+0.1867)+2.004))-101)/100)ELSE 0

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

TYPE: variable

FUNCTION: calculation

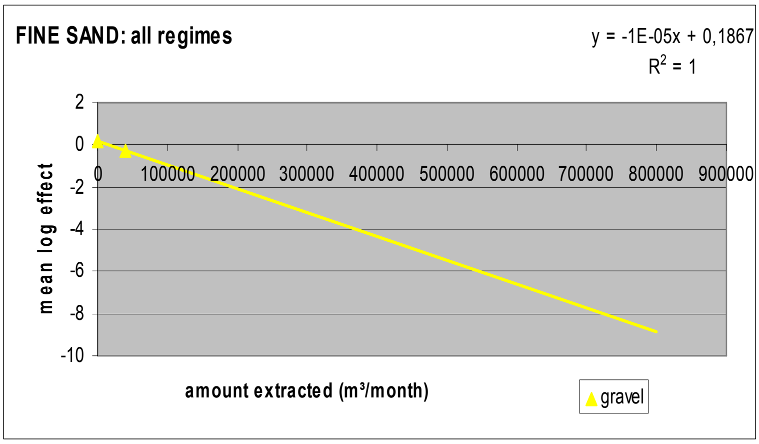
LINKS:

- Input: R3_3; Extraction per zone and type
- Output: Sum of effects amount gravel

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

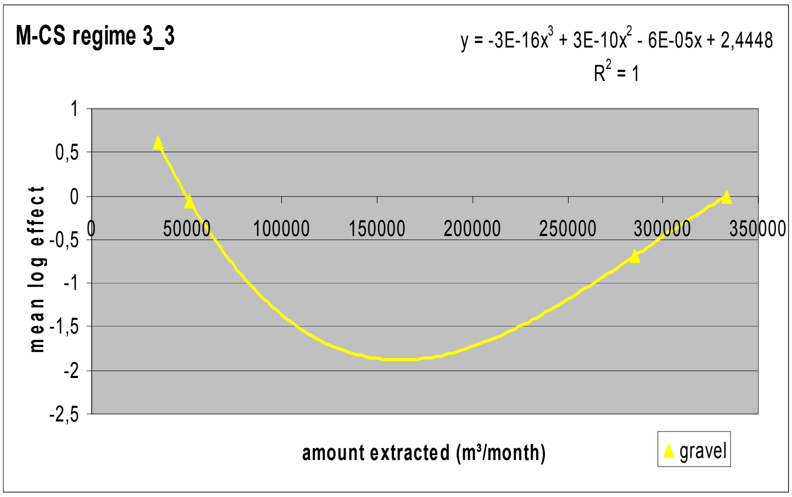
GRAPH 66: Mean (logarithmic) effect of the extraction of a certain amount of sediment in fine sand habitats on the gravel grain size fraction of the sediment (when regime 3_3 is valid).



effect_amount_gravel_3[Zone*,Fine_Sand] = IF(R3_3[Zone*,Fine_Sand]=1)THEN(((10^((-1*(10^(-5))*(Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000)+0.1867)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of fine sand are the same.

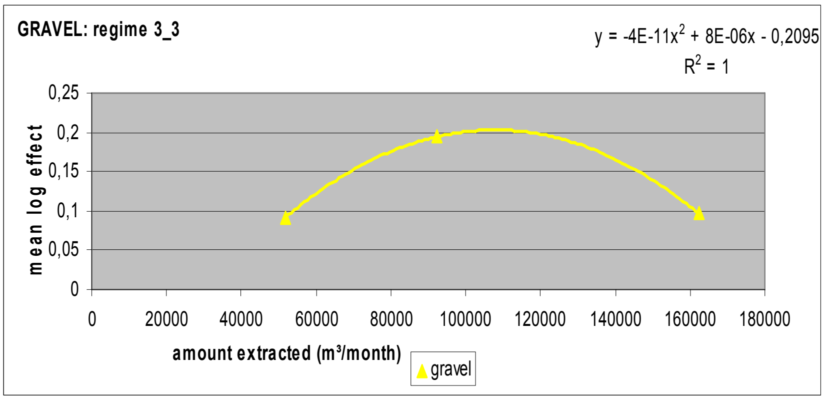
GRAPH 67: Mean (logarithmic) effect of the extraction of a certain amount of sediment in medium-coarse sand habitats on the gravel grain size fraction of the sediment (when regime 3_3 is valid).



effect_amount_gravel_3[Zone*,Medium_Coarse_Sand] = IF(R3_3[Zone*,Medium_Coarse_Sand]=1)THEN(((10^((-3*(10^(-16))*((Extraction_per_zone_and_type[Zon e*,Medium_Coarse_Sand]/1000000)^3))+(3*(10^(-10))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^2))-(6*(10^(-5))*(Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)+2.4448)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

GRAPH 68: Mean (logarithmic) effect of the extraction of a certain amount of sediment in gravel habitats on the gravel grain size fraction of the sediment (when regime 3_3 is valid).



effect_amount_gravel_3[Zone*,Gravel] = IF(R3_3[Zone*,Gravel]=1)THEN(((10^((-4*(10^(-11))*((Extraction_per_zone_and_type[Zone*,Gravel]/1000000)^2))+(8*(10^ (-6))*(Extraction_per_zone_and_type[Zone*,Gravel]/1000000)-0.2095)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of gravel are the same.

7.12 effect amount MCS 3

DEFINITION: Effect of the extraction of a certain amount of sediment on the medium-coarse sand grain size fraction when regime 3_3 is valid

EQUATION: IF(R3_3[Zone1a,Fine_Sand]=1)THEN(((10^(((2*(10^(-9))*((Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000)^2))-(0.0001*((Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000))-0.0097)+2.004))-101)/100)) ELSE 0

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

TYPE: variable

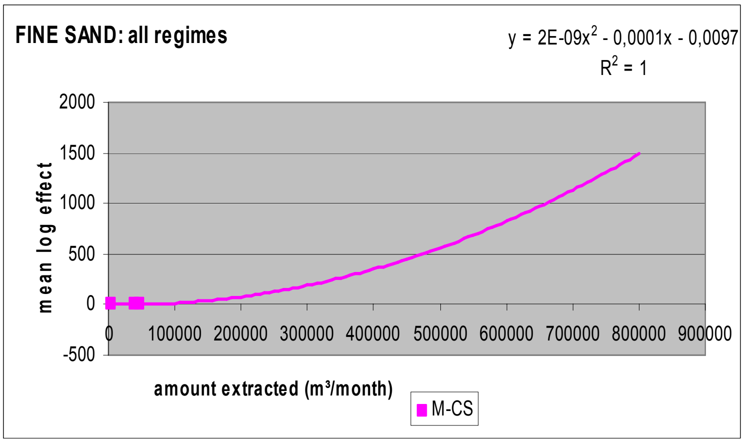
FUNCTION: calculation
LINKS:

- Input: R3_3; Extraction per zone and type
- Output: Sum of effects amount MCS

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

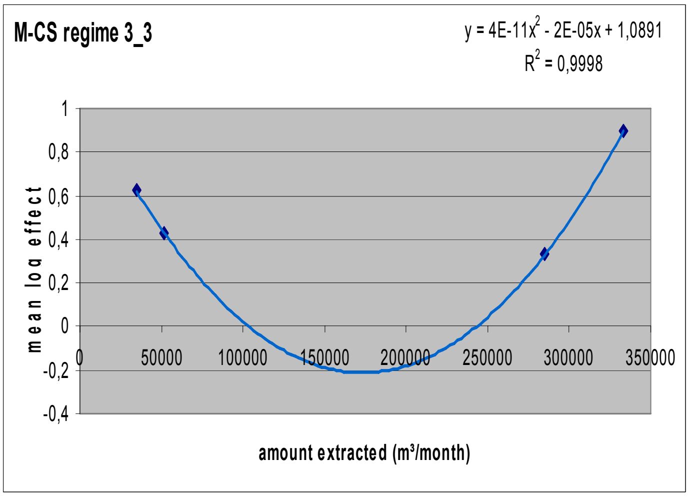
GRAPH 69: Mean (logarithmic) effect of a certain amount of sediment in fine sand habitats on the medium-coarse grain size fraction of the sediment (when regime 3_3 is valid).



effect_amount_MCS_3[Zone*,Fine_Sand] = IF(R3_3[Zone*,Fine_Sand]=1)THEN(((10^(((2*(10^(-9))*((Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000)^ 2))-(0.0001*((Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000))-0.0097) +2.004))-101)/100)) ELSE 0

Note: The equations for all other zones of fine sand are the same.

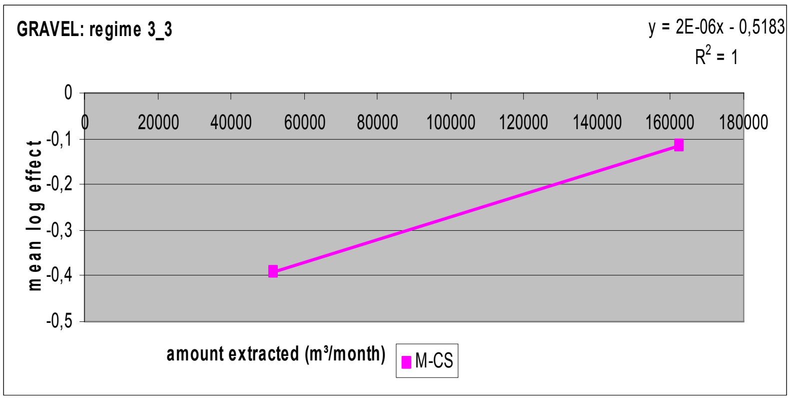
GRAPH 70: Mean (logarithmic) effect of a certain amount of sediment in medium-coarse sand habitats on the medium-coarse grain size fraction of the sediment (when regime 3_3 is valid).



effect_amount_MCS_3[Zone*,Medium_Coarse_Sand] = IF(R3_3[Zone*,Medium_Coarse_Sand]=1)THEN(((10^((4*(10^(-11))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^2))-(2*(10^(-5))*(Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)+1.0891)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of medium-coarse sand are the same.

<u>GRAPH 71:</u> Mean (logarithmic) effect of the extraction of a certain amount of sediment in gravel habitats on the medium-coarse grain size fraction of the sediment (when regime 3_3 is valid).



effect_amount_MCS_3[Zone*,Gravel] = IF(R3_3[Zone*,Gravel]=1)THEN(((10^((2*(10^(-6))*(Extraction_per_zone_and_type[Zone*,Gravel]/1000000)-0.5183)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of gravel are the same.

7.13 effect amount FS 3

DEFINITION: Effect of the extraction of a certain amount of sediment on the fine sand grain size fraction when regime 3_3 is valid

EQUATION: IF(R3_3[Zone1a,Fine_Sand]=1)THEN(((10^(((-3*(10^(-21))*((Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000)^4))+(2*(10^(-15))*((Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000)^3))-(5*(10^(-10))*((Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000)^2))+(3*(10^(-5))*((Extraction_per_zone_and_type[Zone1a,Fine_Sand]/1000000))+0.3643)+2.004))-101)/100)) ELSE 0

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

TYPE: variable

FUNCTION: calculation

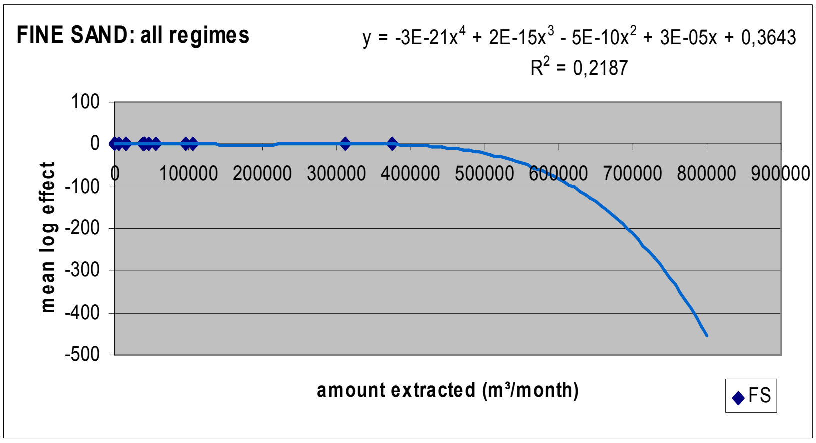
LINKS:

- Input: R3_3; Extraction per zone and type
- Output: Sum of effects amount FS

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see subsection 2.1.

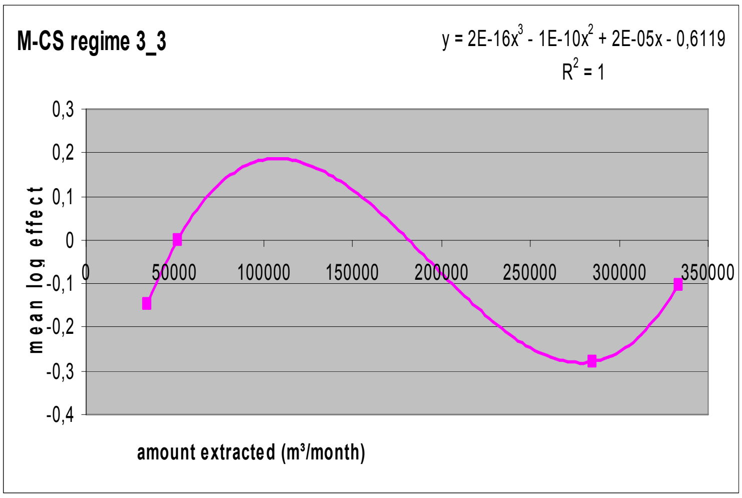
GRAPH 72: Mean (logarithmic) effect of the extraction of a certain amount of sediment in fine sand habitats on the fine sand grain size fraction of the sediment (when regime 3_3 is valid).



effect_amount_FS_3[Zone*,Fine_Sand] = IF(R3_3[Zone*,Fine_Sand]=1)THEN(((10^(((-3*(10^(-21))*((Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000)^4))+(2*(10^(-15))*((Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000)^3)) - (5*(10^(-10))*((Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000)^2))+(3*(10^(-5))*((Extraction_per_zone_and_type[Zone*,Fine_Sand]/1000000))+0.3643)+2.004))-101)/100)) ELSE 0

Note: The equations for all other zones of fine sand are the same.

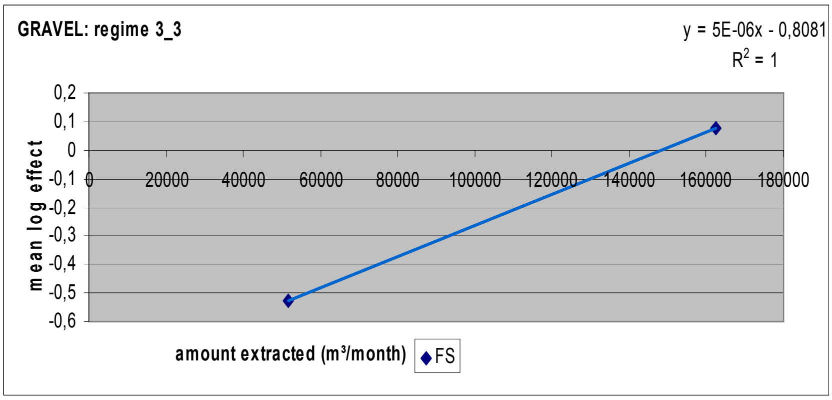
GRAPH 73: Mean (logarithmic) effect of the extraction of a certain amount of sediment in medium-coarse sand habitats on the fine sand grain size fraction of the sediment (when regime 3_3 is valid).



effect_amount_FS_3[Zone*,Medium_Coarse_Sand] =IF(R3_3[Zone*,Medium_Coarse_Sand]=1)THEN(((10^((2*(10^(-16))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^3))-(1*(10^(-10))*((Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)^2))+(2*(10^(-5))*(Extraction_per_zone_and_type[Zone*,Medium_Coarse_Sand]/1000000)-0.6119)+2.004))-101)/100)ELSE0

Note: The equations for all other zones of medium-coarse sand are the same.

GRAPH 74: Mean (logarithmic) effect of the extraction of a certain amount of sediment in gravel habitats on the fine sand grain size fraction of the sediment (when regime 3_3 is valid).



effect_amount_FS_3[Zone*,Gravel] = IF(R3_3[Zone*,Gravel]=1)THEN(((10^((5*(10^(-6))*(Extraction_per_zone_and_type[Zone*,Gravel]/1000000)-0.8081)+2.004))-101)/100)ELSE 0

Note: The equations for all other zones of gravel are the same.

7.14 sum of effects of amount gravel

DEFINITION: Sum of the effects of the extraction of a certain amount of sediment for all regimes on the gravel grain size fraction

EQUATION: IF(R_continuous_3[Zone,Grain]=1)THEN0 ELSE(SUM(effect_amount_gravel_1[Zone,Grain]+effect_amount_gravel_3[Z one,Grain]+effect_amount_gravel_2[Zone,Grain]))

ARRAY: zone vs. grain type

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

TYPE: variable

FUNCTION: calculation

LINKS:

- Input: R continuous 3; Effect amount gravel 1; Effect amount gravel 2; Effect amount gravel 3
- Output: Decrease by extraction

DATA: calculated but not verifiable

7.15 sum of effects of amount MCS

DEFINITION: Sum of the effects of the extraction of a certain amount of sediment for all regimes on the medium-coarse sand grain size fraction

EQUATION: IF(R_continuous_3[Zone,Grain]=1)THEN 0 ELSE (SUM(effect_amount_MCS_1[Zone,Grain]+effect_amount_MCS_3[Zone,Grain]+effect_amount__MCS_2[Zone,Grain]))
ARRAY: zone vs. grain type
UNITS: numerical
VALUE: range between 0 and unlimited; +/-
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: R continuous 3; Effect amount MCS 1; Effect amount MCS 2; Effect amount MCS 3
- Output: Decrease by extraction 2

DATA: calculated but not verifiable

7.16 sum of effects of amount FS

DEFINITION: Sum of the effects of the extraction of a certain amount of sediment for all regimes on the gravel grain size fraction
EQUATION: IF(R_continuous_3[Zone,Grain]=1)THEN 0 ELSE (SUM(effect_amount_FS_1[Zone,Grain]+effect_amount_FS_3[Zone,Grain]+effect_amount__FS_2[Zone,Grain]))
ARRAY: zone vs. grain type
UNITS: numerical
VALUE: range between 0 and unlimited; +/-
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: R continuous 3; Effect amount FS 1; Effect amount FS 2; Effect amount FS 3
- Output: Decrease by extraction 3

DATA: calculated but not verifiable

SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY
(SPSD II)

Part 2:
Global change, Ecosystems and Biodiversity

Annex 3

BALANS
BALANCING IMPACTS OF HUMAN ACTIVITIES IN THE NORTH SEA

EV/21

Coordinator and promotor:
Prof. Dr. F. Maes, Maritime Institute, University Gent

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Ir. Serge Scory, Management Unit of the North Sea Mathematical Models
Ir. D. Leroy, Ecolas nv

February 2007

BELGIAN SCIENCE POLICY

ANNEX 3:
SAND AND GRAVEL EXTRACTION
SOCIO-ECONOMY

1 ECONOMIC RESULT

1.6 aggregate price

DATA:

- Source: Communication L. Vandekerckhove (August 2006)
- Dataset: range between 3 and 5 EUR/m³ (independent of grain type; dependent of landing facility)

1.10 fee rate

DATA:

- Source: Royal Decree of 01/09/2004 concerning the conditions, the geographical delimitation and the allocation procedure of the concessions for the exploration and the exploitation of mineral and other non-living resources in the territorial sea and on the continental shelf (RD 01/09/2004)
- Dataset:

	Fine sand (€)	Medium-coarse sand (€)	Gravel (€)
Zone 1a	0.54	0.54	1.14
Zone 1b	0.54	0.54	1.14
Zone 2a	0.54	0.54	1.14
Zone 2b	0.54	0.54	1.14
Zone 2c	0.54	0.54	1.14
Zone 3a	0.35	0.35	1.14
Zone 3b	0.35	0.35	1.14
Zone 4	0.54	0.54	1.14

1.11 adaptation coefficient

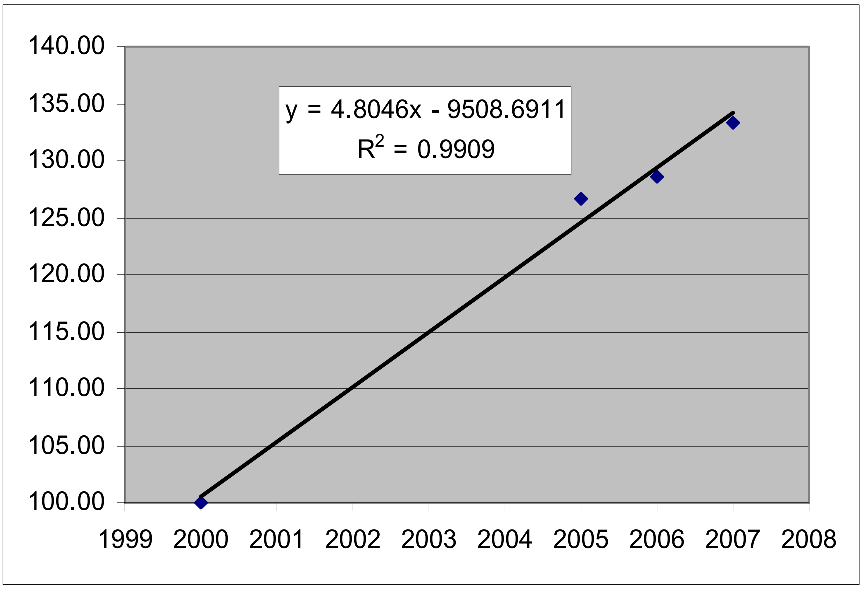
DATA: calculated but not verifiable

- Source: Ministry of Economy, SME's, Self-employed and Energy, National Institute of Statistics, Fund for Sand extraction (May 3, 2006).

- Dataset: Fees and

Fee:	
Year	Value
2000	100.00
2005	126.67
2006	128.58
2007	133.25

Figure 1: Best linear fit through the available data gives, assuming the simulations always start in 2005 : 4.8046*(int(TIME/12)+2005)-9508.6911



2 VARIABLE COST

2.7 average loading capacity per fleet type

DATA:

- Source: Ecolas nv. (2006): Environmental Impact Assessment for the extraction of marine aggregates on the BPNS. 194 pp. + Annexes
- Data: Fleet A (1266 m³); Fleet B (3903 m³)

	Average loading capacity (m³)
Fleet A	1266
Fleet B	3903

2.9 fuel consumption extraction per vessel type

DATA:

- Source: Zeegra Vzw (2005)
- Data: Fleet A (350 l/h); Fleet B (400 l/h)

	Fuel consumption extraction (l/h)
Fleet A	350
Fleet B	400

2.10 time extraction per trip per vessel type

DATA:

- Source: Reimerswaal (May 2004); Zeegra vzw (2005)
- Dataset: Fleet A (1hr); Fleet B (1.5 hr)

2.12 fuel consumption sailing per vessel type

DATA:

- Source: Zeegra Vzw (2005)
- Dataset: Fleet A (0.05 l/m); Fleet B (0.075 l/m)

	Fuel consumption sailing (l/m)
Fleet A	0.050
Fleet B	0.075

2.13 fuel price

DATA:

- Source: FPS Economy, SMEs, Self-employed and Energy: Ecodata. Official maximum prices of petroleum products (incl. BTW) (1999-2005).
- Dataset: 0.54 €/l (last update from 20/12/2005); 0.51 €/l (average 2005)

3 SEMI-FIXED COST

3.6 maintenance ratio fleet B

DATA:

- Source: Expert judgement Ecolas
- Dataset: 0.02 (=2%)
-

3.7 monthly maintenance cost per vessel type

DATA:

- Source: Estimation by Ecolas based on interview Reimerswael (2004)
- Dataset: Fleet A (37,500 EUR/vessel); Fleet B (50,000 EUR/Vessel)

3.9 cost per employee

DATA:

- Source: Bel-First (database of financial data from Belgian corporations), Average cost per employee for the year 2002 for the following companies: ALGEMENE ZAND- EN GRINTHANDELMAATSCHAPPIJ ALZAGRI, BELMAGRI, CAMBEL AGREGATS, CHARLES KESTELEYN ZAND EN GRINTHANDEL, DEME BUILDING MATERIALS, GHENT DREDGING, HANSON AGGREGATES BELGIUM and INTERNATIONAL SAND AND GRAVEL
- Dataset: 4583 EUR/employee

3.10 number of employees per vessel type

DATA:

- Source: Interview Reimerswael (2004)
- Dataset: Fleet A (4 Employee/vessel); Fleet B (6 Employee/Vessel)

4 FIXED COST

4.6 investment ratio fleet B

DATA:

- Source: Expert judgement Ecolas
- Dataset: 0.02 (=2%)

4.9 investment cost per vessel per vessel type

DATA:

- Source: WES (2004). The economical importance of the aggregate sector at sea in Belgium [Dutch: Het economische belang van de sector van zandwinning op zee in België]. By order of Zeegra vzw. December 2004.
- Dataset: Fleet A (10,000,000 EUR); Fleet B (13,000,000 EUR)

4.10 insurance rate

DATA:

- Source: Expert judgement Ecolas
- Dataset: 0.075 (=7.5%)

4.11 economic lifetime

DATA:

- Source: Expert judgement Ecolas
- Dataset: 30 years

4.12 monthly interest rate

DATA: calculated but not verifiable

A one time investment cost can be expressed in **yearly costs** using the annuity formula:

$$I_0\left[\frac{r(1+r)^n}{(1+r)^n-1}\right].$$

I0 = One time investment
r = yearly real interest rate (= nominal interest rate corrected for inflation)
n = economic lifetime of the investment in years

Example: investment cost for a vessel of 10 million euro with an economic lifetime of 30 years and applying an interest rate of 10% => yearly investment cost = 1.06 million euro.

A one time investment cost can be expressed in **monthly costs** using the same annuity formula, taking into account the following adaptations:
n = economic lifetime of the investment in months (number of years * 12)
r = real interest rate expressed per month
This monthly interest rate can be calculated starting from the yearly real interest rate:

[(1+(yearly real interest rate/12))^12-1]/12

Example: investment cost for a vessel of 10 million euro with an economic lifetime of 30 years and applying a yearly interest rate of 10%
=> monthly interest rate: 0.8726%
=> monthly investment cost: 91259 euro

4.13 yearly real interest rate

DATA:

- Source: Vito (2003) Background document of environmental cost model. [Dutch: Achtergronddocument milieukostenmodel]: private real interest rate, p. 47 http://www.emis.vito.be/EMIS/Media/BBT_rapport_milieukostenmodel.pdf
- Dataset: 0.1 (= 10%)

SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY
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Annex 4

BALANS

BALANCING IMPACTS OF HUMAN ACTIVITIES IN THE NORTH SEA

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Ir. D. Leroy, Ecolas nv

February 2007

ANNEX 4:
SHRIMP FISCHERIES
DRIVING FORCE

1 SWEPT AREA

1.1 effort

DATA:

- Source: Ministry of the Flemish Community. Administration of the Agriculture and Horticulture. Department of Agriculture and Fishery Management – Sea Services Division (Period 2003-2005)
- Dataset: in hr (depending per month)

	2003	2004	2005	Average per month
Jan	366	230	103	233
Feb	86	143	71	100
Mrt	172	369	263	268
Apr	320	317	465	367
Mei	260	527	551	446
Jun	547	547	957	683
Jul	789	930	749	822
Aug	994	922	1006	974
Sep	997	834	713	848
Okt	972	1077	932	993
Nov	854	982	1009	948
Dec	733	938	750	807

1.4 speed

DATA:

- Source: Polet, 2003
- Dataset: 5093 m/h

1.5 width

DATA:

- Source: Polet, 2003
- Dataset: 7.65 m
-

1.6 shrimp density submodel

DATA:

- Source: ILVO-Fisheries database. Based on intensive sampling on board of commercial vessels in 1996-97.
- Dataset:

Numbers of shrimp per m²

Length	Q1	Q2	Q3	Q4
1	0.000	0.000	0.000	0.000
1.5	0.000	0.610	0.067	0.000
2	0.045	1.627	0.494	0.043
2.5	0.037	2.435	1.144	0.210
3	0.138	2.914	1.048	0.482
3.5	0.441	2.823	0.978	0.516
4	0.534	1.558	0.763	0.389
4.5	0.410	0.738	0.487	0.229
5	0.356	0.434	0.300	0.117
5.5	0.226	0.363	0.206	0.070
6	0.167	0.116	0.170	0.051
6.5	0.071	0.026	0.073	0.022
7	0.011	0.006	0.017	0.005
7.5	0.001	0.001	0.002	0.001
8	0.000	0.000	0.000	0.000
8.5	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000

1.10 gs: gear selectivity

DATA:

- Source: Polet, 2003
- Dataset:

<u>*Definition*</u>:

Selectivity: The selection of fish by fishing gear in the widest possible sense, given in Wileman et al. (1996), is: the process which causes the catch of a gear to have a different composition from that of the fish population in the geographical area in which the gear is being used. There are many causes of these differences with chance playing a big part in the capture process. Gears will select by species and for each species there will also be size selection.

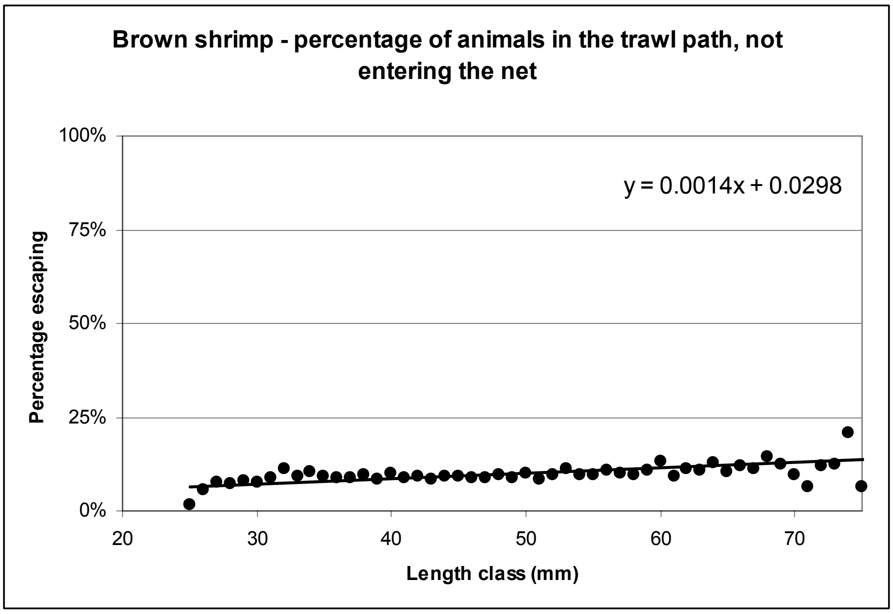
Also: Ability to target and capture fish by size and species during harvesting operations, allowing by-catch of juvenile fish and non-target species to escape unharmed. In stock assessment, conventionally expressed as a relationship between retention and size (or age) with no reference to survival after escapement.

Gear selection: This process is described by the selectivity at the entrance of the gear, i.e. the net mouth.

Application in the model: For each species and each length class, the percentage of all animals in the trawl path that do not enter the gear.

Unit: % by species and length class

Data:



PEsc = 0.0298 + 0.0014 LC

PEsc: percentage escaping (%) ; LC: Length class (mm)

More detailed data, inclusive confidence limits, are given in Polet (2003) but for practicability, a simple linear regression formula will be used.

1.12 mrate swept escape

DATA: between 0% and 100% but for the time being fixed at 1%

2 GEAR

2.1 ns standard: net selectivity

DATA:

- Source: Polet, 2003
- Dataset:

Definition: This process is described by the selectivity of the net (without cod-end).

Application in the model: For each species and each length class, the percentage of all animals entering the gear that escape through the net meshes (exclusive the cod-end).

Unit: % by species and length class

Data: For brown shrimps, detailed data are available (Polet, 2003).

PEsc : for simplicity, a linear model was fitted to the data in the ILVO-Fisheries database.

PEsc = 0.9599-0.01362 LC
with LC expressed in mm

2.3 mrate gear escape

DATA: between 0% and 100% but for the time being fixed at 1%

3 COD END

3.1 cs: cod end selectivity

DATA:

- Source: ILVO- Fisheries
- Dataset:

Definition: This process is described by the selectivity of the cod-end.

Application in the model: For each species and each length class, the percentage of all animals entering the cod-end that escapes through the cod-end meshes.

Unit: % by species and length class

Data: For brown shrimps, detailed data are available (Polet, 2003).

- Cod-end selection is usually represented by a selection curve *r(l)*. *r(l)* is the probability that a fish of length *l* is retained in the cod-end, given it entered the cod-end. Often the logistic curve is used to describe cod-end selectivity (Wileman et al., 1996):

$$r(l) = \frac{\exp(a+b*l)}{1+\exp(a+b*l)}$$; a and b are the parameters to be estimated.

- Three other parameters are relevant:

L50 : the length at 50% retention = -a/b
SR: the selection range representing the slope of the curve = 2.197/b
SF : the selection factor = L50/mesh size

Based on these parameters, the a and b can be calculated for another mesh size.

- For a standard shrimp beam trawl, as used in the Belgian shrimp fishery, with a cod-end mesh opening of 20 mm, the parameters are:

a	b	L50	SR	SF	Mesh
-7.4622	0.1894	39.4 mm	11.6 mm	1.97	20 mm

Using the above mentioned formulae, the parameters can be calculated for e.g. a 30mm cod-end mesh opening.

a	b	L50	SR	SF	Mesh
-11.1933	0.1894	59.1 mm	11.6 mm	1.97	30 mm

This selection curve can be used to calculate the numbers of shrimps caught and escaped for each length class.

3.3 mrate cod end escape

DATA: between 0% and 100% but for the time being fixed at 1%

4 FINAL CATCH

4.1 fs: fishermen's selection

DATA:

- Source: ILVO- Fisheries
- Data:

Definition: The process where fishermen divide the catch into catch to be landed and discard.

Application in the model: For each species and each length class, the percentage of all animals retained and discarded by the crew.

Unit: % by species and length class

Data: Shrimps are processed on board through a rotating shrimp sieve. Each sieve has its typical selectivity properties which can be represented by a selection curve, along the same methodology as for the cod-end selectivity.

- An average selection curve was calculated for 5 shrimp trawlers:

a	b	L50	SR
-20.96	0.43	48.7	5.1

4.3 mrate discard

DATA:

- Source: Revill, A., Pascoe, S., Radcliffe, C., Riemann, S., Redant, F., Polet, H., Damm, U., Neudecker, T., Kristensen, P. and Jensen, D., 1999. The economic & biological consequences of discarding in the European Crangon fisheries. Final report to the European Commission, Contract No. 97/SE/025.
- Data: 25%

5 LANDINGS

5.1 weight per class

DATA:

- Source: Redant, F., 1978. Konsumptie en produktie van post-larvale Crangon crangon (L.) (Crustacea, Decapoda) in de Belgische kustwateren. PhD thesis, Free University of Brussels.
- Dataset:

W = 3.212 * 10-6 * TL^3.178

- W = fresh weight of a Brown Shrimp (g)
- TL = total length of a Brown Shrimp (cm)

5.4 processing

DATA: 0% - Not applicable for shrimp

5.9 total commerical biomass per month

DATA:

- Source: Ministry of the Flemish Community. Administration of the Agriculture and Horticulture. Department of Agriculture and Fishery Management – Sea Services Division (Period 2003-2005)
- Data: landings in kg for 7 vessels

	2003	2004	2005	Average per month
Jan	5,333.79	2,191.13	920.05	2,814.99
Feb	1,349.81	1,322.92	282.99	985.24
Mrt	1,353.83	2,403.12	1,160.79	1,639.24
Apr	2,931.75	4,322.90	4,528.68	3,927.78
Mei	3,129.12	12,771.43	9,668.72	8,523.09
Jun	6,735.51	12,710.36	16,265.93	11,903.93
Jul	13,816.98	19,667.75	13,525.00	15,669.91
Aug	31,202.63	22,194.56	24,692.75	26,029.98
Sep	34,543.16	23,042.92	20,685.75	26,090.61
Okt	29,800.04	24,725.60	31,558.69	28,694.78
Nov	12,971.44	13,155.73	23,562.02	16,563.07
Dec	9,205.11	8,212.33	11,707.28	9,708.24
Total per year	12,905.73	12,574.89	13,677.90	

5.11 fish landings per unit of effort

DATA:

- Source: Ministry of the Flemish Community. Administration of the Agriculture and Horticulture. Department of Agriculture and Fishery Management – Sea Services Division (Period 2003-2005)
- Data: average 20.89 kg/hr

	2003	2004	2005	Average per month
Jan	14.57	9.53	8.93	11.67
Feb	15.70	9.25	3.99	10.22
Mrt	7.87	6.51	4.41	6.48
Apr	9.16	13.64	9.74	10.77
Mei	12.04	24.23	17.55	19.84
Jun	12.31	23.24	17.00	17.73
Jul	17.51	21.15	18.06	19.05
Aug	31.39	24.07	24.55	26.74
Sep	34.65	27.63	29.01	30.77
Okt	30.66	22.96	33.86	29.17
Nov	15.19	13.40	23.35	17.50
Dec	12.56	8.76	15.61	11.98
Average per year	21.84	19.31	21.69	20.89

5.12 shrimp size per class

DATA:

- Source: ILVO- Fisheries
- Data: 15, 25, 35, 45, 55, 65, 75, 85 (mm)

SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY
(SPSD II)

Part 2:
Global change, Ecosystems and Biodiversity

Annex 5

BALANS

BALANCING IMPACTS OF HUMAN ACTIVITIES
IN THE NORTH SEA

EV/21

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Ir. D. Leroy, Ecolas nv

February 2007

ANNEX 5:
SHRIMP FISCHERIES
ENVIRONMENT

1 MACROBENTHIC DENSITY AT THE FISHED SITE: STOCKS AND FLOWS

1.1 macrobenthos density

DATA:

- Source: MACRODAT database (Section Marine Biology); Van Hoey et al. (2004)
- Dataset: available at Section Marine Biology, University of Ghent

TABLE 1: Characterization of the species assemblages of the Belgian Continental Shelf (adapted from Van Hoey et al., 2004)

Species assemblage	**SA1**	**SA2**	**SA3**	**SA4**	**SA5**	**SA6**	**SA7**	**SA8**	**SA9**	**SA10**
Sediment type	FS	FS	MS	MS	MS	MS	FS	FS	FS	FS
Median grain size (µm)	219	208	268	274	333	409	219	243	230	248
Mud content (%)	5.8	4.3	1.9	0.4	0.2	0.3	<0.1	0.1	<0.1	<0.1
Depth (m)	-13	-8	-14	-12	-16	-15	-2	2	2	4
Species richness (#/m²)	30	18	13	7	8	5	5	8	5	5
Density	6432	2746	2017	402	304	190	135	482	101	983
Name	Type I SA *Abra alba-Mysella bidentata* community	Type II SA	Type II SA	Type I SA *Nepthys cirrosa* community	Type II SA	Type I SA *Ophelia limacina-Glycera lapidum* community	Type II SA	Type II SA	Type II SA	Type I SA Eurydice pulcra-Scolelepis squamata community

1.3 mortality rate

DATA:

- Source: Blackford (1997); Duplisea (1998)
- Dataset: Although several data for mortality rate of macrobenthos are circulating in literature, we chose the value of Blackford (1997) for deposit feeders and suspension feeders because these functional groups dominate in continental shelf ecosystems according to Silvert (1991). The value of Blackford (1997) is also determined for environmental conditions similar to the ones valid for the BPNS.

TABLE 2: Data on mortality rate found in literature

Source		Mortality rate
Blackford (1997)	- deposit feeders/suspension feeders - predators	0.001/d 0.003/d
Duplisea (1998)		0.0014/d
Chosen value (Blackford, 1997)		0.001/d or 0.05/month

1.5 birth rate

DATA:

- Source: Sohma et al. (2001); Duplisea (1998); Ortiz & Wolff (2002)
- Dataset: Although several data for birth rate of macrobenthos are circulating in literature, we chose the value of Ortiz & Wolff (2002) because this value is also determined for environmental conditions similar to the ones valid for the BPNS (i.e. sandy habitats).

TABLE 3: Data on birth rate found in literature

Source	Birth rate
Sohma et al. (2001)	0.053/d
Duplisea (1998)	0.185/d
Ortiz & Wolff (2002)	0.012/d
Chosen value (Ortiz & Wolff, 2002)	0.012/d or 0.36/month

1.6 density for competition

DATA:

- Source: MACRODAT database (Section Marine Biology)
- Dataset: available at Section Marine Biology, University of Ghent

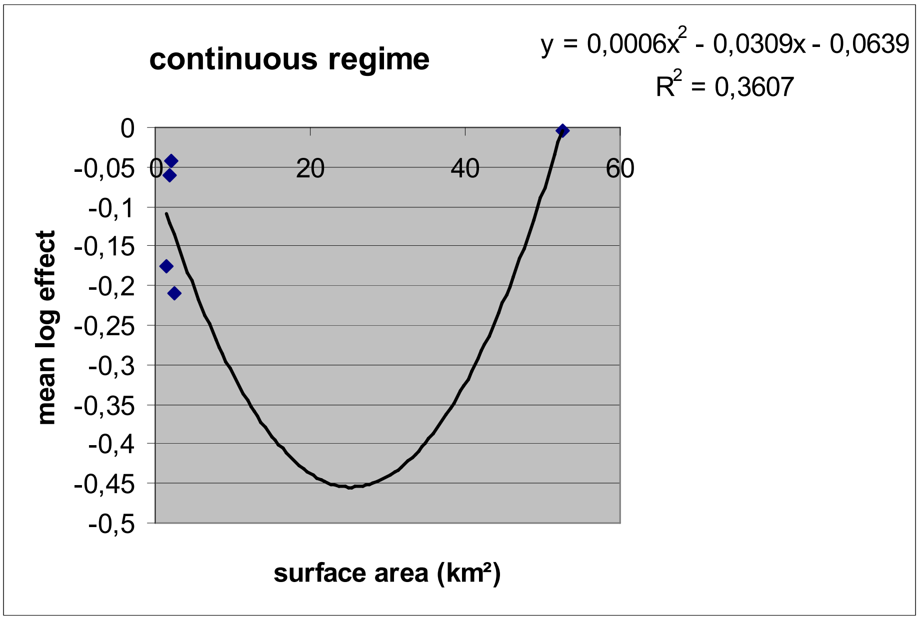
2 EFFECT OF FISHING

2.7 effect surface area cr

DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see AnnexS&GEnvSofie.

GRAPH 3: Mean (logarithmic) effect of fishing a certain surface area, when the continuous regime is valid, on the macrobenthic density of the fished site.

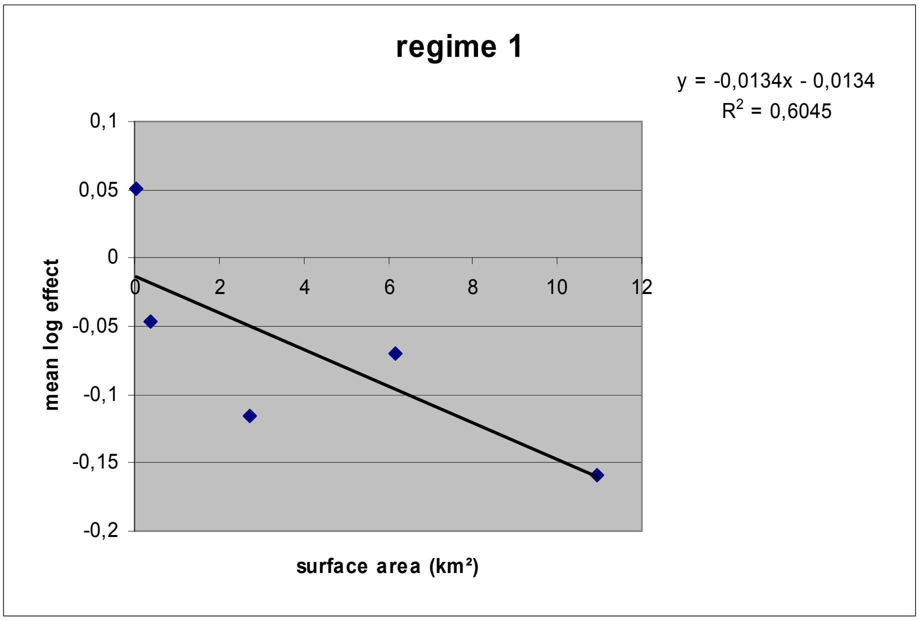


2.8 effect surface area r

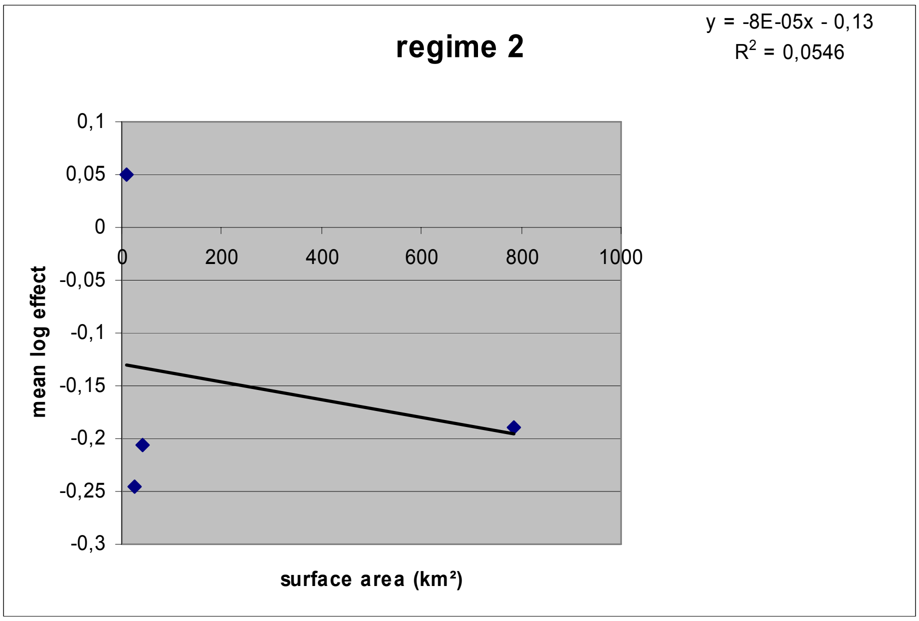
DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see AnnexS&GEnvSofie.

GRAPH 1: Mean (logarithmic) effect of fishing a certain surface area, when regime 1 is valid, on the macrobenthic density of the fished site



GRAPH 2: Mean (logarithmic) effect of fishing a certain surface area, when regime 2 is valid, on the macrobenthic density of the fished site.



3 SEDIMENT COMPOSITION AT THE FISHED SITE

The mean sediment composition at a fished site was deduced from the meta-analysis and was classified into three fractions: a fine sand fraction, a medium-coarse sand fraction and a gravel fraction. The equations for the fine sand fraction of the sediment at the fished site are given first. The equations for the medium-coarse sand fraction and gravel fraction of the sediment are given at the end of the annex (from 3.8 onwards).

3.1 sediment extraction site fs

DATA: Calculated from meta-analysis

TABLE 3: The initial value (%) of the sediment fractions present at the fished site (as deduced from meta-analysis).

Sediment fraction	Initial value (%)
Gravel	12.67
Medium-coarse sand	41.58
Fine sand	45.75

3.3 infilling rate fs

DATA: Calculated from meta-analysis

For more information on the methodology of the meta-analysis see AnnexS&GEnvSofie.

TABLE 4: The infilling rate of the sediment fractions present at the fished site (as deduced from meta-analysis).

Sediment fraction	Infilling rate
Gravel	1.0269
Medium-coarse sand	1.0183
Fine sand	1.0113

3.4 sand transport fs

DATA: Calculated from meta-analysis

For more information on the methodology of the meta-analysis see AnnexS&GEnvSofie.

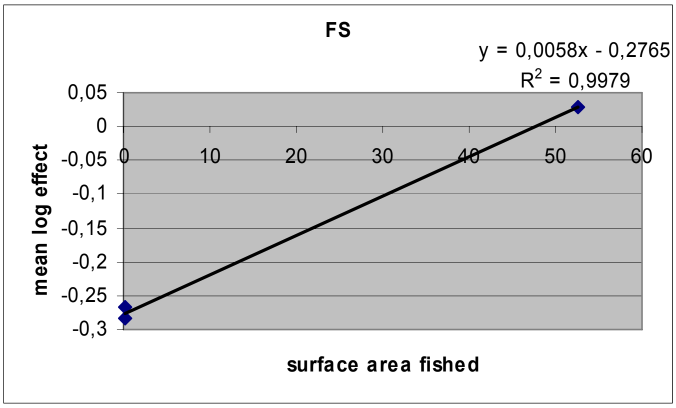
TABLE 5: The sand transport rate of the sediment fractions present at the fished site (as deduced from meta-analysis).

Sediment fraction	Sand transport rate
Gravel	1.00548
Medium-coarse sand	1.0052
Fine sand	1.0083

3.6 effect of fishing fs
DATA: calculated in meta-analysis

For more information on the methodology of the meta-analysis see AnnexS&GEnvSofie.

GRAPH 4: Mean (logarithmic) effect of fishing a certain surface area, when the continuous regime is valid, on the fine sand fraction of the fished site sediment.



3.8 sediment extraction site MCS
DEFINITION: The percentage of the medium-coarse sand grain size fraction that is present in a fished area
EQUATION: sediment_extraction_site_MCS(t-dt)+(natural_input_3+increase_due_to_fi shing_3-natural_decrease_by_transport_3-decrease_due_to_fishing_3)*dt
ARRAY: none
UNITS: %
VALUE: initial value = 41.58; range between 0 and unlimited; only +
TYPE: stock
FUNCTION: objective

LINKS:

- Input: Natural input MCS
- Output: Natural Decrease by transport MCS; Being influenced by fishing MCS; natural input MCS

DATA: Calculated from meta-analysis (see Annex)

See Table 3 above (subsection 3.1)

3.9 natural input MCS

DEFINITION: The percentage of the medium-coarse sand grain size fraction that is coming in the zone due to natural sediment transport processes

EQUATION: infilling_rate_MCS * sediment_extraction_site_MCS

ARRAY: none

UNITS: %

VALUE: range from 0 to unlimited; only +

TYPE: flow

FUNCTION: calculation

LINKS:

- Input: Infilling rate MCS; sediment extraction site MCS
- Output: Sediment extraction site MCS

DATA: calculated but not verifiable

3.10 infilling rate MCS

DEFINITION: The rate at which the medium-coarse sand grain size fraction is transported to an area

EQUATION: Constant

ARRAY: none

UNITS: numerical

VALUE: 1.0183

TYPE: parameter

FUNCTION: scenario

LINKS:

- Output: Natural input MCS

DATA: Calculated from meta-analysis (see Annex)

See TABLE 4 above (subsection 3.3)

3.11 sand transport MCS

DEFINITION: The rate at which the medium-coarse sand grain size fraction is transported away from an area

EQUATION: constant

ARRAY: none

UNITS: numerical

VALUE: 1.0052

TYPE: parameter

FUNCTION: scenario

LINKS:

- Output: Natural decrease by transport MCS

DATA: Calculated from meta-analysis (see Annex)

For more information on the methodology of the meta-analysis see AnnexS&GEnvSofie.

See Table 5 above (subsection 3.4)

3.12 natural decrease by transport MCS

DEFINITION: The percentage of the medium-coarse sand grain size fraction that leaves the zone due to natural sediment transport processes

EQUATION: sand_transport_MCS*sediment_extraction_site_MCS

ARRAY: none

UNITS: %

VALUE: range from 0 to unlimited; only +

TYPE: flow

FUNCTION: calculation

LINKS:

- Input: Sand transport MCS; Sediment extraction site MCS

DATA: calculated but not verifiable

3.13 effect of fishing MCS

DEFINITION: Effect of fishing a certain surface area on the percentage of the medium-coarse sand grain size type.

EQUATION:((10^(((0.0406*LOGN(Swept_area))-0.0777)+2.004))-101)/100

ARRAY: none

UNITS: numerical

VALUE: range between 0 and unlimited; +/-

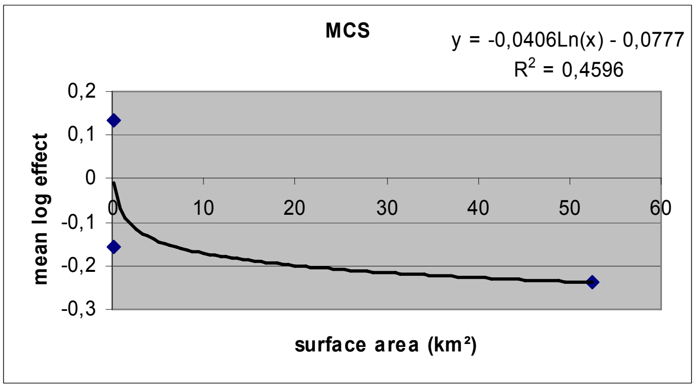
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: Swept area from Driving Forces sub-model
- Output: Being influenced by fishing MCS

DATA: calculated in meta-analysis (see Annex)

For more information on the methodology of the meta-analysis see AnnexS&GEnvSofie.

GRAPH 5: Mean (logarithmic) effect of fishing a certain surface area, when the continuous regime is valid, on the medium-coarse sand fraction of the fished site sediment.



3.14 being influenced by fishing MCS

DEFINITION: The percentage of the medium-coarse sand grain size fraction that fills in or is removed from the fished area
EQUATION: (effect_of_fishing_MCS)*sediment_extraction_site_MCS
ARRAY: none
UNITS:%
VALUE: range from 0 to unlimited; +/-
TYPE: flow
FUNCTION: calculation
LINKS:

- Input: Effect of fishing MCS; Sediment extraction site MCS

DATA: calculated but not verifiable

3.15 sediment extraction site GR

DEFINITION: The percentage of the gravel grain size fraction that is present in a fished area

EQUATION: sediment_extraction_site_GR(t-dt)+(natural_input_GR+increase_due_to_fishing_GR-natural_decrease_by_transport_GR-decrease_due_to_fishing_GR)*dt

ARRAY: none

UNITS: %

VALUE: initial value = 12.67; range between 0 and unlimited; only +

TYPE: stock

FUNCTION: objective

LINKS:

- Input: Natural input GR
- Output: Natural Decrease by transport GR; Being influenced by fishing GR; natural input GR

DATA: Calculated from meta-analysis (see Annex)

See Table 3 above (subsection 3.1)

3.16 natural input GR

DEFINITION: The percentage of the gravel grain size fraction that is coming in the zone due to natural sediment transport processes

EQUATION: infilling_rate_GR * sediment_extraction_site_GR

ARRAY: none

UNITS: %

VALUE: range from 0 to unlimited; only +

TYPE: flow

FUNCTION: calculation

LINKS:

- Input: Infilling rate GR; sediment extraction site GR
- Output: Sediment extraction site GR

DATA: calculated but not verifiable

3.17 infilling rate GR

DEFINITION: The rate at which the gravel grain size fraction is transported to an area

EQUATION: Constant

ARRAY: none

UNITS: numerical
VALUE: 1.0269
TYPE: parameter
FUNCTION: scenario
LINKS:

- Output: Natural input GR

DATA: Calculated from meta-analysis (see Annex)

See TABLE 4 above (subsection 3.3)

3.18 sand transport GR

DEFINITION: The rate at which the gravel grain size fraction is transported away from an area
EQUATION: constant
ARRAY: none
UNITS: numerical
VALUE: 1.00548
TYPE: parameter
FUNCTION: scenario
LINKS:

- Output: Natural decrease by transport GR

DATA: Calculated from meta-analysis (see Annex)

For more information on the methodology of the meta-analysis see AnnexS&GEnvSofie.

See Table 5 above (subsection 3.4)

3.19 natural decrease by transport GR

DEFINITION: The percentage of the gravel grain size fraction that leaves the zone due to natural sediment transport processes
EQUATION: sand_transport_GR*sediment_extraction_site_GR
ARRAY: none
UNITS: %
VALUE: range from 0 to unlimited; only +
TYPE: flow
FUNCTION: calculation
LINKS:

- Input: Sand transport GR; Sediment extraction site GR

DATA: calculated but not verifiable

3.20 effect of fishing GR

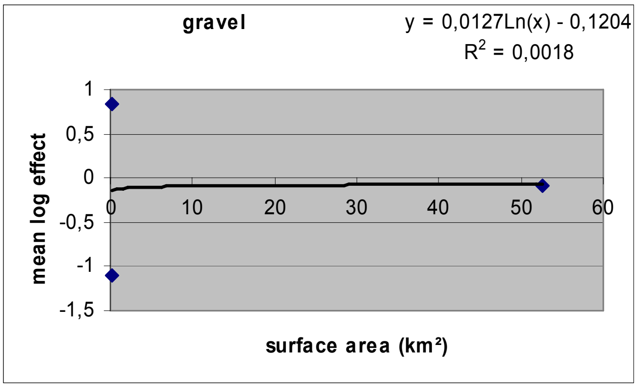
DEFINITION: Effect of fishing a certain surface area on the percentage of the gravel grain size type.
EQUATION: ((10^(((0.0127*LOGN(Swept_area))-0.1204)+2.004))-101)/100
ARRAY: none
UNITS: numerical
VALUE: range between 0 and unlimited; +/-
TYPE: variable
FUNCTION: calculation
LINKS:

- Input: Swept area from Driving Forces sub-model
- Output: Being influenced by fishing GR

DATA: calculated in meta-analysis (see Annex)

For more information on the methodology of the meta-analysis see AnnexS&GEnvSofie.

GRAPH 6: Mean (logarithmic) effect of fishing a certain surface area, when the continuous regime is valid, on the gravel fraction of the fished site sediment.



3.21 being influenced by fishing GR

DEFINITION: The percentage of the gravel grain size fraction that fills in or is removed from the fished area
EQUATION: (effect_of_fishing_GR)*sediment_extraction_site_GR
ARRAY: none

UNITS:%
VALUE: range from 0 to unlimited; +/-
TYPE: flow
FUNCTION: calculation
LINKS:

- Input: Effect of fishing GR; Sediment extraction site GR

DATA: calculated but not verifiable

SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY
(SPSD II)

Part 2:
Global change, Ecosystems and Biodiversity

Annex 6

BALANS

BALANCING IMPACTS OF HUMAN ACTIVITIES
IN THE NORTH SEA

EV/21

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Ir. D. Leroy, Ecolas nv

February 2007

ANNEX 6:
SHRIMP FISCHERIES
SOCIO-ECONOMY

1 ECONOMIC RESULT

1.5 fish price

DATA:

- Source: Ministry of the Flemish Community. Administration of the Agriculture and Horticulture. Department of Agriculture and Fishery Management – Sea Services Division (Period 1999-2005)
- Data: in Eur/kg

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Average per month
Jan	4.58	4.31	3.21	8.06	4.30	5.72	5.39	4.68	4.86	6.60	5.17
Feb	6.52		5.01	8.25	5.15	5.93	5.26	4.23	6.20	4.92	5.72
Mrt	7.43	6.24	4.65	7.34	6.20	7.53	5.62	5.00	4.84	6.20	6.11
Apr	8.80	6.58	5.86	8.86	6.79	7.74	7.21	4.90	4.27	5.98	6.70
Mei	6.73	6.20	5.15	7.59	6.65	7.90	6.64	3.72	3.95	4.39	5.89
Jun	5.65	3.92	5.19	7.42	5.91	6.43	6.19	4.10	3.38	4.66	5.28
Jul	4.96	3.68	5.55	5.47	5.87	5.46	5.47	3.43	3.45	4.90	4.82
Aug	3.96	2.50	4.85	3.22	4.49	4.12	5.60	3.36	2.98	3.64	3.87
Sep	3.36	2.52	4.35	3.14	4.16	3.92	3.58	3.44	2.66	2.50	3.36
Okt	3.17	2.98	4.64	3.43	4.20	4.34	3.83	3.07	3.17	1.84	3.47
Nov	3.52	3.85	4.98	4.46	5.05	4.64	4.05	3.21	4.17	2.17	4.01
Dec	3.84	4.58	7.21	6.14	5.61	5.41	4.63	4.18	5.66	4.31	5.16
Average per year	4.49	3.59	5.03	4.94	5.07	5.32	4.72	3.65	3.80	3.68	4.43

2 VARIABLE COST

2.3(& 2.4) trips per fish ground (inshore and offshore fish grounds)

DATA:

- Source: Ministry of the Flemish Community. Administration of the Agriculture and Horticulture. Department of Agriculture and Fishery Management – Sea Services Division (Period 1996 – 2005)
- Dataset: inshore 64 trips/month; offshore 19 trips/month (approximate values)

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Average per month
Inshore[1] fishery	70	67	47	68	55	53	62	69	75	79	64
Offshore[2] fishery	23	12	13	14	24	21	20	24	26	18	19

(1) Inshore fishery during March to November; (2)Offshore fishery during December to February

2.8 fuel consumption fishing

DATA:

- Source: Personnal communication fishermen
- Data: 782 l/ 24hr or 38 l/hr

2.10 (&2.11) time fishing per trip (inshore and offshore fish grounds)

DATA:

- Source: Ministry of the Flemish Community. Administration of the Agriculture and Horticulture. Department of Agriculture and Fishery Management – Sea Services Division (Period 2003 – 2005)
- Data: inshore 9.5 hr/trip; offshore 16.4 hr/trip

	2003	2004	2005	Average
Inshore[1] fishery	9.41	9.72	9.49	9.54
Offshore[2] fishery	15.23	16.65	18.08	16.44

(1) Inshore fishery during March to November; (2)Offshore fishery during December to February

2.12 fuel price

DATA:

- Source: FPS Economy. SMEs. Self-employed and Energy: Ecodata. Official maximum prices of petroleum products (excl. BTW) (1999-2005).
- Data: in €/l

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Average	0.19	0.19	0.15	0.18	0.30	0.28	0.25	0.26	0.31	0.43

2.14 fuel consumption sailing

DATA:

- Source: Personnal communication fishermen
- Dataset: 2.3 l/km

2.15 & 2.16 average steamed distance per fish ground per trip

DATA:

- Source: Hans Polet - DVZ
- Dataset: inshore fish ground (18.5 km); offshore fish ground (46 km)

2.19 ratio turnover

DATA:

- Source: Ministry of the Flemish Community. Administration of the Agriculture and Horticulture. Department of Agriculture and Fishery Management – Sea Services Division (Period 2002)
- Data: (Estimation from data period 2002)

	Landings	Average shrimp price	Turnover	Personnel cost	Ratio
2002	84217	4.72	397504.24	88568	0.22

2.21 number of employees per vessel

DATA:

- Source: Maes F, Schrijvers J, Van Lancker V, Verfaillie E, Degraer S, Derous S, De Wachter B, Volckaert A, Vanhulle A, Vandenabeele P, Cliquet A, Douvere F, Lambrecht J and Makgill R (2005) Towards a spatial structure plan for sustainable management of the sea. Research in the framework of the BSP programme "Sustainable Management of the Sea" – PODO II. June 2005. pp. 539.

- Dataset: 3 employee/vessel

2.22 number of vessels in small fleet

DATA:

- Source: Ministry of the Flemish Community. Administration of the Agriculture and Horticulture. Department of Agriculture and Fishery Management – Sea Services Division
- Data: 7 vessels (subset of total)

2.24 ratio other costs

DATA:

- Source: Ministry of the Flemish Community. Administration of the Agriculture and Horticulture. Department of Agriculture and Fishery Management – Sea Services Division (based on year 2002)
- Dataset: ratio is 0.13

3 FIXED COST

3.3 monthly maintenance cost per vessel

DATA:

- Source: Ministry of the Flemish Community. Administration of the Agriculture and Horticulture. Department of Agriculture and Fishery Management – Sea Services Division (estimate based on year 2002)
- Dataset: 460 Eur/vessel

3.5 insurance rate

DATA:

- Source: Personnal communication Fortis Corporate Insurance nv
- Dataset: 0.0175 (=1.75%) estimate based on an investment cost of 800,000€ per vessel and the dimensions of the small fleet

3.6 investment cost per vessel

DATA:

- Source: Personnal communication fisher
- Dataset: 800000 EUR/vessel (based on the building cost of new shrimp vessel – traditional beam-trawler, 2006)

3.8 economic lifetime of a ship

DATA:

- Source: Expert judgement DVZ

- Data: 30 years

3.9 monthly interest rate

DATA: calculated but not verifiable

A one time investment cost can be expressed in **yearly costs** using the annuity formula:

$$I_0\left[\frac{r(1+r)^n}{(1+r)^n-1}\right]$$

I0 = One time investment
r = yearly real interest rate (= nominal interest rate corrected for inflation)
n = economic lifetime of the investment in years

Example: investment cost for a vessel of 10 million euro with an economic lifetime of 30 years and applying an interest rate of 10% => yearly investment cost = 1.06 million euro.

A one time investment cost can be expressed in **monthly costs** using the same annuity formula. taking into account the following adaptations:
n = economic lifetime of the investment in months (number of years * 12)
r = real interest rate expressed per month
This monthly interest rate can be calculated starting from the yearly real interest rate:

[(1+(yearly real interest rate/12))^12-1]/12

Example: investment cost for a vessel of 10 million euro with an economic lifetime of 30 years and applying a yearly interest rate of 10%
=> monthly interest rate: 0.8726%
=> monthly investment cost: 91259 euro

3.10 yearly real interest rate

DATA:

- Source: Vito (2003) Background document environmental cost model: private real interest rate. p. 47 http://www.emis.vito.be/EMIS/Media/BBT_rapport_milieukostenmodel.pdf
- Dataset: 0.1 (= 10%)

SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY
(SPSD II)

Part 2:
Global change, Ecosystems and Biodiversity

Annex 8

BALANS

BALANCING IMPACTS OF HUMAN ACTIVITIES
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Ir. D. Leroy, Ecolas nv

February 2007

USER INPUTS

1. SAND AND GRAVEL

Table 1-1 Input parameters Sand and Gravel – General User Interface

Name	Range or possible value	Default value	Unit
Intensity of demand	[0.5; 10]	1	Dimensionless
Percentage of overlap	[0;1]	0	Dimensionless
Fuel price	[0;10]	0.54	EUR/l
Price of aggregates	[0;15] (for each zone)	4	EUR/m³
Manpower cost	[0;10,000]	4,583	EUR/person

Table 1-2 Input parameters for the Sand and Gravel thematic page 'Driving Forces'

Name (×2 means one value for each of the types of vessels)	Range or possible value	Default value	Unit
Quota over five years	[0;20,000,000]	15,000,000	m³
Critical Depth	[0;10]	4.0	m
Maximum number of trips per day and per vessel	[0;10]	2	Dimensionless
Regime of the zones	{0|1} for each of the zones, "1" means it is open for ex-ploitation, 0 means it is closed	(1,1,0,1,1,1,0,0)	Dimensionless
Extraction depth of gear	[0.1;1]	0.5	m

Table 1-3 Input parameters for the Sand and Gravel thematic page 'Socio–economy'

Name (×2 means one value for each of the types of vessels)	**Range or possible value**	**Default value**	**Unit**
Average loading capacity (×2)	[0;10,000]	1,266 3,903	m³
Fuel consumption while extracting (×2)	[0;1,000]	350 400	l/h
Fuel consumption while sailing (×2)	[0;1,000]	0.05 0.075	l/m
Time extraction per trip (×2)	[0;24]	1.0 1.5	h
Number of employees per vessel (×2)	[0;10]	4 6	person
Monthly maintenance cost per vessel (×2)	[0;100,000]	37,500 50,000	EUR/mo
Investment cost per vessel (×2)	[0;100,000,000]	10,000,000 13,000,000	EUR
Number of vessels in the fleet (×2)	[0;20]	3 9	
Investment ratio fleet B	[0;1]	0.02	Dimensionless
Maintenance ratio fleet B	[0;1]	0.02	Dimensionless
Insurance rate	[0;1]	0.075	Dimensionless
Economic lifetime	[0;50]	30	year
Yearly interest rate	[0;1]	0.1	Dimensionless

Table 1-4 Input parameters for the Sand and Gravel thematic page 'Environment'

Name	**Range or possible value**	**Default value**	**Unit**
Birth rate	[0;5]	0.36	$Ind.m^{-2}mo^{-1}$
Mortality rate	[0;5]	0.05	$Ind.m^{-2}mo^{-1}$
Density for competition	[0;10,000]	1,000	$Ind.m^{-2}$

2. SHRIMP FISHERIES

Table 2-1 Input parameters Shrimp Fisheries – General User Interface

Name	Range or possible value	Default value	Unit
Intensity of effort	[0;1.5]	1.0	Dimensionless
Mesh size	{20|30}	20	mm
Fuel price	[0;10]	0.43	EUR/l
Discount on fuel price	[0;1]	0.0	Dimensionless
Fish price	[0;100]	4.43	EUR/kg
Subsidy on fish price	[0; 20.0]	0.0	EUR/kg

Table 2-2 Input parameters for the Shrimp fisheries thematic page 'Driving Forces'

Name	Range or possible value	Default value	Unit
Swept escape rate	[0;1]	0.01	Dimensionless
Gear escape rate	[0;1]	0.01	Dimensionless
Cod end escape rate	[0;1]	0.01	Dimensionless
Discard rate	[0;1]	0.25	Dimensionless
Density intensity	[0;2]	1.00	Dimensionless

Table 2.3 Input parameters for the Shrimp fisheries thematic page 'Socio-economy'

Name	Range or possible value	Default value	Unit
Trips per fish ground	[0;100]	65 19	Dimensionless
Fuel consumption while fishing	[0;100]	38.0	l/h
Fuel consumption while sailing	[0;100]	2.3	l/h
Average steamed distance per fish ground and per trip	[0;60]	18.5 46.0	km

Time fishing per trip per fish ground	[0;24]	9.5 16.4	h
Number of employees per vessel	[0;10]	3	Person
Ratio turnover	[0;1]	0.22	Dimensionless
Ratio to other costs	[0;1]	0.15	Dimensionless
Monthly maintenance cost per vessel	[0;100,000]	460.00	EUR
Investment cost per vessel	[0;10,000,000]	800,000.00	EUR
Public help on investment	[0;10,000,000]	0.00	EUR
Insurance rate	[0;1]	0.0175	Dimensionless
Economic lifetime of a ship	[0;50]	30	Year
Yearly interest rate	[0;1]	0.1	Dimensionless
Number of vessels in small fleet	[1;25]	7	Dimensionless

Table 2-4 Input parameters for the Shrimp fisheries thematic page 'Environment'

Name	Range or possible value	Default value	Unit
Benthos Birth rate	[0.0;5.0]	0.37	Ind.$m^{-2}mo^{-1}$
Benthos Mortality rate	[0.0;2.0]	0.05	Ind.$m^{-2}mo^{-1}$
Density for competition	[0;100,000]	22,000	Ind.m^{-2}
Infilling rate Fine Sand	[0;2]	1.0113	Dimensionless
Infilling rate Medium Coarse Sand	[0;2]	1.0183	Dimensionless
Infilling rate Gravel	[0;2]	1.0269	Dimensionless
Sand transport Fine Sand	[0;2]	1.0083	Dimensionless
Sand transport Medium Coarse Sand	[0;2]	1.0052	Dimensionless
Sand transport Gravel	[0;2]	1.00548	Dimensionless

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BELGIAN SCIENCE POLICY

MARITIEM INSTITUUT

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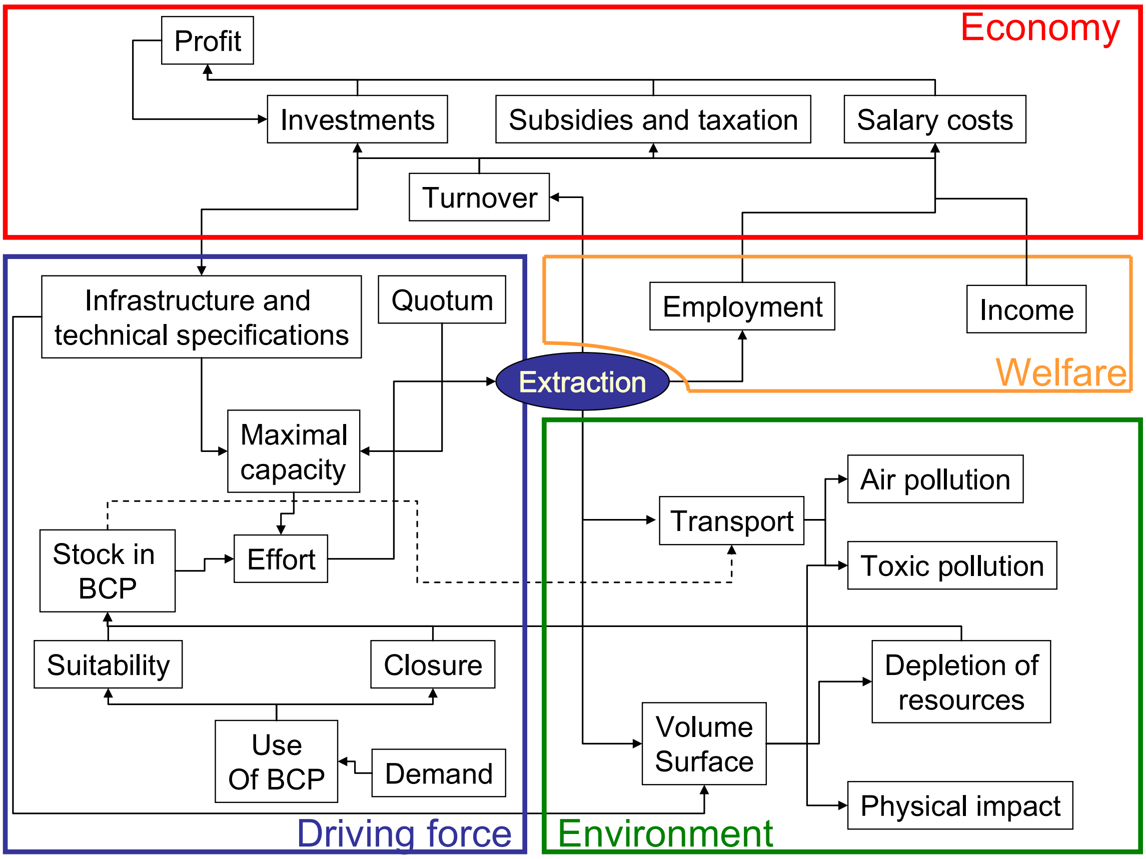
ECOLAS ENVIRONMENTAL CONSULTANCY & ASSISTANCE

Mariene Biologie Vakgroep Biologie

MUMM BMM UGMM

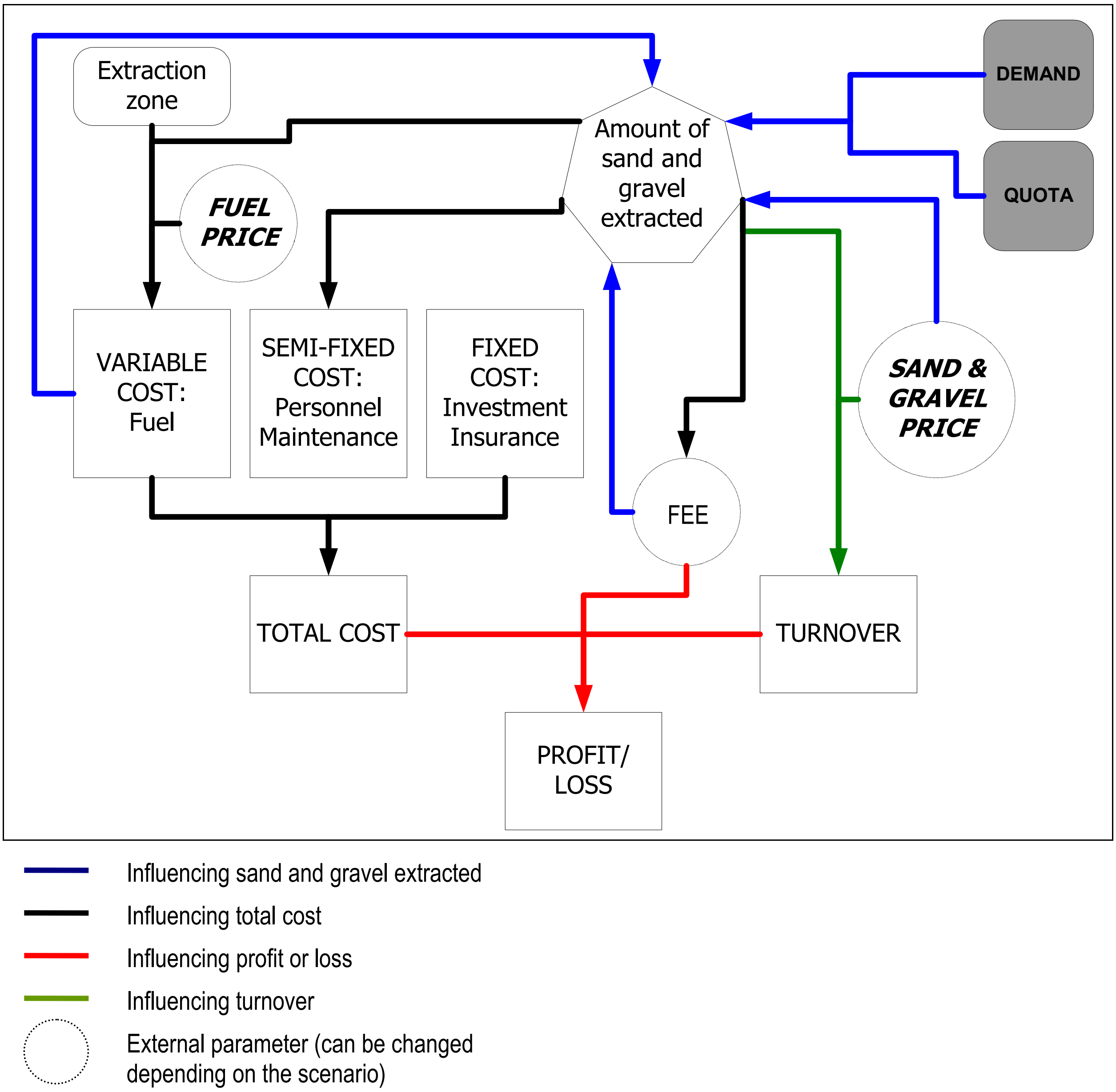
ANNEX 9:
CONCEPTUAL MODEL
SAND AND GRAVEL

Fig. 1. Sand and Gravel Conceptual Model for economic, social, environmental, and driving force aspects



The main goal of the socio-economical model is the calculation of the profit or loss due to the aggregate extraction activities. The general outlook of the socio-economical model is drawn in the figure below. It is a (mainly) demand driven business model. Starting from the driving forces components 'demand' and 'quota', the model calculates profit or losses for the whole sector. A description per component is given below.

Fig. 2. Sand and Gravel Conceptual Model for socio-economic model expanded



AMOUNT OF SAND AND GRAVEL EXTRACTED (BLUE LINES)

The amount of sand and gravel extracted is mainly driven by 'demand' and 'quota' (see 'driving forces'). In the current market situation, the market price (compared with the variable cost on extracted sand and gravel) has no large influence on the amount of sand and gravel extracted. Price, variable cost and fee will only have an influence when importing sand and gravel from other areas (such as British CS) will be competitive (e.g. when Belgian fee should rise much).

TOTAL COST (BLACK LINES)

The total cost can be divided into variable costs, semi-fixed (or semi-variable) and fixed costs.

Variable costs vary directly with the activity (in this case the amount of sand and gravel extracted). Fixed costs (in the short term) stay equal when the activity changes. Semi-fixed components are partly variable and partly fixed.

The variable costs consist only of fuel cost and are driven by the total amount sand and gravel extracted, the extraction area and the characteristics of the vessel (loading capacity, etc.). The fuel cost per amount of sand and gravel extracted (unit cost) is influenced by the extraction area. The further the extraction area is from the port, the higher the unit cost price (fuel cost per m^3 sand and gravel extracted). *Fuel price can be changed depending on the scenario.*

In this model the semi-fixed costs consist of personnel costs and maintenance costs. Since we have no data on how these semi-fixed costs vary with the amount extracted, in the model we assume them to be fixed.

In this model the fixed costs consist of investment costs and insurance costs. Investment costs can be expressed in equal annual costs using the annuity formula. The annual investment cost consists of depreciation and interest.

TURNOVER (GREEN LINES)

The turnover is calculated by simply multiplying the amount extracted with the price. *Sand and gravel price can be changed depending on the scenario.*

FEE

The fee is calculated by multiplying the unit fee with the amount extracted. *Unit fee can be changed depending on the scenario.*

PROFIT/LOSS (RED LINES)

The profit or loss is calculated by decreasing the turnover with the total cost and fee. When turnover is higher then the sum of total costs and fee, then there is a profit, when lower, then there is a loss.

SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY
(SPSD II)

Part 2:
Global change, Ecosystems and Biodiversity

Annex 10

BALANS
BALANCING IMPACTS OF HUMAN ACTIVITIES IN THE NORTH SEA

EV/21

Coordinator and promotor:
Prof. Dr. F. Maes, Maritime Institute, University Gent

Promotors:
Dr. Hans Polet, Institute for Agricultural and Fisheries Research
Prof. Dr. M. Vincx, Marine Biology Section, University Gent
Prof. Dr. Colin Janssen, Laboratory for Biological Research in Aquatic Pollution, University Gent
Ir. Serge Scory, Management Unit of the North Sea Mathematical Models
Ir. D. Leroy, Ecolas nv

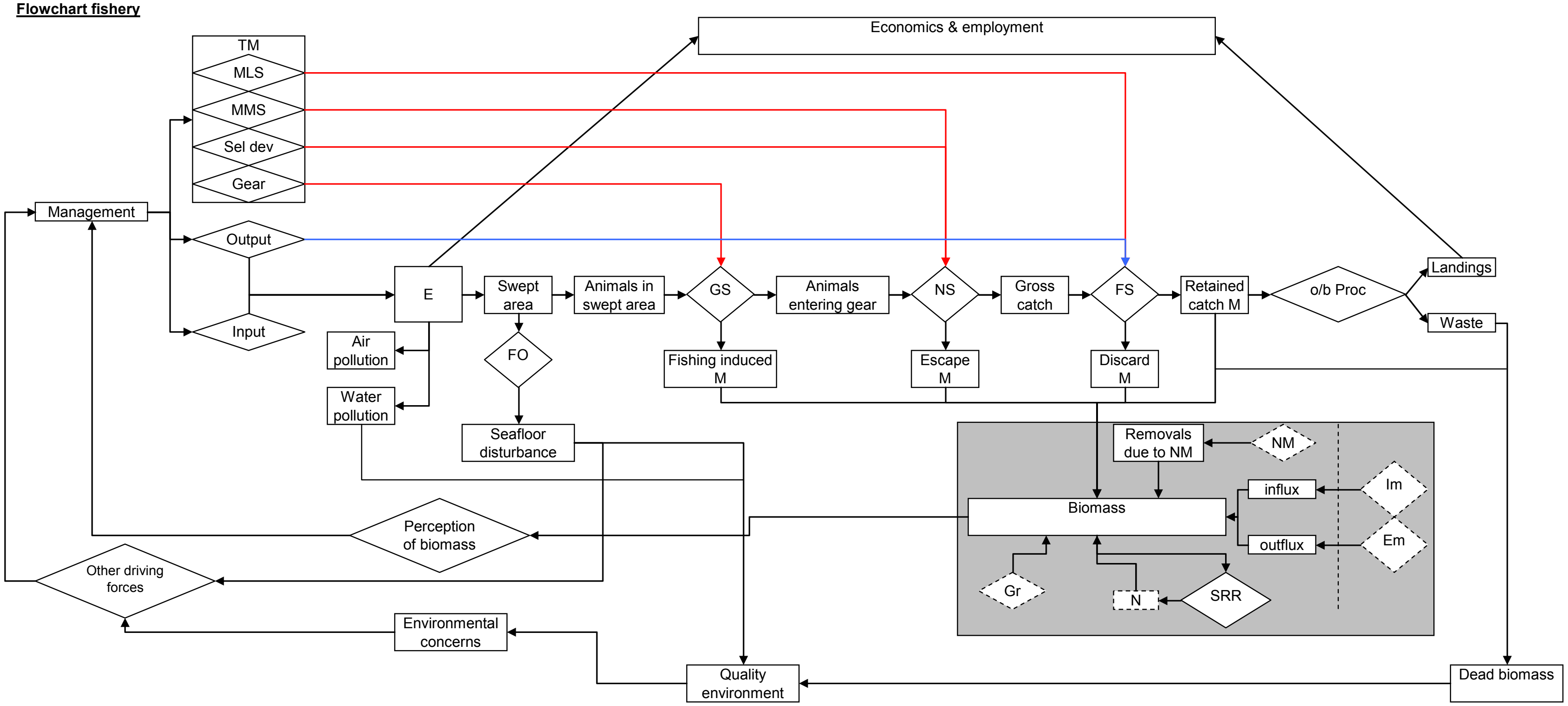
February 2007

BELGIAN SCIENCE POLICY

ANNEX 10:
CONCEPTUAL MODEL
SCHRIMP FISHERIES

Fig. 1. Shrimp Fisheries Conceptual Model for economic, social, environmental, and driving force aspects

Flowchart fishery

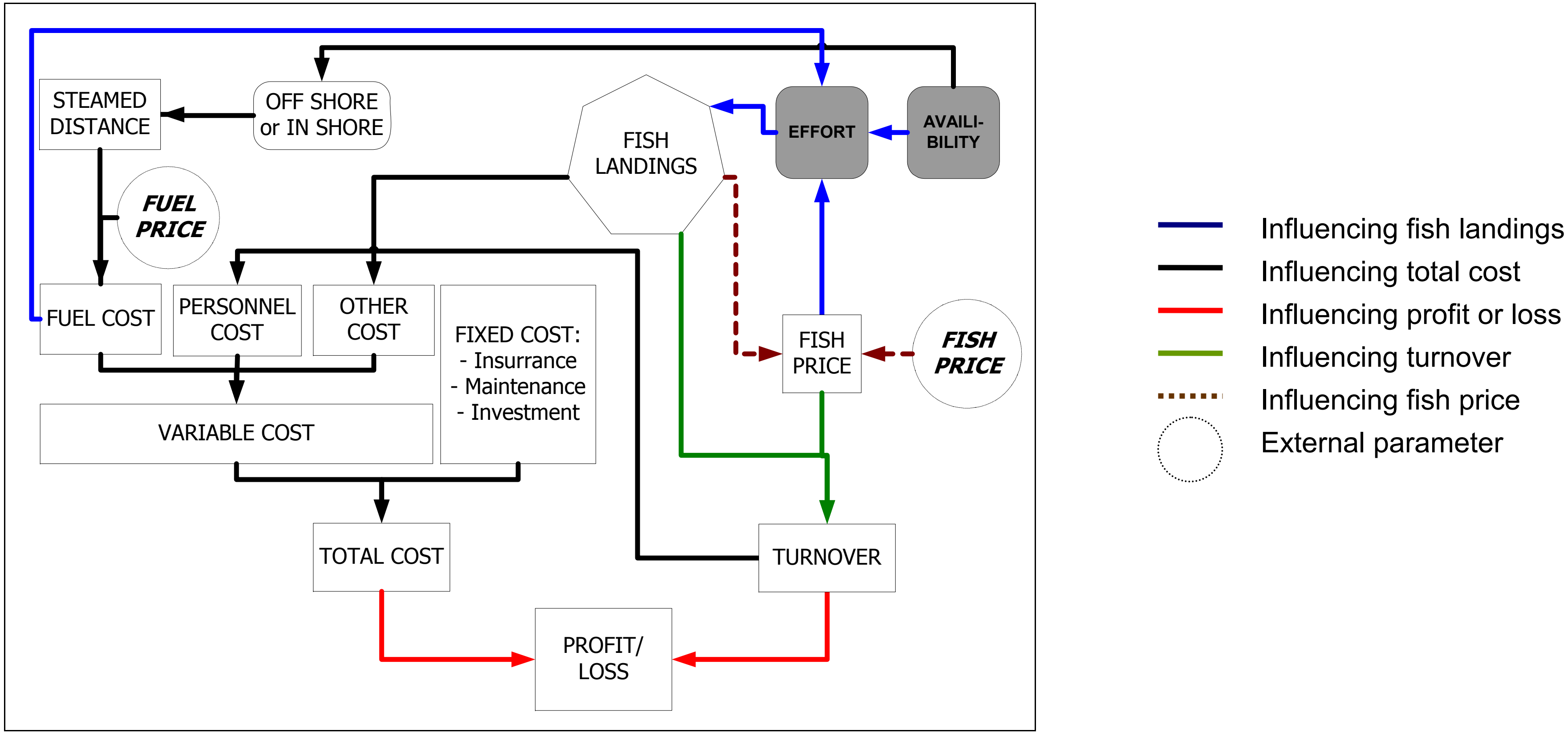


N: natality
NM: predation etc.; natural mortality
Gr: growth
MMS: minimum mesh size
MLS: minimum landing size
TM: technical measures
E: effort
GS: gear selection
NS: net selection
FS: fishermen's selection
o/b proc: on board processing
FO: fishing gear operation
SRR: stock recruitment relationship

xxx effect
xxx (dashed) fluctuates randomly between most likely values
x (diamond) process

The socio-economical model calculates the profit or loss made by the local shrimp fisheries. The general outlook of the model is drawn in the figure below. The shrimp business is driven partly by availability and partly by the market price (which can be influenced by external parameters such as public help and the international price[1]). Starting from the driving forces components 'availability' and 'effort' the model calculates profit or loss for the whole sector. A description per component is given below.

Fig. 2. Shrimp Fisheries Conceptual Model for socio-economic model expanded



[1] In the BALANS project the influence of the international market was not taken into account.

TOTAL COST (BLACK LINES)

The total cost is the summation of the variable and the fixed costs.
The variable costs consist of fuel cost (sailing, fishing), personnel cost and other variable costs. The fuel cost is determined by the steamed distance (dependent on the fish ground), time fishing and the fuel price (inclusive public help). *Fuel price can be changed depending on the scenario.* Due to a lack of detailed information, both the personnel cost and the other variable costs are expressed as a certain percentage of the turnover. Other costs consist of fish gear, loading and unloading, ice, etc..
In this model the fixed costs consist of investment costs, maintenance cost and insurance costs. Investment costs can be expressed in equal annual costs using the annuity formula. The annual investment cost consists of depreciation and interest.

TURNOVER (GREEN LINES)

The turnover is calculated by simply multiplying the fish landings with the price.
The fish price on the local market is determined by the fish landings (offer) and the public help (subsidies). The model does not include the influence of the international market on the local fish price.

PROFIT/LOSS (RED LINES)

The profit or loss is calculated by decreasing the turnover with the total cost. When turnover is higher then the total costs, then there is a profit, when lower, then there is a loss.

SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY
(SPSD II)

Part 2:
Global change, Ecosystems and Biodiversity

Annex 11

BALANS
BALANCING IMPACTS OF HUMAN ACTIVITIES
IN THE NORTH SEA

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February 2007

BELGIAN SCIENCE POLICY

ANNEX 11:
ECOTOXICOLOGY

Scientific report:

Summary of main results and conclusions

Laboratory of Environmental Toxicology and Anquatic Ecology

Vincent Dufour and Colin Janssen

1 INTRODUCTION

As stated in the introduction of this report, the BALANS project is the first attempt to create an instrument that allows science-based policy choices to be made when assessing the impact of human activities on the Belgian part of the North Sea. In the context of this tool development, the project concentrated on what drives two human activities (1) sand and gravel extraction and (2) shrimp fisheries, and how they affect the environment and trigger the socio-economic system.
Starting from the flowchart analysis the major aspects were identified that are relevant for the development of the conceptual model. The model developed for sand and gravel extraction is given in Fig. 1.

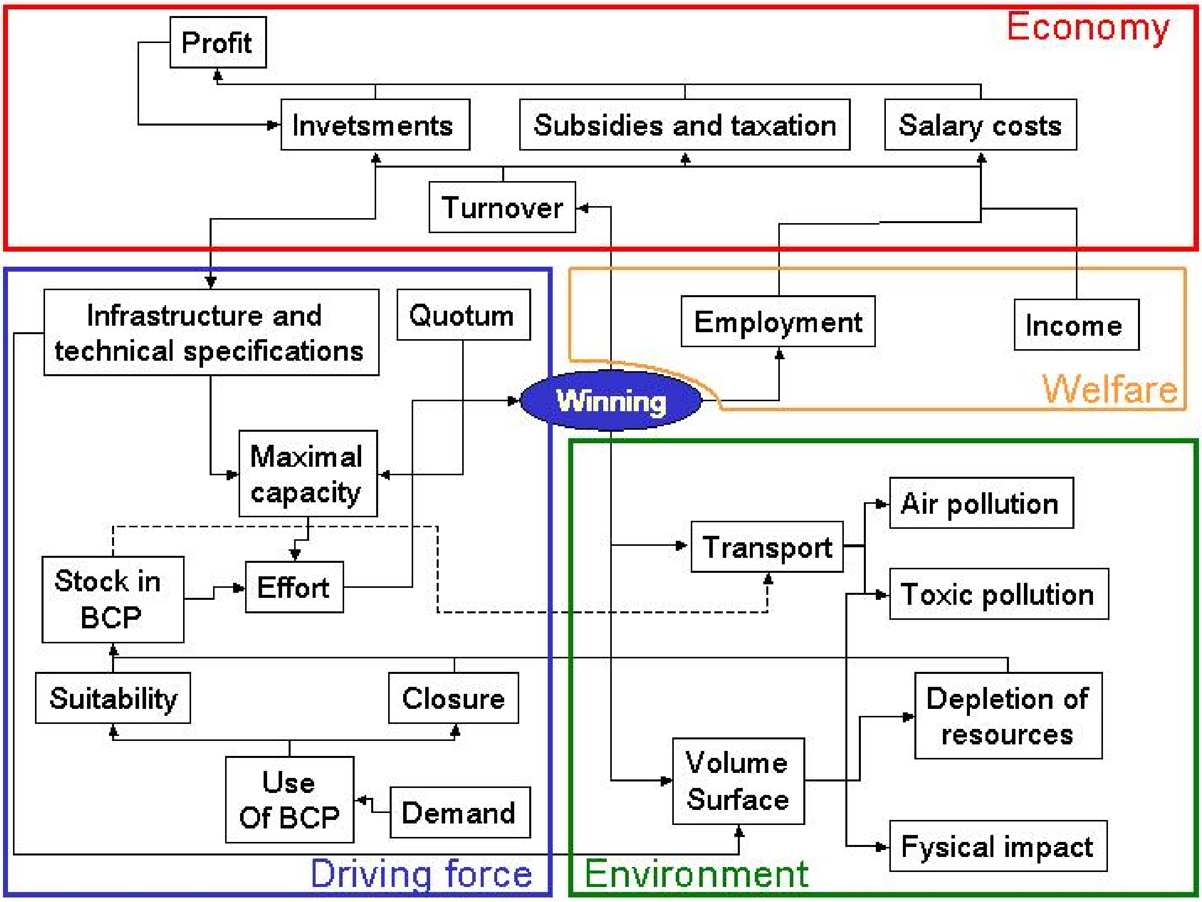

Fig. 1 Conceptual model used for the assessing sand and gravel extraction in the BALANS project.

This overall conceptual model was used for the developments of a quantitative simulation model Stella which is the systems thinking instrument that shapes the step between conceptual modeling and final simulation and calculation (see main report).

Within the BALANS project the general tasks of the Laboratory of Environmental Toxicology and Aquatic Ecology were:

Selection and development of relevant ecotoxicological indicators reflecting the impact of various industrial activities in the Belgian part of the North Sea (fisheries, sand- and gravel extraction and resulting emission of contaminants);

Selection of representative indicators of the ecological status of the marine environment, based the chemical properties of the water column and the sediment, including ecological indicators of the effects of pollutants on the marine ecosystem;

Support of the actions taken in the context of the policy development.

Based on literature, previous projects, and the extensive discussion among the partners and the user committee the following indicators were selected as relevant environmental indicators of potential impact through human activity:

- Pollution (air and water)
- Physical impact
- Depletion of resources
- Ecosystem health
- Hydrodynamics

Within the tasks assigned to the Laboratory of Environmental Toxicology and Aquatic Ecology, the main research activities developed were aimed at assessing the importance and magnitude of pollution caused by the selected human activities: i.e. (shrimp) fisheries and gravel (and sand) extraction and the resulting effects on resource depletion and ecosystem health.

The following gives an overview of the methods used to perform these assessments and summarize the main results and conclusions obtained.

2 METHODS AND RESULTS

2.1 Sand and gravel extractions: selection and evaluation of potential ecotoxicological indicators associated with the extraction itself

All extraction techniques results in the re-suspension of the sediment in the water column forming a temporary sediment plume. Additionally sediment plumes can be also formed through onboard release of sediment rejected by the means of overflow. The re-suspended sediment can result in the following potential impact: (1) adverse effects on filter feeding organisms and/or phytoplankton (through decrease the light availability), and (2) remobilization of sediment-associated pollutants, nutrients and organic matter.

The envisaged methodology to be developed was to **quantitatively link adverse effects on biota caused by extraction-associated re-suspension events to the duration and turbidity level of the plume**. However, the extensive literature searches performed in the context of this project demonstrated that although some reports are available on the duration and intensity of re-suspension events in Belgian coastal water, no to very little information is available linking this information to (potential) impacts on marine organisms. Some papers report both negative, toxic effects on the benthos and positive effects on the primary production, however, the type of data presented does not allow to quantitatively assess the impact of increased turbidity or locally increased contaminant concentration of the resident biota**.** Form this literature (and as reported in progress report 2003) it was (qualitatively) **concluded that considering the local occurrence of the plume and short duration of the extraction associated re-suspension events the impact of this physical disturbance to pelagic organisms is probably negligible**.

Extraction and re-suspension may also potentially **re-mobilize sediment associated contaminants**. Considering that in some areas of the Belgian Continental Shelf (BCF, mainly east of Ostend towards the Western Scheldt) the sediments are contaminated with a various chemicals (metals and organic compounds), we attempted to assess the magnitude of contaminant remobilisation and their potential effect on marine biota. Based on the type and concentration of chemicals present in the sediments occurring in Belgian coastal waters and using the equilibrium partitioning approach (combined with the SEM/AVS approach for metals, i.e. metal associated sulphides in reduced sediments) we simulated how much of the sediment associated chemicals would partition into the water phase during an extraction event. Results indicated that for the model chemicals considered (benzoapyrene, Cd and Cu) the expected increase in local Predicted Environmental Concentration in the water column was less than 1%. Given these simulation results, the results from the laboratory simulation experiments (performed by the contractor in the context of other projects), the local nature and known short re-suspension periods and the high dilution factor occurring in Belgian coastal water, **it is concluded remobilisation of contaminants due to extraction events will not lead to significant increases in chemicals/contaminants concentrations in the water phase and as such does not pose as additional risk to pelagic communities.**

2.2 Sand and gravel extractions: selection and evaluation of potential ecotoxicological indicators associated with the shipping & transport at sea

After having established that environmental risks of the release of chemicals from sediments and the potential effects of turbidity is low we focused on the assessment of the potential impact of extraction related shipping activity on the marine environment in Belgian coastal waters. In this project we assessed the **quantity of contaminants released by (extraction) dredging and transport in coastal waters as established if these concentrations pose a risk to ecosystem health**. We did not assess harbour associated pollution. From literature we established that three main types of contaminants are emitted by the dredging ships: **copper and tributyltin leaching** from the ship's hull, **zinc** released from the sacrificial **anodes** used to prevent corrosion and a mixture of contaminants released via the air and resulting from the **combustion of fossil fuels** (air pollution). Although extensively explored (see progress report 2003-2004), the latter was not further developed in this project as (1) there were no quantitative data (as a function of distance traveled) available on the type and concentration of the emitted air pollutants and (2) the effects of this type of local contribution of this source to the overall potential air pollution at sea are indistinguishable form transboundary and land-borne sources. For the two former contaminants identified (local) risk assessments and risk simulations were performed to evaluate the contribution to the potential risk to the health of the marine ecosystem in Belgian coastal waters.

The **risk assessment procedures applied in this project are in accordance with EU requirements** and described in detail in the EU technical guidance document. For clarity this methodology is briefly described hereunder. In a first step the Predicted No Effect Concentration for the marine environment ($PNEC_{marine}$) is established. This is done through the use of acute and chronic toxicity data for marine organisms. The PNEC may be calculated using an assessment factors or statistical extrapolation models, both of which account for degree of uncertainty in extrapolation from test data to the real environment. In a second step the Predicted Environmental Concentration (PEC) for the selected toxicants is calculated/estimated. In this project the PECs in the coastal waters resulting from extraction and shrimp fishing associated shipping was calculated using a modified version of the computer model MAMPEC (see below). This model calculates the contaminant emissions from the vessels in combination with chemical speciation. The last step in the risk assessment procedure is to evaluate the possible risks by comparing the PEC and PNEC. Its should be noted that extensive simulations of possible PEC values, depending on shipping scenario's, were performed.

Based on an extensive literature review and recently performed EU risk assessments of Cu and Zn, a PNEC for both the sediment and pelagic compartment of the marine environment was established. A PNEC should be viewed as that concentration (or lower) at which no long-term adverse effects on marine biota are expected. The PNEC for Cu for example is based on ecotoxicity data of 19 species of marine algae, 11 species of marine invertebrates and one marine fish species. A graphical representation of the sensitivity distribution of these species is given in Fig. 2. For metals and other natural substances one needs to consider that anthropogenic and natural sources contribute to the environmental concentration of the metal. Considering the natural background it was, using statistical extrapolation models, calculated that the **PNECtotal$_{\text{, marine water}}$ is 0.3 µg Cu/l**[1] **A similar approach was to derive the PNEC for the sediment compartment, a value of 79.5 mg Cu/kg dw** was derived and used in this study. It should be noted that because of the lack ecotoxicity data with benthic species, this PNEC was derived from tests with freshwater benthic species. It should be stressed that for both compartments the metal bioavailability may change as a function of environmental characteristics. In the present project we assumed the worst case scenario: i.e. the total metal concentration being bioavailable.

In general terms, the **PNECs for TBT was derived in a similar way and are 0.01 ng/l and 0.25 mg/ kg dw for the water and sediment compartment**, respectively. For Zn – again through the lack of sufficient marine toxicity data – **PNECs were based on freshwater data and were 15 µg/ and 78 mg/kg dw for these compartments**.

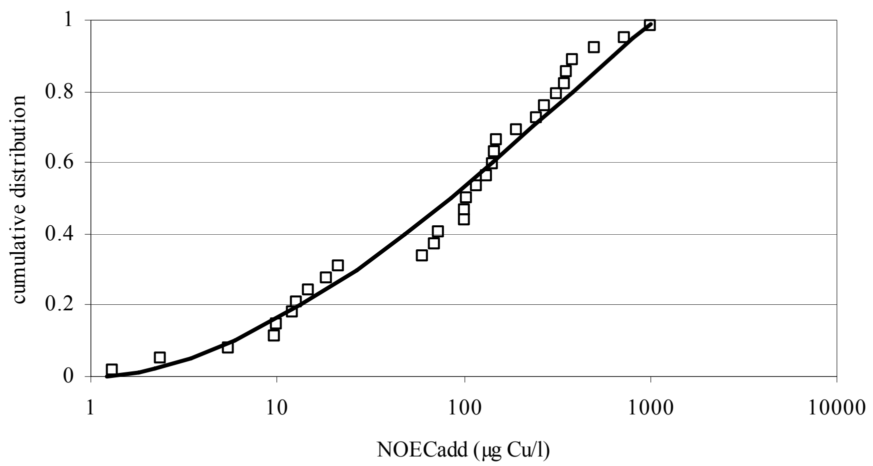

Fig. 2 Species sensitivity distribution for Cu (expressed as added Cu, *i.e*. without background concentrations) based on the chronic ecotoxicity data with marine species.

To derive the PEC in marine environments for active substances used in antifouling products in water column and sediment compartments the computer model MAM-PEC PEC (Marine anti-fouling model to predict environmental concentrations) is used. This model allows us to derive PEC values for a number of generalised **environmental scenarios** relevant to European Union waters, *i.e.*:

- yachting marina
- commercial harbour
- shipping Lane
- estuary, and
- open sea.

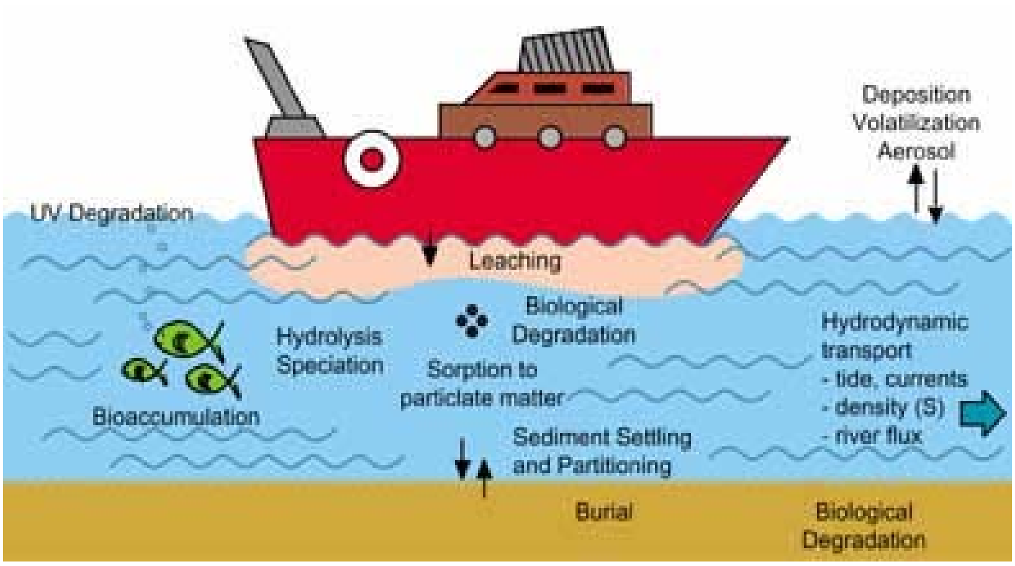

Fig. 3 Generalized scheme of the Marine anti-fouling model to predict environmental concentrations (MAMPEC) used in this project to predict environmental concentrations of chemicals leaching from ship hulls treated with antifouling products.

These standard environments can be adapted and customized scenarios can be introduced. The environmental scenarios have the flexibility to account for differences in: water temperature, salinity, pH, water movement (tide) and volume.

Emissions of antifouling products emissions are quantified as the product of a leaching rate (ug / cm2 / day) and the total underwater area treated with antifouling product (i.e. ship's hull). The leaching rate depends on the type of compound, characteristics and age of paint matrix and velocity of the ship. The total antifouling treated (underwater) area depends on shipping intensities, dimensions of the various categories of ships, and many other factors such as cargo load and residence time of the various ships.

After extensive literature searches and frequent contacts with the stakeholders we were able to collect the relevant data (i.e. for the Belgian coastal zone and the gravel extraction and transport vessel) required to run MAMPEC. Briefly the following data were compiled:

- product parameters: type of paint and antifouling agent
- ship parameters such as size, underwater hull area, number of active vessels per time unit, distance travelled/ vessel, routes, and average cruising speed;
- environmental parameters: salinity, temperature, wave speed and size.

A summary of the numerous simulations performed to derive the current and possible future emissions of Cu and TBT originating from the use of extraction and transport vessel in Belgian coastal water is given in Table 1

The following data were used: distances from the port of Zeebrugge to the eight Zagri extractions zones ranges between 14.5 and 53.5 km with an average of 36 km. Of the total of 12 (Ecolas nv. (2006): Environmental Impact Assessment for the extraction of marine aggregates on the BPNS. 194 pp. + Annexes) available extraction vessels only 3 are active on the BCP on a regular basis resulting in a maximum of 1 ship at berth and 1 ship moving at any time of the day (= normal operation). Simulations of the three scenario are presented here:

Scenario 1: normal operation and vessels active in only one extraction zone (minimal dilution).
Scenario 2: normal operation and vessels active in all 8 extraction zones (maximal dilution).
Scenario 3: Worst case, doubling activity (maximal emission)

The main parameters used in the calculations and reflecting the current situation in the Belgian coastal zone are:

Silt concentration	: 35.0	:g/m3
Particular organic carbon conc	: 1.0	:g Organic Carbon/m3
Dissolved organic carbon conc	: 2.0	:g/m3
Temperature	: 15.0	:oC
Salinity	: 3.40E+01	:s.e.
Depth well-mixed sediment top layer	: 1.00E-01	: m
Sediment density	: 1.000E+03	:kg/m3
Fraction organic carbon in sediment	: 3.00E-02	:kg/m3
Nett sedimentation velocity	: 2.00E-01	:m/d
pH	: 8.0	:(-)
Length shipping lane	: max 36000	:m

	: min 14500	:m
Width	: 1000	:m
	: 500	:m
Depth of harbor	: 10	:m
Flow	: 1	:m/s
Tidal height	: 1.5	:m
Tidal period	: 12.41	:h
Exchange surface	: 5000	:m2
Depth at harbour mouth	: 10	:m
Exchange volume in 1 tidal period	: 34000	:m3

Table 1. Predicted environmental concentrations of Cu and TBT in water and sediment originating from extraction and transport vessels (treated with antifouling products) operating in Belgian coastal waters.

	Contribution to the PEC of Cu in water phase (ng/l)	Contribution to the PEC of Cu in sediment phase (ng/g dw)	Contribution to the PEC of TBT in water phase (ng/l)	Contribution to the PEC of TBT in sediment phase (ng/g dw)
Scenario 1	6.77E-1	2.23	5.41E-2	2.91E-3
Scenario 2	5.99E-2	1.98E-1	4.78E-3	2.57E-4
Scenario 3	3.24	10.7	2.58E-1	1.39E-2

In the **risk characterisation phase** of the project, the PEC and PNECs for the two aquatic compartments were subsequently combined to assess the potential risk to the marine environment of Cu and TBT leaching from extraction and transport vessels operation in the Belgian coastal zone. The **PEC/PNEC ratio is used as an indicator of risk**:

- PEC/PNEC < 1 : so no adverse effects are anticipated
- PEC/PNEC = 1 : indicating that adverse effects may occur.
- PEC/PNEC > 1 : meaning that adverse effects are likely to occur.

A summary of the risk quotients calculated for Cu and the main scenarios studied is given in Table 2.

Table 2. Ecotoxicological indicator: risk quotients for Cu and TBT in water and sediment originating from extraction and transport vessels (treated with antifouling products) operating in Belgian coastal waters.

	RQ for Cu in water phase	RQ for Cu in sediment phase	RQ for TBT in water phase	RQ for TBT in sediment phase
Scenario 1	2.25E-3	2.80E-5	5.41	1.16E-5
Scenario 2	1.99E-4	2.49E-6	0.478	1.03E-6
Scenario 3	1.08E-2	1.35E4	25.8	5.56E-5

Conclusions:

- The additional risk to both benthic and pelagic communities posed by **copper released – through leaching – from extraction vessels can be considered very low to negligible**. Indeed the risk quotients indicate that the PEC are 2 to 4 and 4 to 6 orders of magnitude lower that the PNEC.
- Similarly, the additional risk posed by TBT to the benthic community can be classified as negligible, i.e. PECs were 5 to 6 orders of magnitude lower that the PNEC. For the **pelagic compartment, however, PEC/PNEC ratio's higher than 1** were obtained indicating a potential risk and thus adverse effects on species in this community. This is not surprising since it has been extensively demonstrated that the TBT concentrations measured in Belgian coastal water are close to those known to adverse affect marine organisms. Additional TBT specific effects have been observed in organisms collected in Belgian coastal waters. It should be noted that the use of TBT is now banned and environmental concentration are expected to decrease in the future.
- Considering that (1) the risk posed by both contaminants - released from extraction vessel activity – to the sediment compartment is very low to negligible, (2) that similar conclusions can be drawn for Cu in the water phase, and (3) that the TBT concentrations (leading to a potential risk) were expected, the consortium concluded that these risk indicators should **not be included in the Stella model as their impact will be very low**.

Next to the chemicals leaching for the ship's hull, we identified that zinc dissolving for the sacrificial anodes used to protect the ship hull against corrosion might be a possible source of additional contaminant concentrations in the study area.

From literature we estimated that for the three vessels that are active on the BCP on a regular base, a total amount of 480 kg Zn is sacrificed per year.

Table 3. Predicted environmental concentrations of Zn in water and sediment originating from extraction and transport vessels (with sacrificial anodes) operating in Belgian coastal water

	Contribution to the PEC of Zn in water phase (ng/l)	Contribution to the PEC of Zn in sediment phase (ng/g dw)
Scenario 1	2.79	16.1
Scenario 2	1.73	10.0

For both compartments the PECs obtained for Zn originating from sacrificial anodes are at least 4 orders of magnitude lower that the PNEC, indicating that the additional risk posed by this source is very low.

2.3 Shrimp fisheries: selection and evaluation of potential ecotoxicological indicators associated with the fishing vessels

This part of the project used the same methods (cf. above) to assess the potential impact of contaminants released from shrimp fishery vessels on water and sediment biota.

From (grey) literature and consultation with the stakeholders we were able to collect the relevant data (i.e. for the Belgian coastal zone and the shrimp vessels) required to make estimations on the contaminant quantities and resulting concentrations of contaminants emitted from this type of activity. A summary of the numerous simulations performed to derive the current and possible future emissions of Cu and TBT originating from the activities of shrimp vessel in Belgian coastal water is given in Table 4
On average approximately 8 vessels are fishing shrimp at any time of the day. The following scenarios were assessed:

Scenario 1: normal operation and vessels active in limited fishing zone (minimal dilution).

Scenario 2: normal operation and vessels active in a larger fishing zone (maximal dilution).
Scenario 3: Worst case, doubling activity (maximal emission)

Predicted environmental concentrations of Cu and TBT in water and sediment originating from shrimp vessels (treated with antifouling products) operating in Belgian coastal waters.

Table 4. Predicted environmental concentrations of Cu and TBT in water and sediment originating from shrimp vessels (treated with antifouling products) operating in Belgian coastal waters.

	Contribution to the PEC of Cu in water phase (ng/l)	Contribution to the PEC of Cu in sediment phase (ng/g dw)	Contribution to the PEC of TBT in water phase (ng/l)	Contribution to the PEC of TBT in sediment phase (ng/g dw)
Scenario 1	2.85E-2	9.42E-2	1.66E-2	8.92E-4
Scenario 2	2.16E-2	7.12E-2	1.25E-2	6.71E-4
Scenario 3	4.16E-1	1.37	3.32E-2	1.78E-3

As for the sand and gravel extraction vessels, a summary of the risk quotients calculated for the main scenarios studied for the shrimp vessel is given in Table 5.

Table 5. Ecotoxicological indicator: risk quotients for Cu and TBT in water and sediment originating from shrimp vessels (treated with antifouling products) operating in Belgian coastal waters.

	RQ for Cu in water phase	RQ for Cu in sediment phase	RQ for TBT in water phase	RQ for TBT in sediment phase
Scenario 1	8.60E-5	1.12E-7	1.66	3.57E-6
Scenario 2	7.2E-5	9.12E-8	1.25	2.68E-7
Scenario 3	1.38E-3	1.75E-5	3.32	7.12E-5

Conclusions:

- **In general the additional (or absence of) risks occurring from Cu and TBT releases due to shrimp fisheries are similar to those observed for the gravel extraction vessel**. I.e. risks are very low to negligible for both contaminants and compartments, except for TBT in the pelagic compartment for which a potential additional was identified.
- Like for the gravel extraction vessel activity, the research consortium deemed that the inclusion of these risk indicators on Stella was not needed.

3 GENERAL CONCLUSIONS

This sub-project aimed at the **selection and development of relevant ecotoxicological indicators for identifying and quantifying the impact of two human activities in the Belgian part of the North Sea** (fisheries, sand- and gravel extraction and resulting emission of contaminants). After extensive literature searches and consulting with stakeholders **a number of potential physical and chemical stressors were identified and their potential impact was evaluated**. Because of the lack of relevant quantitative data for some stressors only a qualitative assessment could be made. **Quantitative ecotoxicological indicators were developed for shipping activity** (of extraction and fishing vessels) using the risk assessment paradigm. In general (except TBT in water phase) the risk indicators showed that the impact of stressors caused by the studied two human activities **had very little to no impact on the ecological status of the studied area**. As such, the consortium partners concluded that these indicators should not be included in the Stella model.