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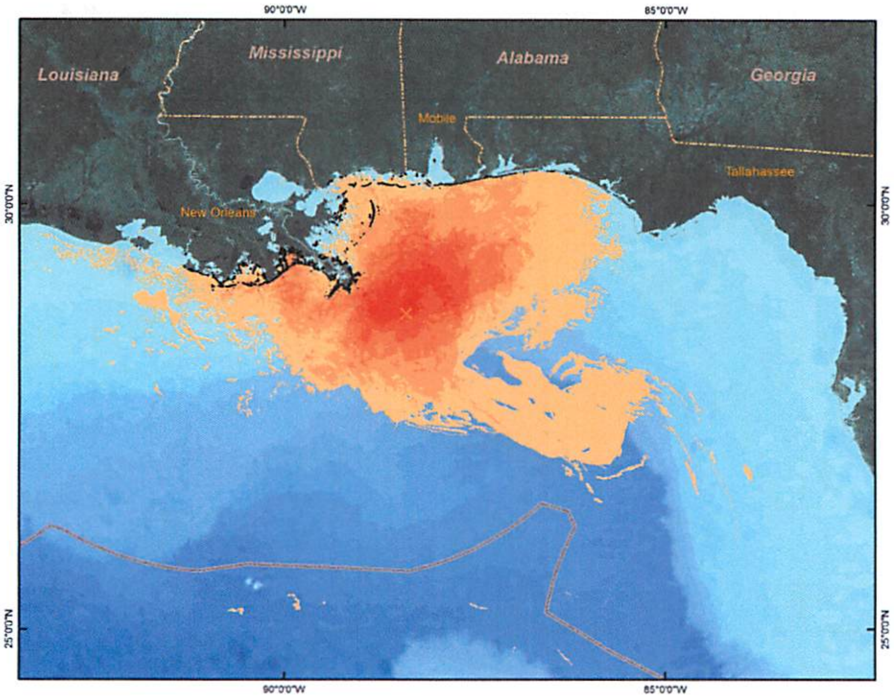
DIVERSITY – Supporting the CBD

DIVERSITY

Deepwater Horizon Oil Spill Spatial Chronology and Habitat Interaction Mapping



Deliverable D4

Summary Report

Issue 1.0

ESA Contract Change notice 4200020096 to the

ESA DUE Project DIVERSITY – Supporting the CBD (20009/06/I-EC)

Document Release Sheet

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TABLE OF CONTENTS

List of Figures

List of Tables

1 EXECUTIVE SUMMARY

On April 20, 2010, catastrophe struck the Gulf of Mexico with the explosion and sinking of BP's Deepwater Horizon oil rig, which killed 11 crew members and left the drilling hole open. Crude oil has been expelled, polluting the marine and onshore environment, destroying many habitats of large natural and economic value throughout the Gulf of Mexico. On July 15, 2010, the drilling hole was initially shut by sealing it with a cap. On September 19, 2010, a relief well was successfully completed by intersecting and cementing the original drilling hole, which was then reported to be effectively closed down. Meanwhile the controversy over the use of dispersants and the fate of the oil in the Gulf has made clear that monitoring of the oil spill dynamics is needed as well as an assessment of its interaction with natural habitats.

The dynamic nature of the BP oil spill due to the changing marine environment is a huge challenge for management authorities, institutions involved in habitat protection as well as a range of communities – from hotel operators to fishermen to local community leaders. The Gulf oil spill situation is continuously evolving, and so are the data and information needs that are addressed in this project by the use of satellite imagery.

The *1planet1ocean* programme (http://www.1planet1ocean.org) of *The Ocean Foundation* (http://www.TheOceanFoundation.org) is exploring, restoring and sustaining oceans through strong international partnerships, offering solutions to pressing ocean related problems. The focus of *The Ocean Foundation* is on habitat conservation and species protection. To respond to the natural catastrophe that struck the GOM with the explosion of the Deepwater Horizon platform and the resulting oil spill, *The Ocean Foundation* is requiring a **documentation of the geographical and temporal impact of the oil spill on a variety of coastal and marine habitats** throughout the north-eastern part of the Gulf of Mexico (GOM). Specifically, a standardized documentation in map and statistical form is needed featuring:

- weekly maps documenting the maximum extent of the oil spill and identifying site impacts of critical terrestrial and marine habitats of natural and economic value
- summary statistics and graphs quantifying area and sequences of oil interaction with habitats

Moreover, ESA requires comprehensive evaluation of the established results with regard to the touched areas in form of a report. In line with *The Ocean Foundation's* and ESA's requirements, this summary report (Deliverable 4) describes the production of a spatial chronology of the oil spill evolution and its site impacts, using state of the art Remote Sensing and GIS based Spatial Analysis tools. This summary report lays the foundation for dedicated communication material in form of an animated web story and a brochure, summarizing the findings of the spatial chronology of the Deepwater Horizon accident, which will be presented to the public at the 10th meeting of the Conference of the Parties to the Convention on Biological Diversity in Nagoya, 18 to 29 October 2010.

2 BACKGROUND OF THE DOCUMENT

This summary report (D4) provides a comprehensive evaluation of the Deepwater Horizon Oil Spill Spatial Chronology and its interaction with coastal and marine habitats. It is delivered within the formal contract change notice "***Deepwater Horizon Oil Spill Spatial Chronology and Habitat Interaction Mapping***" (ESA Contract 4200020096) immediate action project to the ESA DUE project "DIVERSITY – Supporting the CBD" (ESA Contract 20096/06/I-EC).

2.1 CONTENT OF THE DOCUMENT

In ***Chapter 1*** the background of the project is explained in an executive summary.

Chapter 2 provides an overview on the background and content of the document (this chapter). Furthermore, related documents serving as an input and an output are listed (Chapter 2.2).

Chapter 3 provides an overview on the study area and the employed data sets.

In ***Chapter 4*** a technical overview of the products is provided, with focus on a detailed method description.

Chapter 5 shows the results of the oil spill mapping and their interaction with various habitats.

Chapter 6 discusses the input data and results, highlights the added value of this study and provides an outlook.

2.2 RELATED DOCUMENTS

2.2.1 Input

Overview of former documents / deliverables acting as inputs to this document.

Document ID	Descriptor
ESA_GeoVille_CLS_GOM_OilSpillMapping_Proposal_I1.pdf	Technical and Financial Proposal, submitted by GeoVille and CLS to ESA, dated 15/07/2010
ESA CCN to Contract 4200020096	CCN to project "DIVERSITY – Supporting the CBD", provided by ESA, dated 11/08/2010
DeepWater Horizon D1	User requirements, dated 25/08/2010
DeepWater Horizon D2	Service definition plan, dated 31/08/2010
DeepWater Horizon D3	Mapping products, dated 24/09/2010

2.2.2 Output

Overview of other deliverables for which this document is an input.

Document ID	Descriptor
DeepWater Horizon D5	One High Resolution Hotspot Impact Assessment

3 STUDY AREA AND DATA SETS

3.1 STUDY AREA

The spatial extent of the oil spill habitat interaction analysis produced by GeoVille is the entire north-eastern Gulf of Mexico (GOM) (30.83N 94.28W, 22.50N 80.12W) as depicted in Figure 1.

The spatial extent of the Atlantic Bluefin Tuna (ABFT) spawning ground simulation and oil spill impact produced by CLS is performed for the entire Gulf of Mexico. The final product is presented in 0.25°resolution.

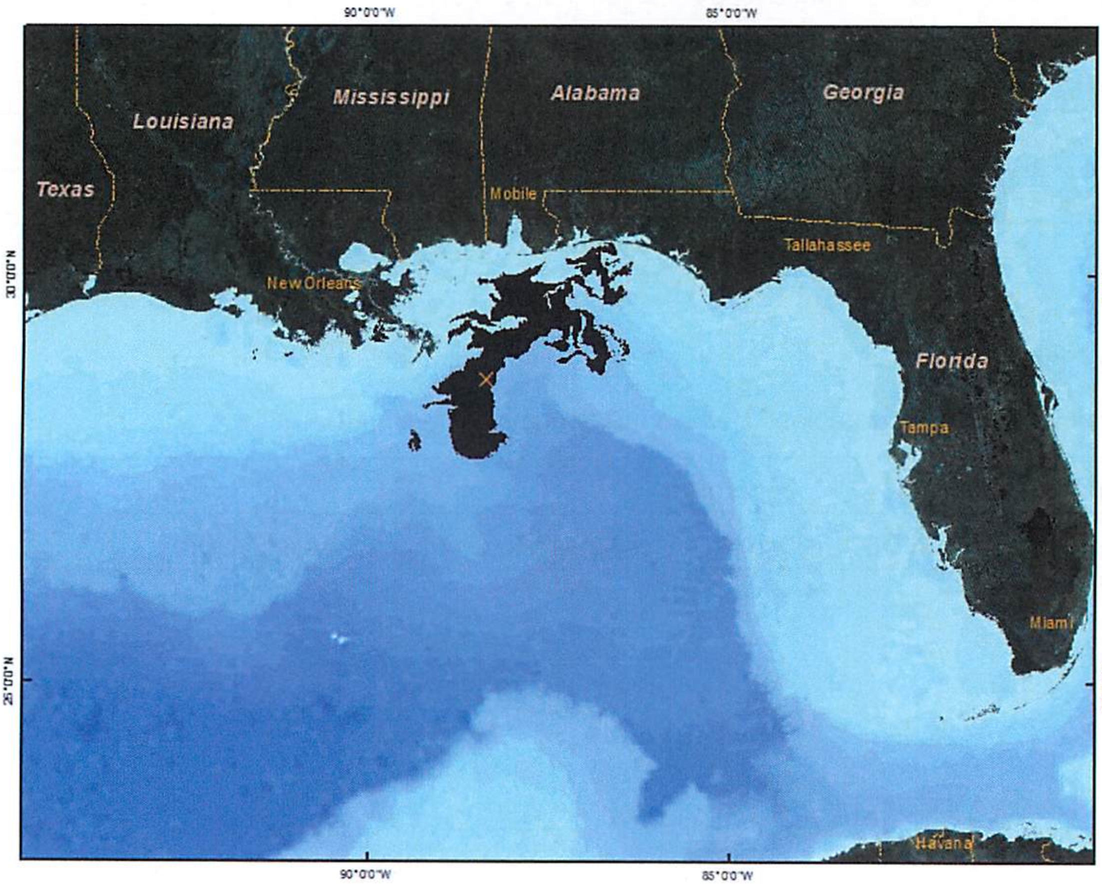


Figure 1. Study area in north-eastern GOM displaying the daily composite map of the oil spill extent on 16th of June 2010.

3.2 DATA SETS

This section lists the input data used for the generation of the respective products. The assessment of the spatial chronology of the Deepwater Horizon accident integrates a variety of geo-information based on the following data sources:

- Satellite based daily oil spill delineations available through the NOAA NESDIS Satellite Analysis Branch (cf. chapter 3.2.1) that are complemented with oil spill delineations derived through ENVISAT MERIS and ASAR scenes, provided by ESA's EOLi-SA (cf. chapter 3.2.2).
- Publicly available GIS map data on
  - Land cover in the GOM, including GlobCover (cf. chapter 3.2.3.1) and NOAA Gulf coast land cover (cf. chapter 3.2.3.2)
  - Turtle habitat maps available through SWOT (http://seaturtlestatus.org/; cf. chapter 3.2.3.3)
  - Map background data from NOAA's Coastal Data Development Center (cf. chapter 3.2.3.4)
    - cities / urban areas
    - administrative boundaries
    - shoreline
    - bathymetry
    - exclusive economic zone (EEZ)
- Data Sets for ABFT habitat impact mapping (cf. chapter 3.2.4)
  - Ocean temperature and velocity profiles needed to force the ABFT habitat model are obtained from the from the MERCATOR operational oceanography centre. Use is made of the outputs of the PSY3v2 version of the MERCATOR global ocean model (http://www.mercator-ocean.fr/). This model has a horizontal resolution of 0.25° and assimilates sea surface height data from ENVISAT and JASON radar altimeters.
  - Primary production (NPP) estimates are obtained from satellite-derived ocean colour measurements and Photosynthetically Available Radiation (PAR) fields. Ocean colour data come from the ESA-MERIS and NASA-MODIS visible radiometers. PAR data are derived from ECMWF analyses of the downward solar flux at the surface.

3.2.1 Daily Oil Spill delineations

Daily composite maps of oil spill extents mapped from various EO Data (MODIS, RADARSAT, Advanced Land Observation Satellite, TerraSAR-X and SPOT) are available through NOAA's NESDIS Satellite Analysis Branch[1] in support of response and mitigation efforts related to the oil spill in the Gulf of Mexico. The extent of the trajectories is verified by weekly NOAA aerial surveys and corrected where necessary. Figure 1 displays the daily composite map of the oil spill extent on 16th of June 2010.

3.2.2 Satellite data

When oil spill delineations were not available, GeoVille used archived ESA radar and optical satellite data to generate custom oil spill extent delineations. In total 12 ENVISAT ASAR and MERIS FRS (Level1&2) scenes acquired over North America were obtained on 26th August 2010 via ESA's EOLi-SA (Table 1).

The following ***ENVISAT ASAR Wide Swath and MERIS FRS*** scenes are employed:

Table 1. ENVISAT ASAR and MERIS FRS scenes obtained via ESA's EOLi-SA.

Id	Mission	Sensor	Product	Date
ENVISAT ASAR				
1	ENVISAT-1	ASAR/WS	ASA_WS__0P	26.04.2010 15:58
2	ENVISAT-1	ASAR/WS	ASA_WS__0P	29.04.2010 03:45
3	ENVISAT-1	ASAR/WS	ASA_WS__0P	29.04.2010 16:04
4	ENVISAT-1	ASAR/WS	ASA_WS__0P	02.05.2010 03:51
5	ENVISAT-1	ASAR/WS	ASA_WS__0P	09.05.2010 15:50
6	ENVISAT-1	ASAR/WS	ASA_WS__0P	12.05.2010 15:55
7	ENVISAT-1	ASAR/WS	ASA_WS__0P	18.05.2010 03:48
ENVISAT MERIS				
8	ENVISAT-1	MERIS	MER_FR__0P	22.04.2010 16:23
9	ENVISAT-1	MERIS	MER_FR__0P	26.04.2010 15:58
10	ENVISAT-1	MERIS	MER_FR__0P	29.04.2010 16:04
11	ENVISAT-1	MERIS	MER_FR__0P	12.05.2010 15:55
12	ENVISAT-1	MERIS	MER_FR__0P	16.06.2010 15:55

[1] ftp://satepsanone.nesdis.noaa.gov/OMS/disasters/DeepwaterHorizon/composites/2010/

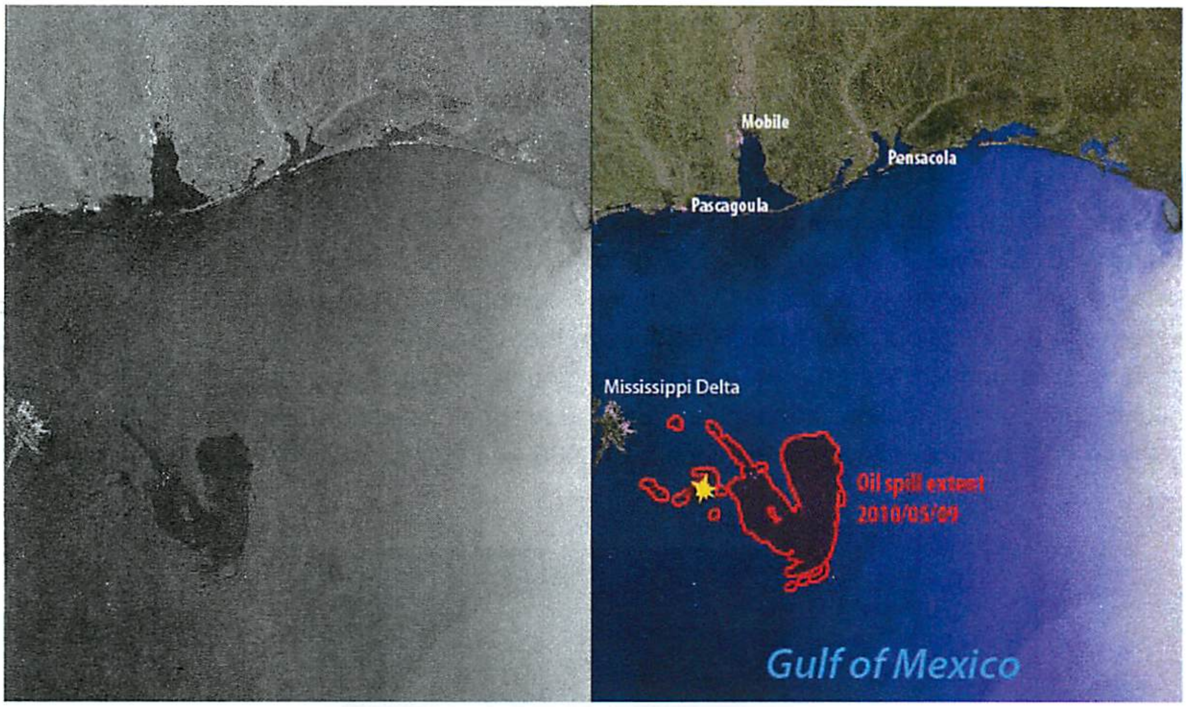


Figure 2. ENVISAT ASAR scene of 9th May 2010 and the derived oil spill extent map.

Figure 3. ENVISAT MERIS scene of 29th April 2010, displaying the oil spill in the GOM.

3.2.3 Data sets for GIS Base Map and Habitats

3.2.3.1 GlobCover

GlobCover is an ESA initiative, which began in 2005 in partnership with JRC, EEA, FAO, UNEP, GOFC-GOLD and IGBP. The GlobCover project has developed a service capable of delivering global composites and land cover maps using as input observations from the 300m MERIS sensor on board the ENVISAT satellite mission (http://ionia1.esrin.esa.int/). Currently, ESA makes available a set of products covering 2 periods: December 2004 - June 2006 and January - December 2009. The GlobCover MERIS composite that is used in this study as a background for the base map is derived from the pre-processing module of GlobCover, which includes a set of corrections as cloud detection, atmospheric correction, geolocalisation and re-mapping. For this study the annual surface reflectance composite of 2009 was employed as displayed in Figure 4.

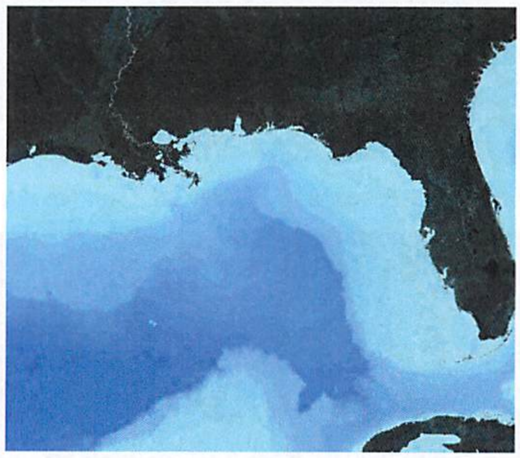


Figure 4. GlobCover Envisat MERIS mosaic over the GOM.

3.2.3.2 Gulf Coast Land Cover

The NOAA Coastal Services Center created land cover and change data for the Gulf of Mexico region according to Coastal Change Analysis Program (C-CAP) standards (http://www.csc.noaa.gov/crs/lca/gulfcoast.html). Products include land cover for 1996, 2001, and 2005, as well as change products that identify the changes between these dates. Land cover data were produced for the U.S. Gulf of Mexico coastal region using 30 meter resolution Landsat Thematic Mapper and Landsat Enhanced Thematic Mapper satellite imagery. For this study, the most recent Gulf Coast Land Cover map of 2005 was employed, which contains the land cover classes that are displayed in Figure 5. To streamline the analyses related classes were joined for the statistical analyses.

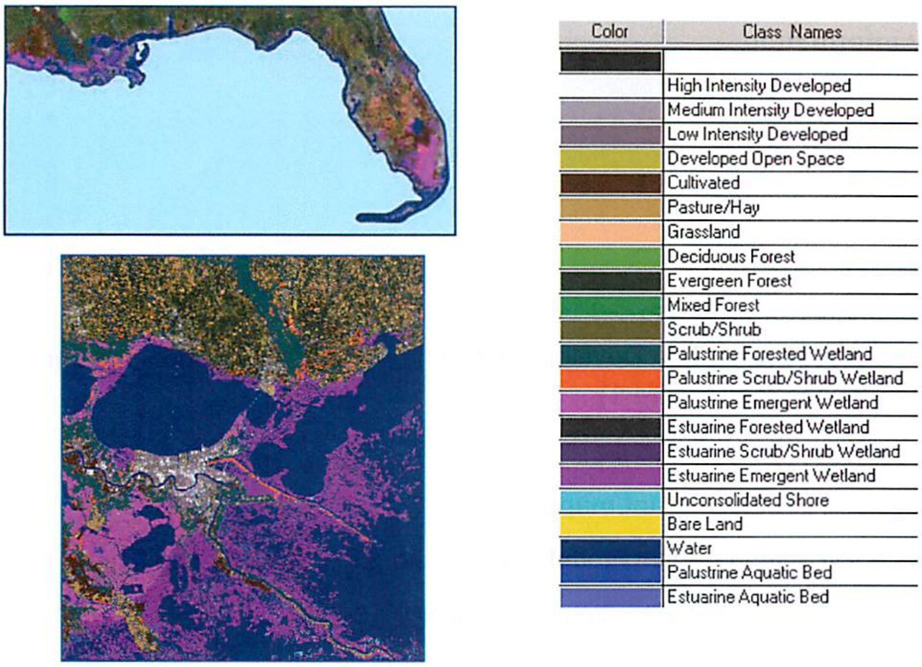


Figure 5. Gulf Coast Land Cover dataset.

3.2.3.3 Sea turtle habitats

Sea turtle habitats for the GOM were obtained from the SWOT database[2] (http://seaturtlestatus.org/). SWOT is a partnership among Conservation International (CI), the IUCN Marine Turtle Specialist Group (MTSG), Duke University's OBIS-SEAMAP[3], and an ever-growing international team of local organizations, scientists and conservationists. Together, this powerful group—the SWOT Team—seeks to create a permanent global network of specialists working to accelerate the conservation of sea turtles and their habitats, pooling and synthesizing data, and regularly sharing the information with audiences who can make a difference. Born out of the necessity to generate a global perspective of sea turtle status able to inform strategic conservation action, SWOT is the first and only effort of its kind. Information about sea turtle nesting beaches was obtained for the entire shoreline of the GOM. Turtle nesting sites affected by oil landfall were identified in Florida, Alabama and Mississippi. The concerned species are Caretta caretta and Chelonia mydas.

[2] *SWOT Report - State of the World's Sea Turtles*, vol. I (2006); *SWOT Report - State of the World's Sea Turtles*, vol. II (2006); *SWOT Report - State of the World's Sea Turtles*, vol. III (2008); *SWOT Report - State of the World's Sea Turtles*, vol. IV (2009).
[3] Read, A.J., Halpin, P.N., Crowder, L.B., Best, B.D., Fujioka, E.(Editors). 2008. OBIS-SEAMAP: mapping marine mammals, birds and turtles. World Wide Web electronic publication. http://seamap.env.duke.edu, Accessed on September 12, 2008.

3.2.3.4 Ancillary information

Ancillary information about

- ✓ cities / urban area
- ✓ administrative boundaries
- ✓ shoreline
- ✓ bathymetry
- ✓ exclusive economic zone (EEZ)

were obtained from NOAA's Coastal Data Development Center (http://www.ncddc.noaa.gov/) and used for the base map creation (see Figure 1).

3.2.4 Data Sets for ABFT habitat impact mapping

Running the CLS SEAPODYM tuna habitat model requires the 2 following forcing fields:

- Ocean temperature and current velocities in the layer 0-1000 m
- Primary production (NPP) and associated euphotic depth

For the 2010 January-June period, temperature and currents are provided by a numerical ocean model (MERCATOR model at resolution 0.25°) that assimilates SST and sea surface height data from ENVISAT and JASON radar altimeters (data were delivered on August 13, 2010). For 2002-2009, the GLORYS1V1 reanalysis is used. It was produced with the same ocean general circulation model and assimilation method. It allowed a correction of the global surface heat flux, realistic location and intensity of surface currents, with eddy field variability in good agreement with altimetric data. Surface eddy kinetic energy compares very well with observations. Analysis of tropical SST and SLA shows very realistic equatorial wave propagations at all wavelength (intensity, phase and phase velocity). Subsurface thermohaline structure also exhibits a mean state and annual to interannual variability in good agreement with observations.

NPP (depth-integrated primary production) estimates are derived from satellite-derived ocean colour measurements and Photosynthetically Available Radiation (PAR) fields using the VGPM Behrenfeld-Falkowski model[4]. For 2002-2009, ocean color data come from the SeaWiFS satellite (www.science.oregonstate.edu/ocean.productivity/). For 2010 (January to June 2010), NPP was computed at CLS using the freely available MODIS and MERIS data. PAR data derived from ECMWF analyses of the downward solar flux at the surface. These data have been interpolated on the grid of the model. Thanks to the data assimilation in the MERCATOR model, a very good match is observed between physics and primary production at the mesoscale level (Figure 6).

[4] Behrenfeld M. J., and P. G. Falkowski, 1997: Photosynthetic rates derived from satellite-based chlorophyll concentration, Limnol. Oceanogr., 42, 1– 20.

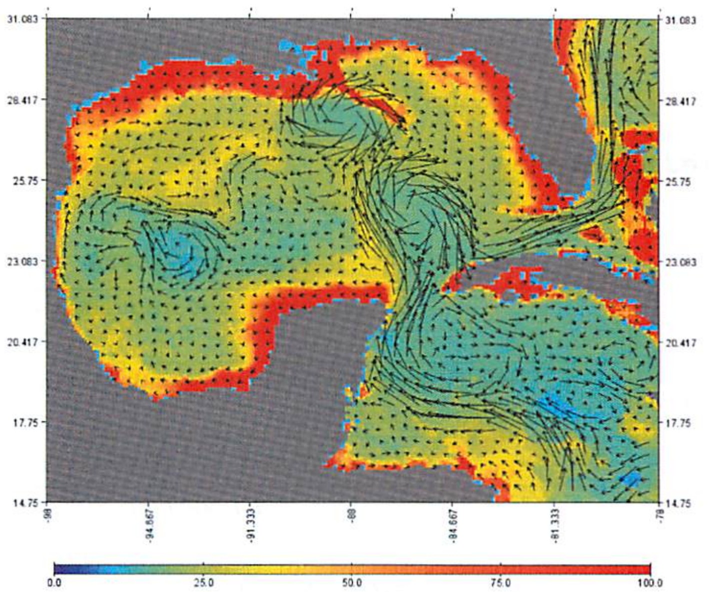


Figure 6. Snapshots showing the SeaWiFS-derived primary production computed following the model of Behrenfeld and Falkowsky (1997) with superimposed surface currents predicted in MERCATOR GLORYS reanalysis.

4 METHODS

4.1 OIL SPILL EXTENT AND FREQUENCY MAPS

4.1.1 Technical product overview

Product description	***1 (Deliverable 3)*** ***Producer: GeoVille*** ***Oil spill extent and frequency maps***
Temporal Requirement	• *Weekly coverage (Monday – Sunday) between 20th of April and 29th of August 2010*
Spatial Coverage	*GOM (see 3.1., Study area)*
Spatial Requirement	*1:1.000.000*
Content	• *19 maps showing the cumulative weekly extent of the daily maximum extent of the oil spill per calendar week* • *One summary frequency map indicating the areas that were most impacted between 20th of April and 29th of August 2010*
Delivery Format	*Shapefiles* *GeoTiffs* *Printable Maps (image and pdf format)*
Coordinate System / Projection	*WGS84 (Lat/Lon)*
Input Data	• *ENVISAT MERIS and ASAR scenes provided by ESA (accessed via the EOLISA archive)* • *Daily composite maps of oil spill extent mapped from various EO data available through NOAA (ftp://satepsanone.nesdis.noaa.gov/OMS/disasters/DeepwaterHorizon/composites/2010/)* • *Various GIS data for the creation of annotated maps (administrative boundaries, bathymetry etc.)*
Methodology	• *Existing daily composite oil spill extent shapefiles are assembled to weekly composite maps (Monday – Sunday) by calculating the maximum extent per week.* • *For missing dates the oil spill extent is mapped from ENVISAT MERIS and ASAR scenes and included in the weekly extent maps.* • *The summary frequency map is the result of a combination of all weekly oil spill extent maps depicting the frequency of oil spill observations in a location.*
Validation	• *Plausibility control of oil spill delineations by using available EO imagery and web resources*

4.1.2 Method description

Cumulative weekly oil spill extents

Daily composite maps of oil spill extent mapped from various EO data available through NOAA (ftp://satepsanone.nesdis.noaa.gov/OMS/disasters/DeepwaterHorizon/composites/2010/) were accumulated to weekly maps (Monday – Sunday) through a UNION tool. In this way, cumulative weekly oil spill delineations were derived for week 16 (19th April – 25th April 2010) to week 34 (23rd August – 29th August 2010). Week 34 contains just one oil spill delineation of 25th August 2010, as there was no more oil detectable on the satellite imagery afterwards.

For days when oil spill delineations were missing or not sufficiently accurate ENVISAT MERIS and ASAR scenes provided by ESA, which were accessed via the EOLISA archive, were employed to derive the oil spill extent. Mapping of the oil spill extent from radar satellite data benefits from the strong absorbance of the radar signal by the oil slick. In order to perform time series mapping, the radar images were adapted to each other by an image histogram matching algorithm. This resulted in comparable imagery with similar mean/standard deviation of the grey values.

The mapping algorithm performs then a semi-automated detection of the oil extent by 1) grey value thresholding (all grey values below a certain threshold a considered as potential oil) and low texture criteria (in radar data oil slicks are shown by a homogeneous smooth surface), thus identifying "seed areas" of the oil slick, and 2) applying spatial neighbourhood criteria (only areas connected or close to the seed areas are considered as being part of the oil slick).

The derived oil extents were visually checked for plausibility and remaining inconsistencies were eliminated. The remotely sensed oil spill extent allows deriving detailed information about the ocean surface covered by oil.

Summary frequency map

Based on the weekly oil spill extents the frequency of oil observations was calculated between 20th of April and 29th of August 2010 using an INTERSECT tool. The summary frequency map is thus the result of a combination of all cumulative weekly oil spill extent maps, identifying for each area how often it was covered by oil during the 19 weeks.

4.2 OIL SPILL INTERACTION WITH NATURAL HABITAT MAPS

4.2.1 Technical product overview

Product description	***2 (Deliverable 3)*** ***Producer: GeoVille***
	Oil spill interaction with natural habitat maps
Temporal Requirement	*Weekly coverage (Monday – Sunday) between 20th of April and 29th of August 2010*
Spatial Coverage	*GOM (see 3.1., Study area)*
Spatial Requirement	*1:1.000.000*
Content	• *19 cumulative weekly maps of oil spill interaction with natural habitats*
Delivery Format	*Shapefile, GeoTiff* *Printable Maps (image and pdf format)*
Coordinate System / Projection	*WGS84 (Lat/Lon)*
Input Data	• *Cumulative weekly oil spill extent maps based on cumulative daily extents (4.1)* • *Habitat information* ✓ *Gulf Coast Land Cover at 30 m resolution based on Landsat data available through NOAA Coastal Service Center (http://www.csc.noaa.gov/crs/lca/gulfcoast.html)* ✓ *Sea Turtle habitats Source: SWOT database[5] (http://seaturtlestatus.org/).* • *Various GIS data for the creation of annotated maps (administrative boundaries, MERIS GlobCover composite of 2009, bathymetry etc.)*
Methodology	• *GIS analysis techniques are employed to extract the interaction areas of the oil spill with various habitats.* • *Quantitative analyses are performed resulting in summary statistics and graphs showing the areas and sequences of oil contact with natural habitats.* • *Based on this assessment hot spot areas are identified (D5).*
Validation	• *Plausibility checking; quality of habitat interaction maps depending on accuracy of input habitat data*

[5] *SWOT Report - State of the World's Sea Turtles*, vol. I (2006); *SWOT Report - State of the World's Sea Turtles*, vol. II (2006); *SWOT Report - State of the World's Sea Turtles*, vol. III (2008); *SWOT Report - State of the World's Sea Turtles*, vol. IV (2009).

4.2.2 Method description

GIS analysis techniques were employed to extract the interaction areas of the oil spill with various habitats.
In a first step, buffered cumulative weekly maps were produced. That is, in order to factor in the geometric accuracy of the coarsest dataset used to delineate the daily cumulative oil spill area, we introduced a buffer of 170 meters, corresponding to the geometric accuracy of the MERIS data (170 ± 10 meters, Saunier et al. 2005 [6]).
In a second step, the buffered cumulative weekly maps were intersected with the Gulf Coast Land Cover, where a habitat was defined as a natural land cover class. This intersection provided all land cover polygons that were in contact with the oil spill land fall. These affected land cover polygons were then converted to lines, allowing for an identification of the length of those lines that were in contact with the ocean. In this way, the length of the shoreline affected by the oil spill was identified for each land cover class. The comparison to the total shoreline length allowed providing information about the percentage of affected habitat. The resulting GIS database provided the basis for the statistical analyses that were carried out for Louisiana, Mississippi, Alabama and Florida. For Florida, only the 5 western provinces (Escambia, Okaloosa, Walton, Santa Rosa, Bay, Gulf) that were affected by the oil spill were included.
Another habitat dataset that was intersected with the buffered cumulative weekly maps was the information about Sea turtle nesting sites obtained from the SWOT database (http://seaturtlestatus.org/). In this way, the frequency of weekly oil spill interactions with known Sea turtle nesting beaches in the northern GOM could be assessed.

4.3 MODELLED ABFT SPAWNING HABITAT

4.3.1 Technical product overview

Product description	***3 (Deliverable 3)*** ***Producer: CLS*** ***Modelled ABFT spawning habitat***
Temporal Requirement	*Weekly coverage from 20/04 to 30/06/2010*
Spatial Coverage	*Whole GOM*
Spatial Requirement	*Resolution of 0.25°*
Content	*Maps of normalized ABFT habitat favourability index*
Delivery Format	*Shapefile, GeoTiff* *Printable Maps (image and pdf form)*

[6] *Saunier, S., Goryl, P., Delwart, S., Ludovic, B., 2005, MERIS full resolution products, geometry aspects. http://www.gael.fr/eoqc/pdf/Saunier_MAVT06.pdf.*

Coordinate System / Projection	*WGS84 (Lat/Lon)*
Input Data	**Ocean topography** (ETOPO2) **For 2002-2009** **Ocean temperature and current velocities** in the layer 0-1000 m provided by GLORYS1v1 reanalysis from MERCATOR Ocean **Primary production (NPP)** based on SeaWiFS and MODIS available on ocean productivity web site: www.science.oregonstate.edu/ocean.productivity/ **For 2010** **Ocean temperature and current velocities** in the layer 0-1000 m provided by MERCATOR Ocean (outputs of the PSY3v2 ocean model) **Primary production (NPP)** computed at CLS using MODIS and MERIS ocean colour data and PAR data derived from ECMWF analyses of the downward solar flux at the ocean surface
Methodology	Habitats are computed from input fields using the SEAPODYM model described in Lehodey et al. (2008)[7] and simulated predicted dynamics of functional groups representing prey (Lower Trophic Level) and predators (Mid-Trophic Level) of larvae (Lehodey et al. 2010)[8]
Validation	• Coincidence of spawning habitat evolution in space and time with observed peaks of spawning in both the GOM and Mediterranean Sea (bibliographic knowledge). • Visual correlation with individual movements as inferred from satellite tagging (kindly from M. Lutcavage; LPRC, USA).

4.3.2 Method description

Interaction between spawning and environmental conditions

Various mechanisms in interaction with the oceanic environment have been proposed to explain the variability in larvae mortality and subsequent fluctuations in the recruitment of juvenile in the adult stock.

Temperature (sea surface temperature: SST) is clearly the first used oceanic variable when searching for a relationship between tuna spawning and environment. During its evolution each fish species has selected a temperature window either wide (eurytherm) or narrow (stenotherm), within which its physiological performances are optimal.

[7] *Lehodey, P., I. Senina and R. Murtugudde, 2008: A spatial ecosystem and population dynamics model (SEAPODYM) - Modelling of tuna and tuna-like populations. Prog. Oceanog., 78, 304-318.*

[8] *Lehodey P., Murtugudde R. and Senina I. (2010) Bridging the gap from ocean models to population dynamics of large marine predators: a model of mid-trophic functional groups. Progress in Oceanography.*

It is well admitted that all tuna spawn in SSTs above 24°C while for bluefin a temperature above 29°C seems a threshold maximum value. Thus, the optimal temperature window for larvae can be defined between the boundary values 24 and 29°C.

However when becoming large adult fish, tuna tend to prefer colder temperature and when they are coming for spawning in high temperature surface waters, they are likely exposed to thermal stress and need to thermo-regulate by diving in colder waters. Thus they likely need a minimum depth in **bathymetry** (e.g., 200 m).

Chlorophyll-a is another key variable that is usually investigated when searching for a spawning index because this is an index of biological productivity, available globally from satellite data since end of 1997. Primary production integrated over the vertical layers can be predicted from this variable and the PAR (Photosynthetically Active Radiation) using empirical approaches based on optical properties of water and a large global database of chlorophyll profiles (Morel 1988; Behrenfeld and Falkowsky 1997). Quickly after hatching, i.e. 2-3 days, tuna larvae start feeding on micro-zooplankton (e.g., copepod nauplii and copepodites), that itself feed on phytoplankton, so that there is a almost direct link between primary production and abundance of prey for early life stage of tuna larvae. However, after a few more days, (i.e., about 10 days), larvae shift to larger **zooplankton** organisms like copepods and eventually fish larvae. The coincidence of prey for larvae at the time of spawning is one of the major mechanisms, known as the match-mismatch mechanisms (Cushing 1975), that has been proposed to explain the variability in survival rates of larvae and the subsequent recruitment in the older cohorts of the population.

Oceanic currents are fundamental characteristics of the oceanic environment of larvae, especially pelagic species that are passively drifting with currents during the first day of life. When they are growing, juvenile fish move by their own with a velocity proportional to their size. However until they reach a significant size they are strongly influenced by mesoscale activity. It has been proposed that some fish species, especially bluefin, can have selected particular regions with mesoscale activity providing favorable zones of retention for larvae (Bakun 1996), e.g., with optimal temperature and sufficient food.

Finally, while starvation likely represents a major source of larvae mortality, the second is certainly predation. Eggs and fish larvae are prey of larger organisms that compose the **micronekton**.

Spawning index and larvae recruitment

We have combined the mechanisms of interaction with the environmental variables described above into a spawning index, i.e.:

- the definition of a spawning temperature window for an optimal growth,
- a minimum depth allowing large mature fish to dive and thermoregulate,
- the coincidence of spawning with presence or absence of food for larvae (match/mismatch),
- the coincidence of spawning with presence or absence of predators of larvae,
- the redistribution of larvae by the oceanic circulation with natural mortality related to new habitat.

The first mechanism is described using a Gaussian distribution $\Phi_0(T_0) = N(T_0^*, \sigma_0)$ with standard deviation σ_0 and optimal mean temperature T_0^*. The second mechanism is simply defined by a sigmoid function using topographic data (ETOPO2) and a minimum depth value (200 m). We modelled the food (zooplankton) and predators (micronekton) of larvae (Lehodey et al., 2010). The redistribution by currents leading to higher or lower mortality according to the retention in favorable habitat or the drift in unfavorable habitat is included in the treatment of the spatial dynamics using a system of Advection-Diffusion-Reaction equations (for details, see Lehodey et al. 2008 and Senina et al. 2008).

Finally, the spawning migration and seasonality is controlled through a switch between feeding and spawning index using seasonal change in day length (Lehodey et al. 2008).

Model parameterization

The timing and the peaks of spawning seasons are particularly useful to consider for the calibration of parameter values of the spawning habitat model. In the Mediterranean Sea, there is a clear propagation of the favourable spawning index starting in the eastern Mediterranean Sea in May and moving west with a peak in the Balearic region in June-July. In the Gulf of Mexico, the spawning season occur from end of March to June, with a peak in May. Time series of SST, primary production (P), zooplankton (Z), micronekton (F) and the ratio Z/F and P/F have been extracted from the geographic boxes corresponding to these different spawning grounds (Figure 7). Individual tracks of bluefin tagged by the Large Pelagic Research Center were used to control visually the movement of mature fish entering and exiting the GOM.

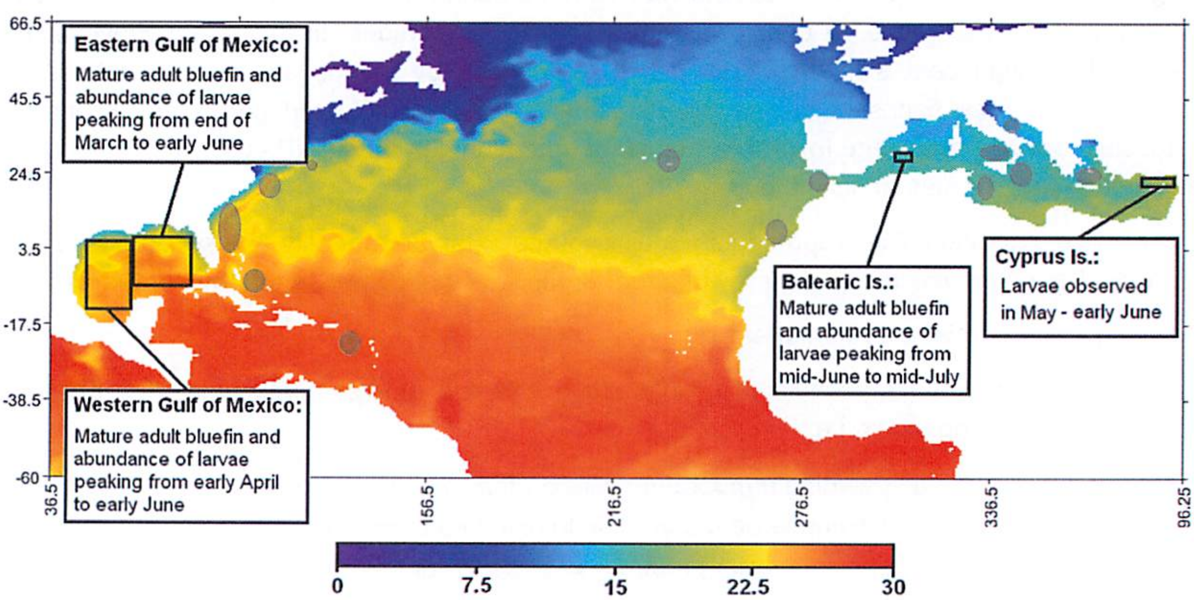


Figure 7. Sea surface temperature map (°C) at the date of June 30, 2010 showing the four geographical boxes used in analysis. The grey shaded areas indicate where mature spawning bluefin or bluefin larvae have been observed in addition to these four areas.

4.4 OIL SPILL INTERACTION WITH ABFT SPAWNING HABITAT

4.4.1 Technical product overview

Product description	***4 (Deliverable 4)*** ***Producer: CLS*** ***Oil spill interaction with ABFT spawning habitat***
Temporal Requirement	*Weekly coverage from 20/04 to 30/06/2010*
Spatial Coverage	*Whole GOM*
Spatial Requirement	*Resolution of 0.25°*
Content	• *10 maps of oil spill interaction with ABFT spawning habitat (maps jointly showing the extent of the oil spill and the ABFT spawning index* • *Time series showing the impact of oil spill on the habitat integrated over the GOM*
Delivery Format	*Shapefile, GeoTiff* *Printable Maps (image and pdf form)*
Coordinate System / Projection	*WGS84 (Lat/Lon)*
Input Data	*Maps of ABFT spawning habitat (product 4)* *Maps of oil spill extent (product 1)*
Methodology	*Simple superposition of two maps. Further numerical analysis is warranted to rigorously quantify impact of the spill on the habitats*
Validation	*Visual check of superimposed maps which have already been individually validated*

4.4.2 Method description

To measure the impact of the oil spill during the spawning season of bluefin, the spawning habitat was simulated using the parameterization achieved in previous analysis and for the first 6 months of 2010. The index was integrated over the spatial domain, i.e., the GOM using the resolution of 1/4° x 1day. The images of the oil spill were processed by Geoville and delivered in a shapefile format to CLS. They were converted into oil spill mask files on a high resolution grid of 2' with a value of 0 in all spatial cells where oil was observed for each corresponding week and a value of 1 in clean water. Then, when degrading the resolution to the one used for habitat modeling (1/4°), the mask value is replaced by the ratio between the sum of 0-cells and the total number of 2' cell in the ¼° cell, thus providing the ratio of polluted area by cell. The example of resulting mask is shown on Figure 8.

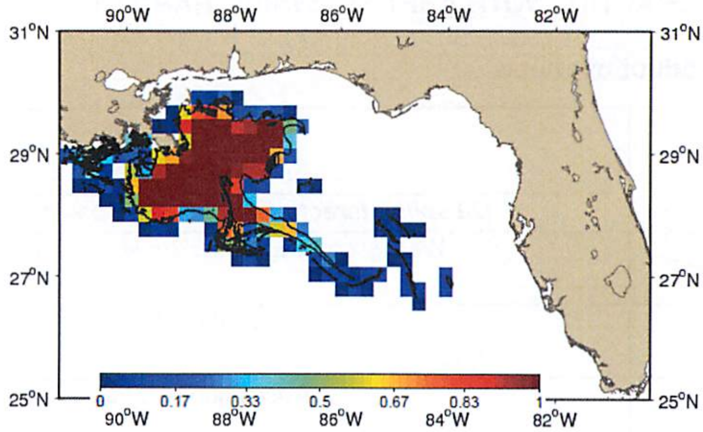


Figure 8. Example of oil spill mask, which was used in Seapodym to compute the impact of spawning habitat index.

Eggs and larvae of bluefin are associated to the surface layer during diurnal cycles, and thus cannot avoid the contact with oil at the surface. Considering that the contact with oil results in 100% mortality, the product of habitat value with the oil spill mask gives a new spawning habitat including the impact of oil spill. The resulting index including the effect of oil was again integrated over the GOM and compared to the previous one without pollution impact.

5 RESULTS

5.1 OIL SPILL EXTENT AND FREQUENCY MAPS

Based on the cumulative daily oil spill extents provided by NESDIS and the mapped daily extents from various ENVISAT ASAR or MERIS satellite images, cumulative weekly oil spill extent maps were derived by GIS overlay for each calendar week from Monday to Sunday. For dates when oil spill delineations were missing or not sufficiently accurate ENVISAT MERIS and ASAR scenes provided by ESA, which were accessed via the EOLISA archive, were employed to derive the oil spill extent. Figure 9 shows a daily oil spill extent of 18.5. 2010 as depicted by ENVISAT ASAR.

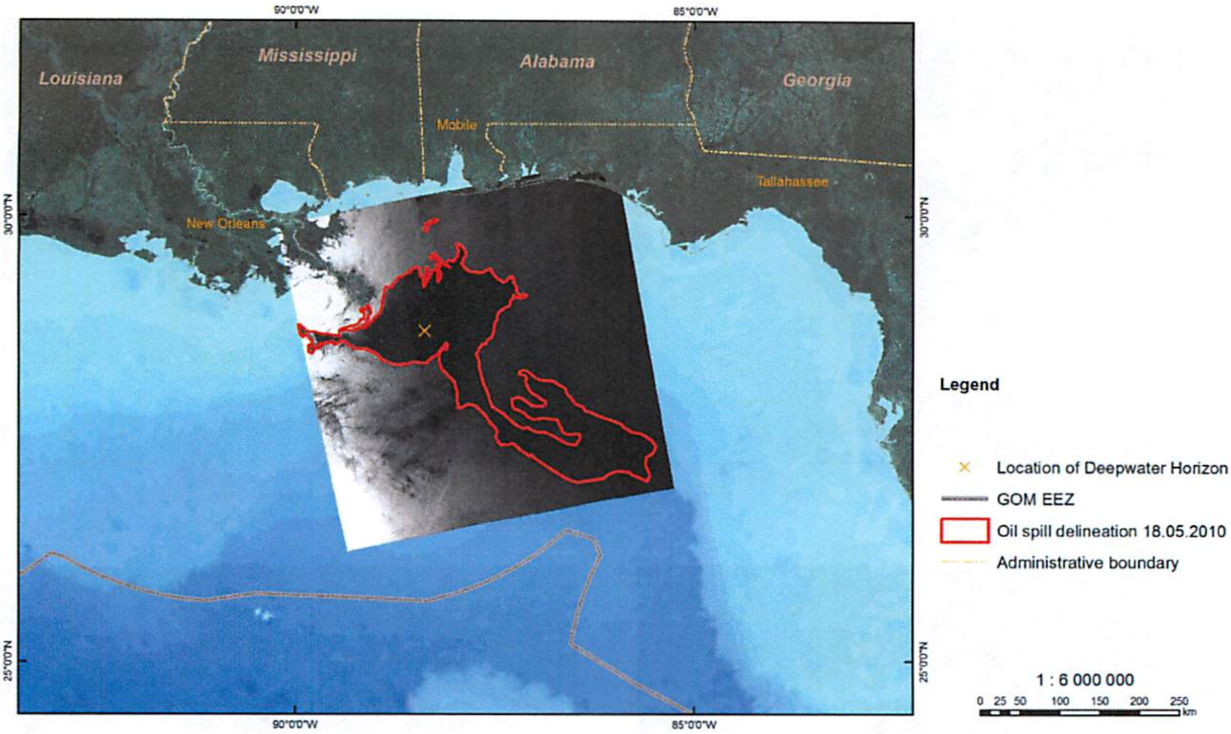
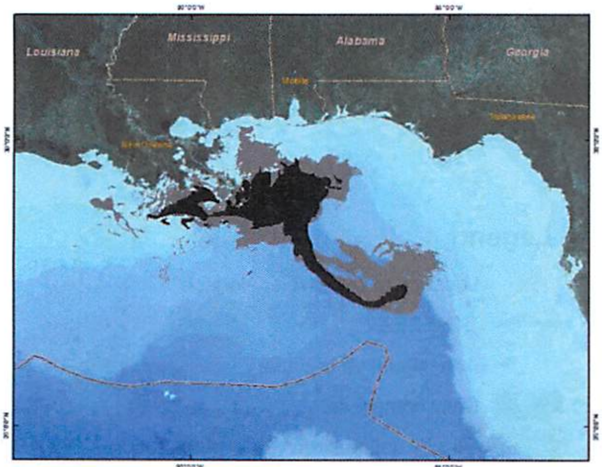
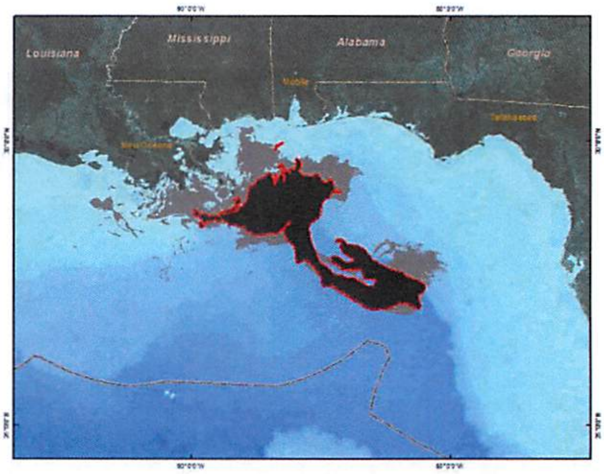


Figure 9. ENVISAT ASAR scene of 18.05.2010 used for mapping the oil spill extent.

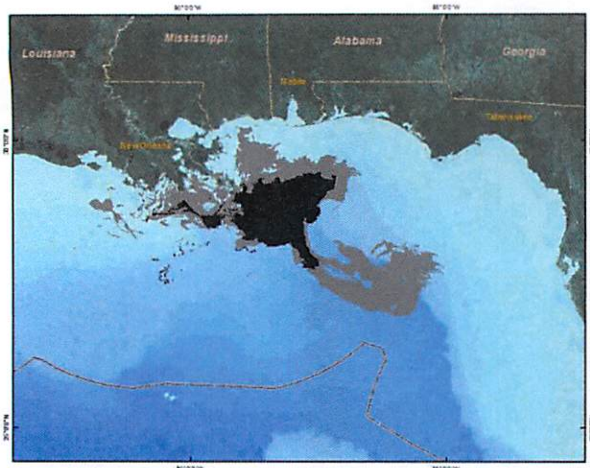
Figure 10 shows the derivation of the cumulative weekly oil spill extent for week 20 (17.05. – 23.05.2010), based on daily composite maps from NESDIS and the daily oil spill delineation derived from an ENVISAT ASAR scene of 18.05.2010.



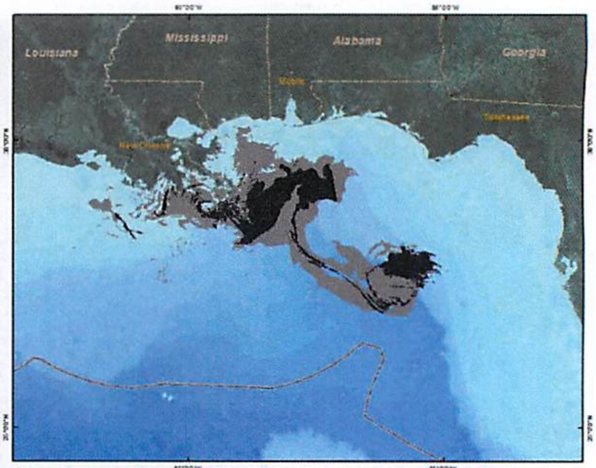
17.05. 2010



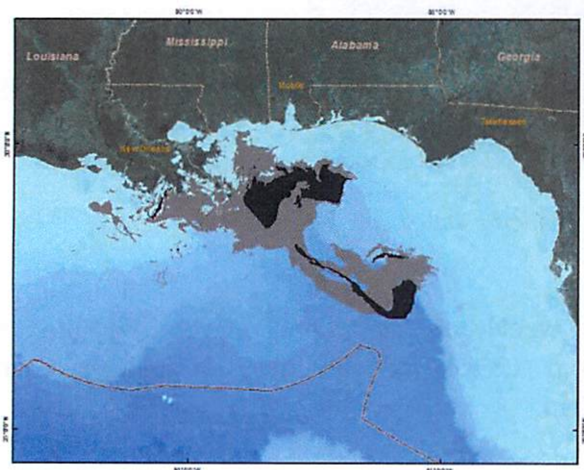
18.05. 2010



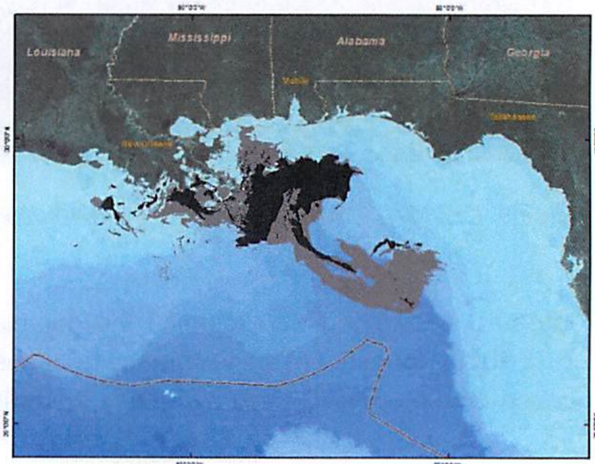
19.05.2010



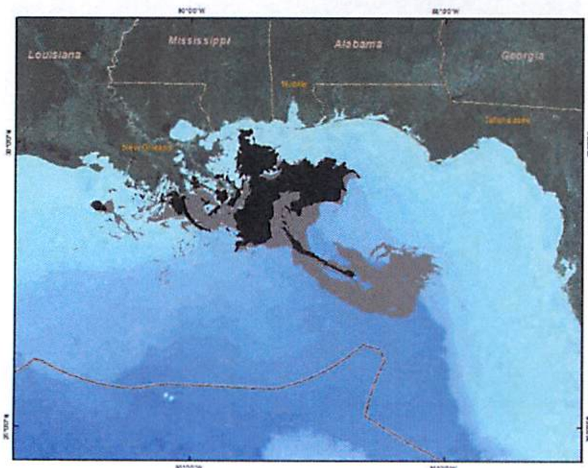
20.05.2010



21.05.2010



22.05.2010



23.05.2010

Legend

- Location of Deepwater Horizon
- GOM EEZ
- Administrative boundary
- Daily composite
- Oil spill delineation ASAR 18.05.2010
- Cumulative oil spill delineation (17.-23.05.2010)

Figure 10. Derivation of the cumulative weekly oil spill extent for week 20 (17. 05. – 23.05. 2010)

The results were 19 cumulative weekly oil spill extent maps from the week of the accident (week 16, 19.04. – 25.04.2010) to week 34 (23.08. – 29.08.2010). Week 34 contains only the oil spill delineation of 25th August, as there was no more oil detectable on the satellite imagery after that date.

Figure 11 shows the cumulative daily oil spill extent for week 20 (17.05. – 23.05.2010), depicting also areas of oil spill landfall.

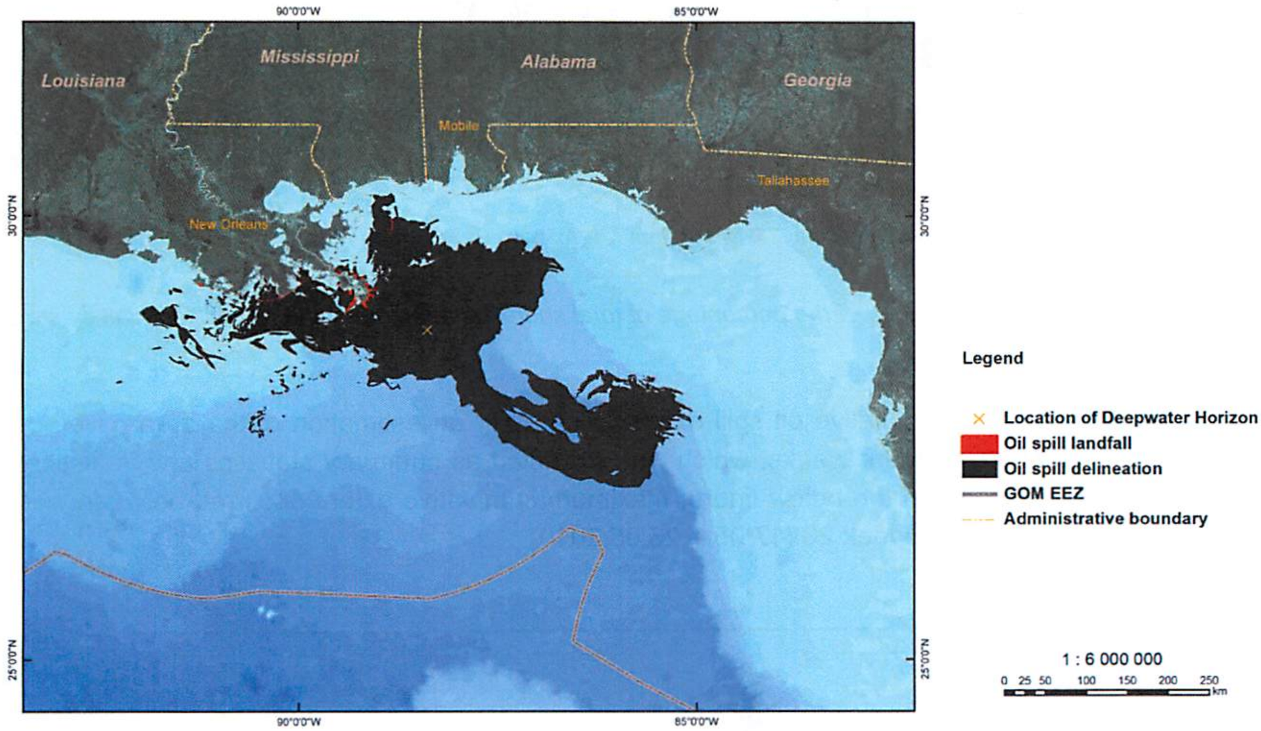


Figure 11. Cumulative daily oil spill extent for week 20 (17.05. – 23.05.2010), depicting also areas of oil spill landfall.

Based on the cumulative weekly maps, the percentage of total shoreline affected by the oil spill land fall was calculated for each week and state. This allowed a detailed chronology of the oil spill land fall for each state, identifying areas that were most affected.

Figure 12 shows that first land fall occurred approximately 2 weeks after the accident, and at the beginning mainly the shoreline of Louisiana was affected. In the consecutive weeks after the accident, the oil spill reached the shorelines of Alabama and then Western Florida. Western Florida was impacted for about a month, but less shoreline was affected compared to the other states. The shoreline of Mississippi was affected only slightly at the beginning of the disaster and most affected from week 25 on.

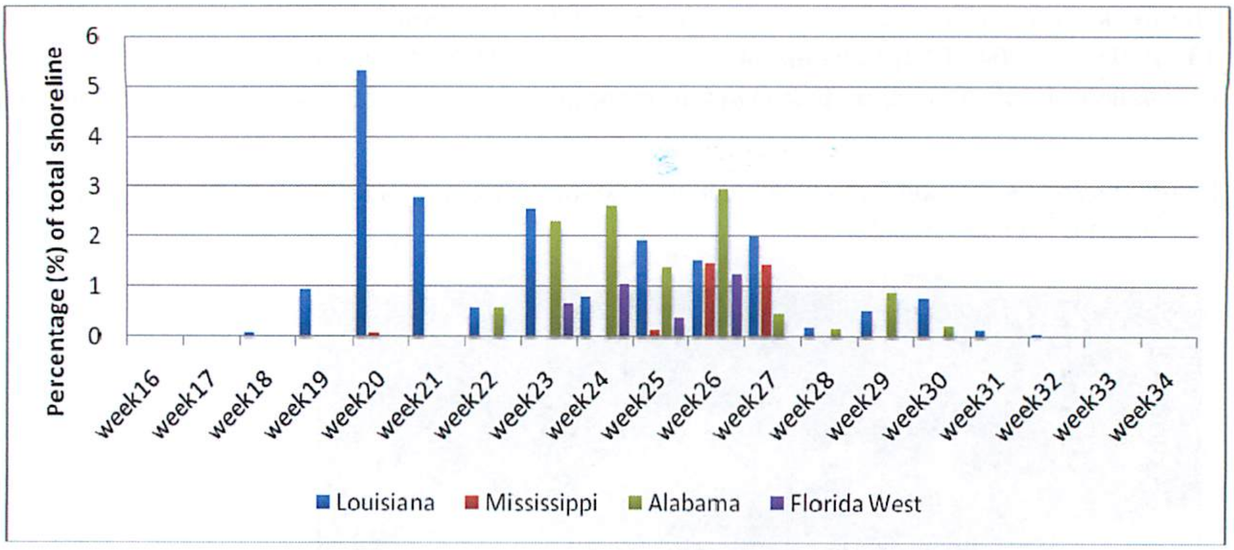


Figure 12. Detailed chronology of the percentage of total shoreline affected by the oil spill land fall by state.

The remotely sensed cumulative oil spill extents also allow an estimation of the area covered by the oil spill between calendar weeks, which was extracted as summary statistics and is displayed in Figure 13. According to the below figure, maximum cumulative extent occurred between weeks 20 and 25, with a peak in week 20 (17.05. - 23.05.2010).

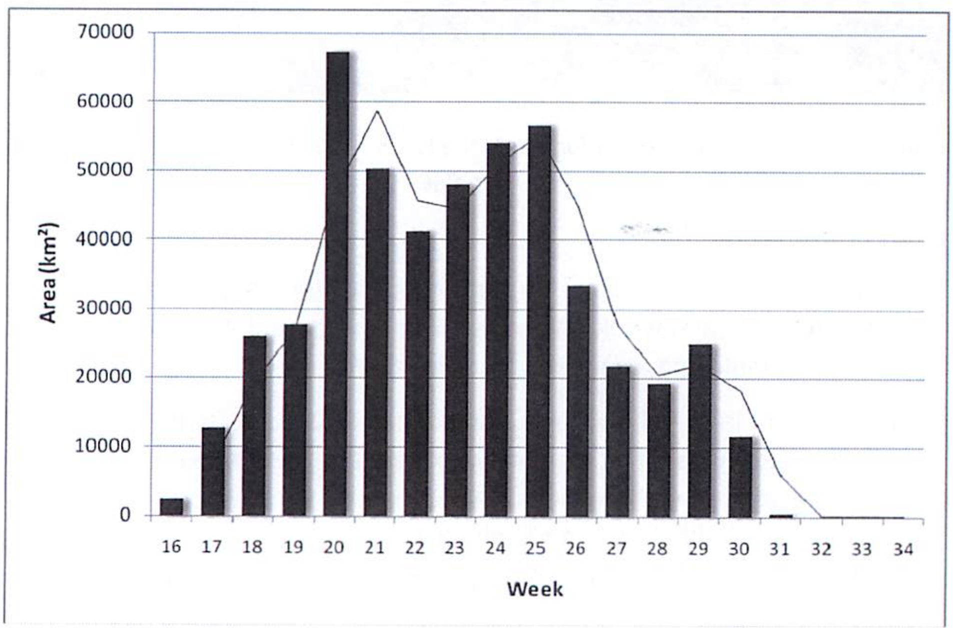


Figure 13. The evolution of the estimated cumulative area covered by the oil spill as depicted with satellite data.

Based on the 19 cumulative weekly maps a summary frequency map was derived using vector based GIS analysis indicating for each area how often the oil was present at a particular location (=frequency of observation). The summary frequency map thus allows identifying most impacted areas. Figure 14 shows the summary frequency map of the oil spill, including information on the oil land fall.

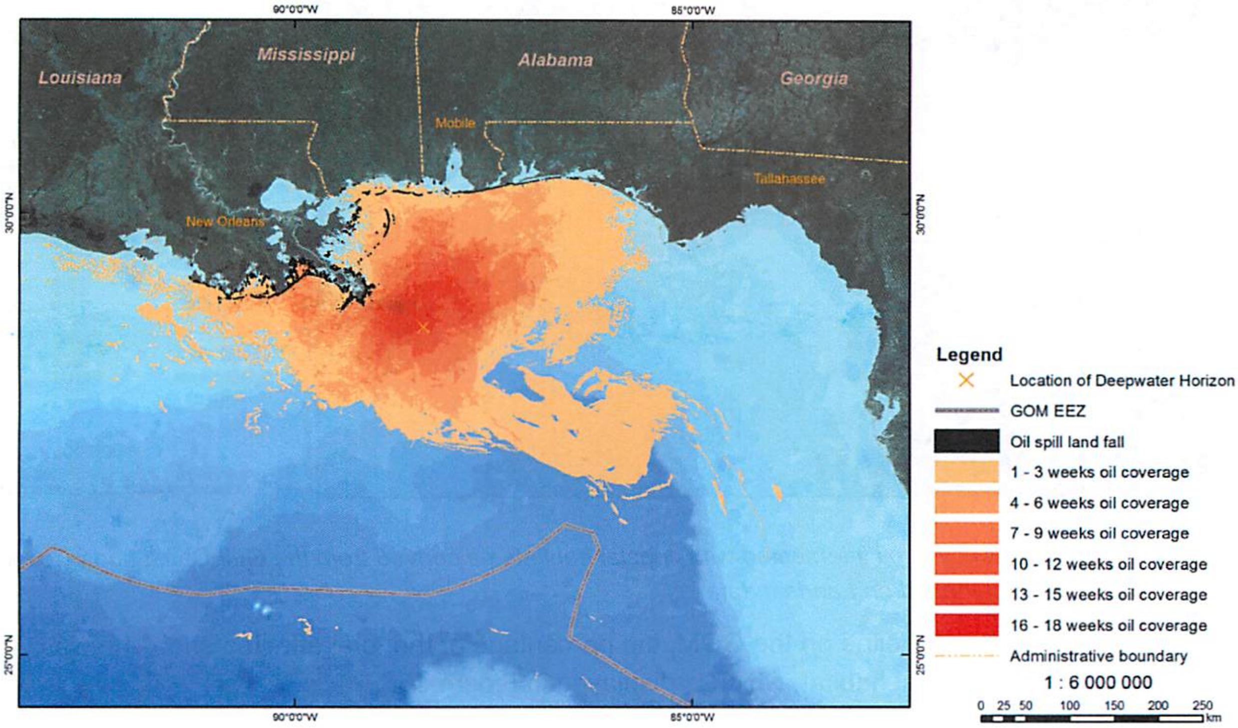


Figure 14. Summary frequency map based on 19 cumulative weekly oil spill extents.

5.2 OIL SPILL INTERACTION WITH NATURAL HABITAT MAPS

To identify the oil spill interaction with natural habitats the buffered cumulative weekly maps were intersected with the coastal Gulf Coast Land Cover available through NOAA Coastal Service Center (http://www.csc.noaa.gov/crs/lca/gulfcoast.html) (Figure 15). In this way, the length of the shoreline affected by the oil spill was identified for each natural land cover class and respective habitat.

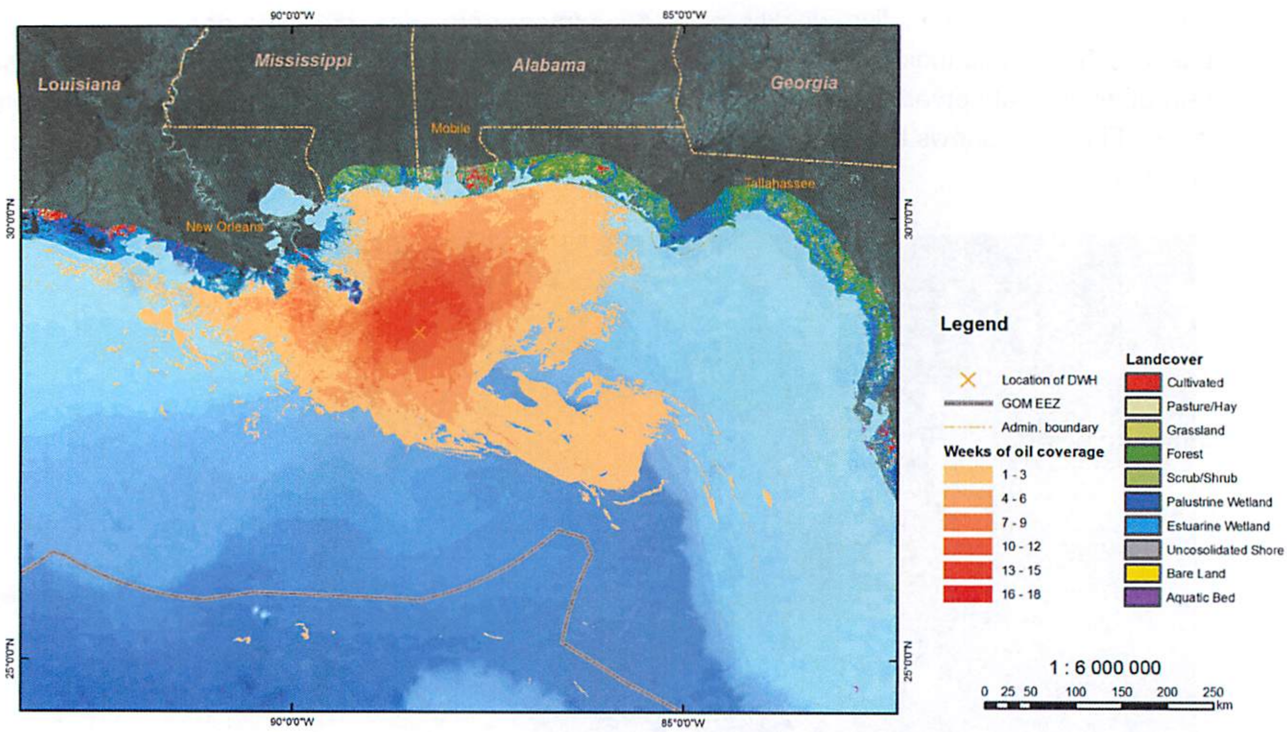


Figure 15. The frequency of oil intersected with coastal habitats as derived from the Gulf Coast Land Cover at 30 meter resolution based on Landsat data.

For each state with a shoreline on the GOM, the percentage of the total affected shoreline was calculated for each natural habitat, which is displayed in Figure 16.

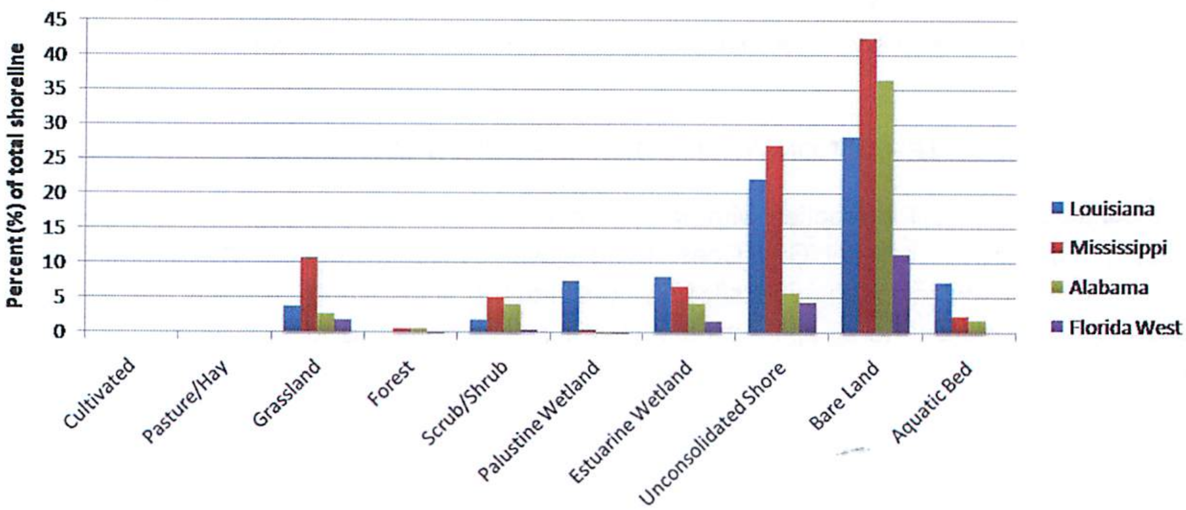


Figure 16. The percentage of total affected shoreline displaying the oil interaction with various habitat types.

Figure 16 shows that mainly unconsolidated shores and bare areas (e.g. beaches), as well as estuarine wetlands were affected by oil landfall. These habitats are home for various animals, amongst others also sea turtles. To understand in how far sea turtles were affected by the oil spill land fall, a map of sea turtle nesting sites was intersected with the cumulative weekly oil spill extent maps (Figure 17).

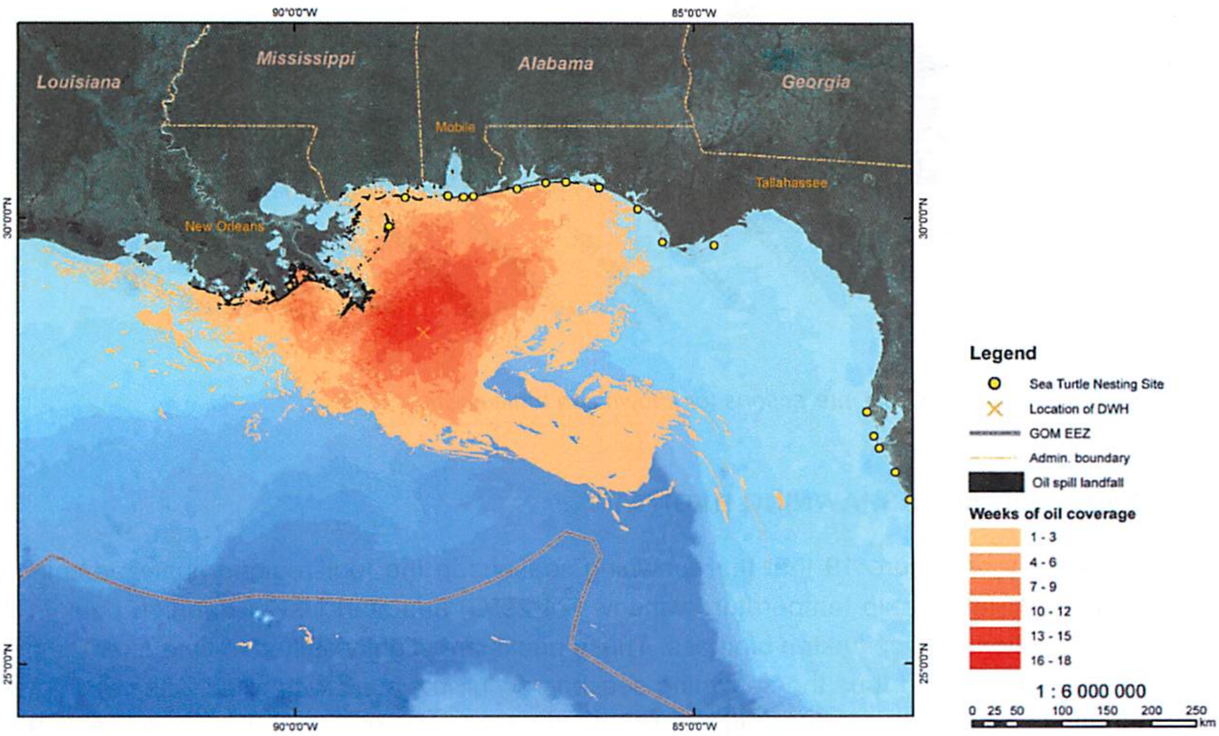


Figure 17. The oil spill interaction with sea turtle nesting sites in the GOM.

The statistical analyses revealed for known sea turtle nesting sites how often they were affected by the oil spill (Figure 18). This allows identifying most affected areas that will be studied more detailed in a high resolution assessment (D5). The number of weeks the oil spill was present at the nesting site is an important indicator for the state of the sea turtle population. Eroded nesting beaches are a major threat to sea turtle populations, together with destroyed foraging habitat, the ingestion of tar, as well as both chemical and physical effects from contact. Major oil spills affect sea turtles at all life stages; and nearly all turtles coming in contact with an oil spill will die or become severely debilitated (http://seaturtlestatus.org/oil-turtles). The derived information is important for conservation issues as carried out by *The Ocean Foundation*.

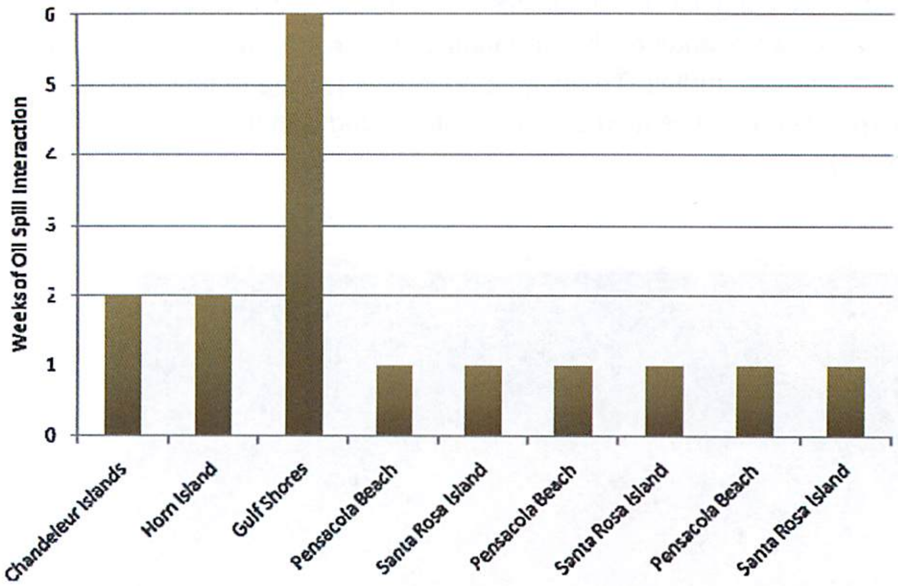


Figure 18. Frequency of oil spill interactions for known sea turtle nesting sites.

5.3 MODELLED ABFT SPAWNING HABITAT

It appears clearly on Figure 19 that the spawning seasons in the four regions analyzed coincide with the timing of favourable temperature window (24-29°C) and start just at the high peak in the seasonal fluctuation of zooplankton biomass. These peaks are slightly shifted in time after the peak of primary production and thus the spawning seasons occur in waters with rapidly decreasing and low abundance of phytoplankton (Figure 19) as generally observed (e.g., Teo et al. 2007). Temperature in the eastern Mediterranean region becomes rapidly too high and limits the favorable time window while in the Balearic region SST exceeds briefly the 29°C limit only during the heat wave of 2003. The end of spawning seasons is associated to a large decrease in the zooplankton biomass. In the Balearic region, there is a secondary peak in zooplankton biomass in winter but at that time SST is well below the favorable temperature window. The opposite occurs in the GOM, where decrease in zooplankton biomass coincides with the seasonal increase of SST above 29°C (Figure 19). The peaks of predicted biomass of micronekton (*F*) are also shifted in time after the peak of zooplankton. Nevertheless, the timing of peaks of Z/F ratio are not very different of those of the zooplankton alone, at least when using spatial average. Their spatial distributions however can differ substantially.

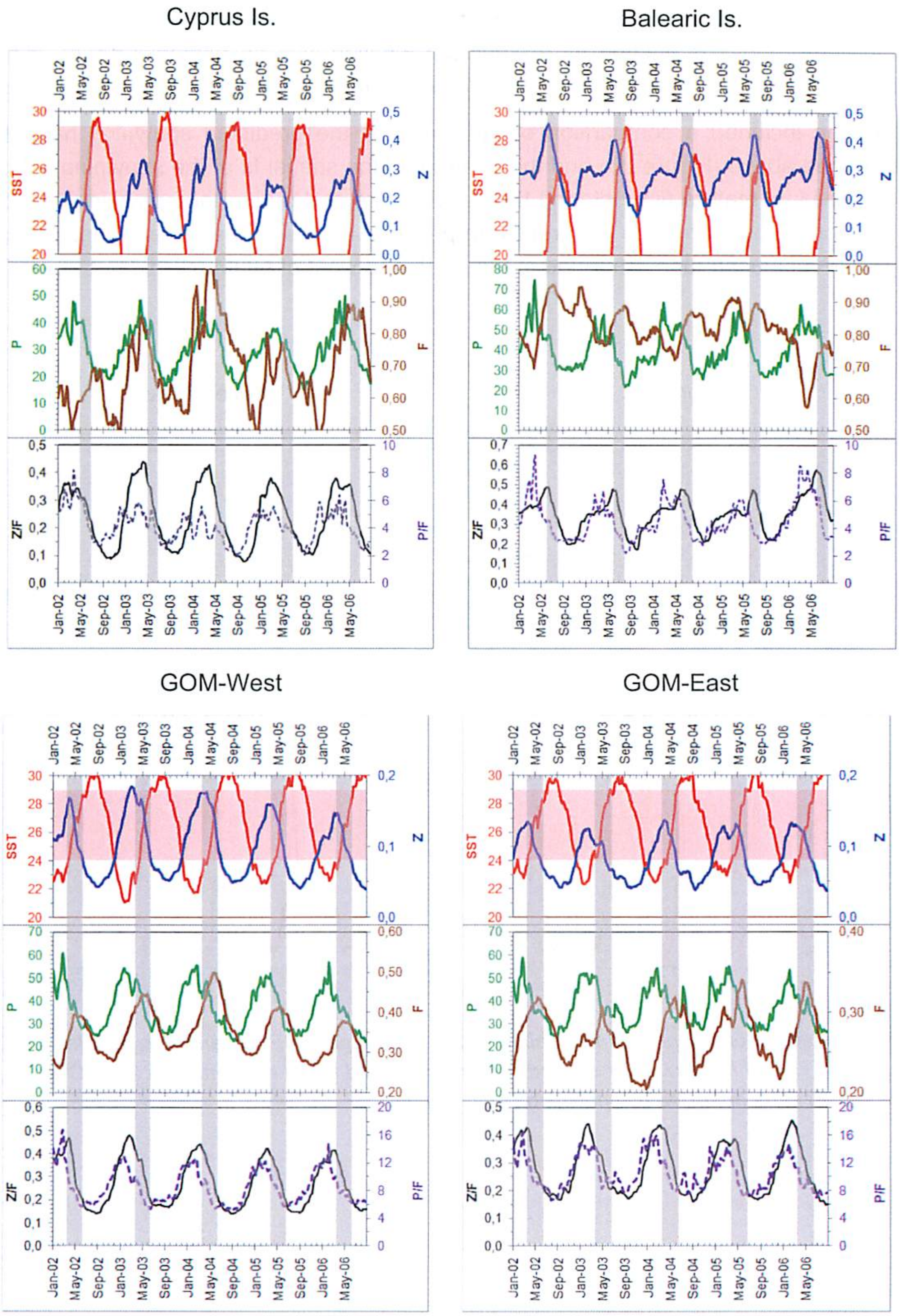


Figure 19. Time series extracted near Cyprus Is. And Balearic Is in the Mediterranean Sea for SST, primary production (P), zooplankton (Z), micronekton (F) and the ratios Z/F and P/F. Grey shaded bands indicate the timing of spawning season in each region.

The analysis above has been used to parameterize the model of spawning habitat for the ABFT. The temperature index is defined by a Gaussian function with an optimal SST of 26.5°C and a standard error of 1.5°C. The Z/F ratio is used to predict the best larvae prey-predator trade off.

The validation included a comparison of the timing of the predicted spawning habitat in the 4 regions defined above (Figure 20) and the analysis of the spatial fit of the spawning index with the tracks of individual mature fish entering the GOM before and during the spawning season (Figure 21). Prediction outputs are also coherent with previous results in the literature indicating that the majority of larval bluefin tuna are found in the north and west of GOM (Nishida et al., 1998; Teo et al. 2007).

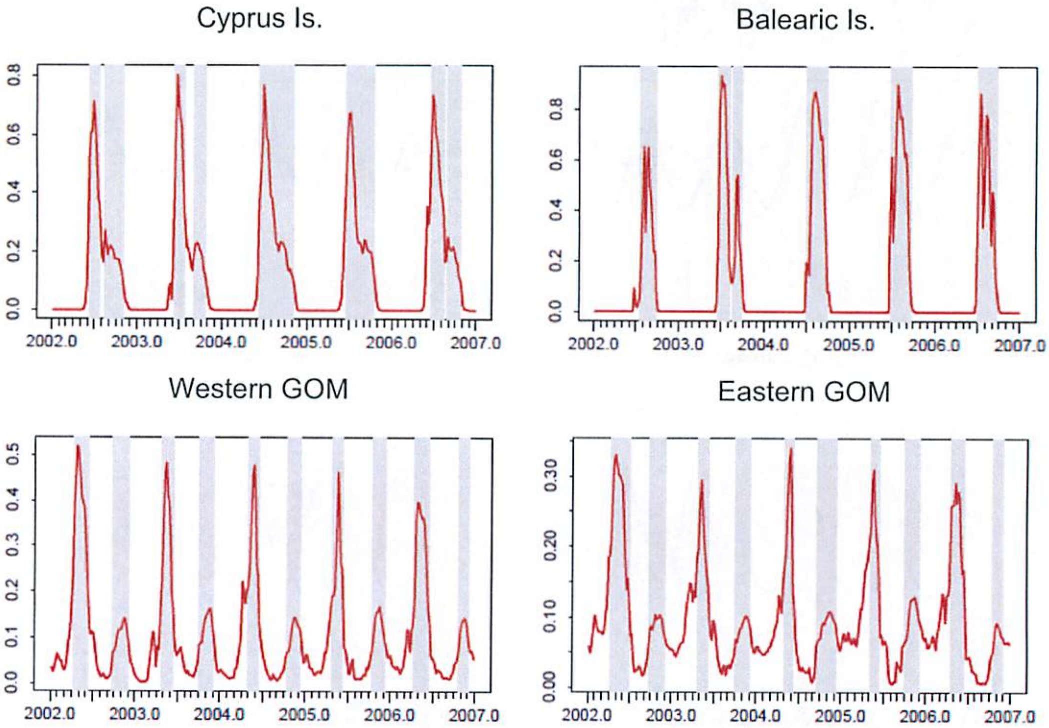


Figure 20. Time series of mean spawning habitat index near Cyprus Is., Balearic Is in the Mediterranean Sea and two parts of Gulf of Mexico. Grey shaded bands correspond to the temperatures 24-29C in the region, which are known to be preferred by spawning bluefin tuna.

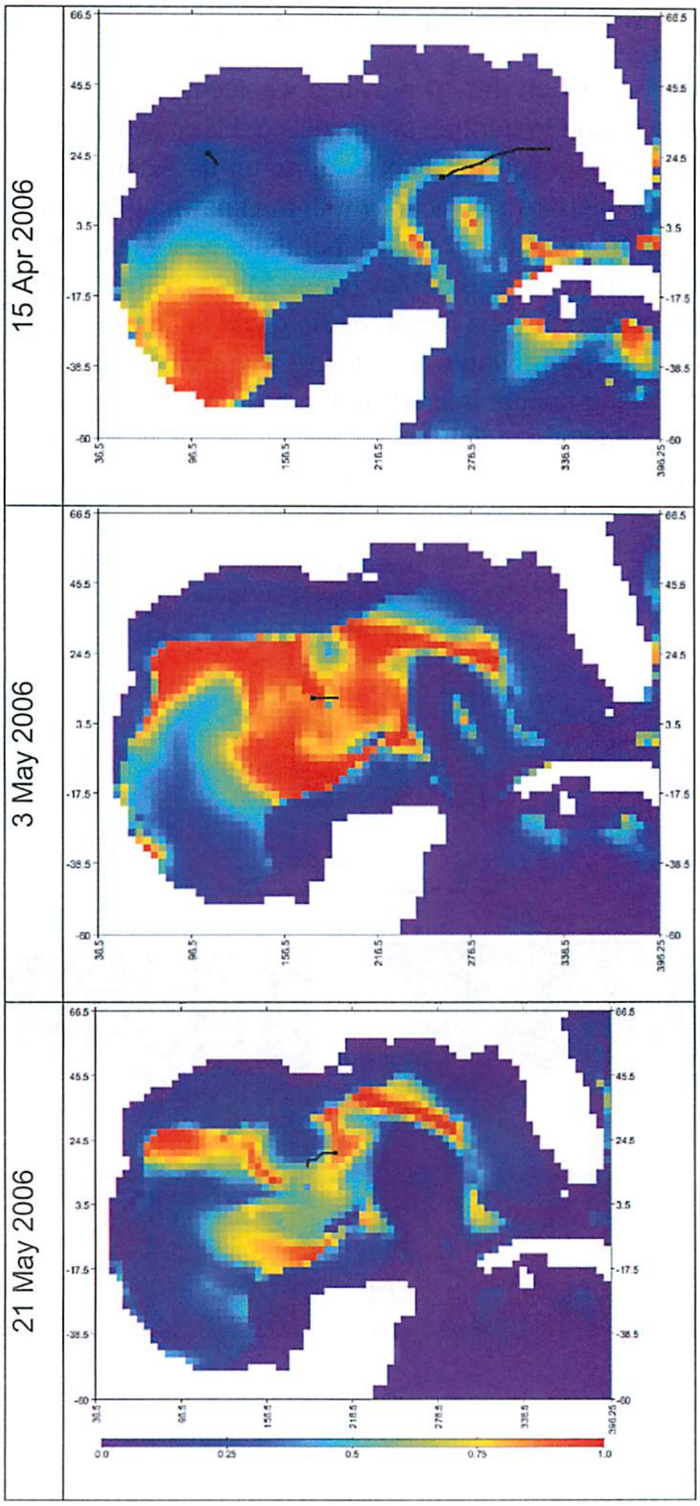
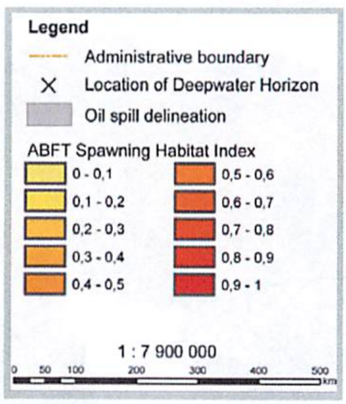
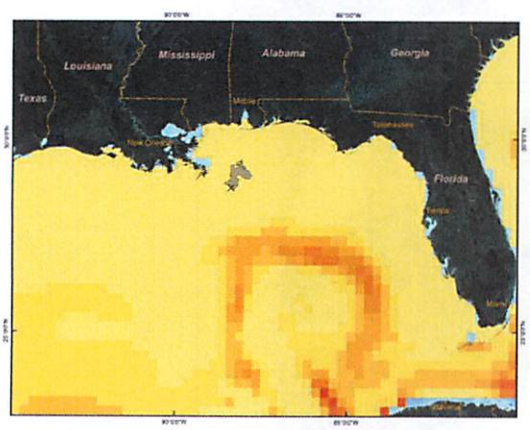


Figure 21. Bluefin spawning habitat in the GOM predicted in 2006 with superimposed track of an individual bluefin entering the Gulf early April and leaving early June (Data kindly provided by M. Lutcavage, LPRC, USA).

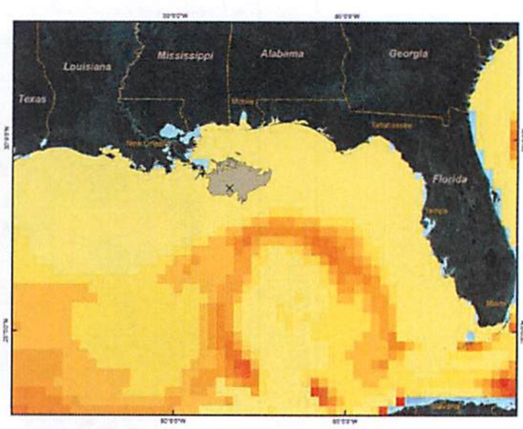
5.4 OIL SPILL INTERACTION WITH ABFT SPAWNING HABITAT

The superimposition of oil spill on the 10 previous weekly maps of predicted spawning habitat is shown on Figure 22. According to our habitat modelling the spawning habitat in the GOM develops after mid-April showing propagation from south to north. Its extension is maximum at the end of May. The oil spill starts to interfere significantly with the spawning habitat in the north-east of GOM after mid-May (week 19: 10. 05 -16. 05. 2010), but there is not interaction with the largest part of habitat in the western GOM. At the end of May (week 21: 24. 05. -30. 05. 2010), the favourability of the spawning habitat in the north-west region of the GOM is quickly decreasing while it reaches a maximum in the north-east region where the oil spill also reaches its largest extension (at least in surface). Since the spawning habitat is predicted to have a larger extension in the western region of the GOM than in the eastern region where the oil spill occurred, the impact of the pollution remains relatively limited until mid-May. However, it increases rapidly after this date.

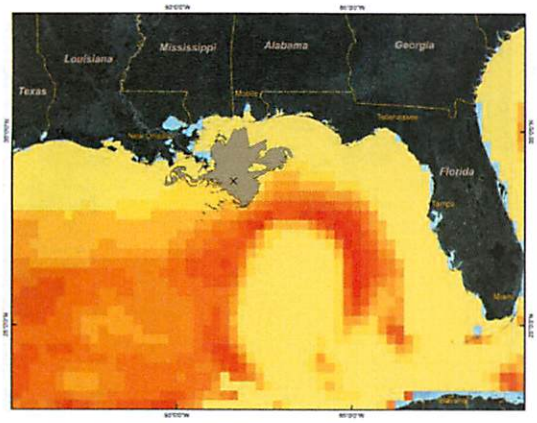




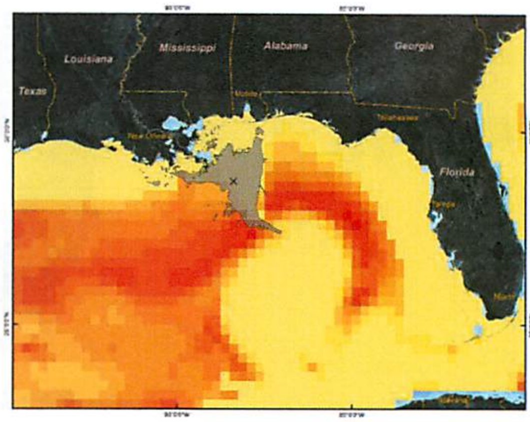
Week 16



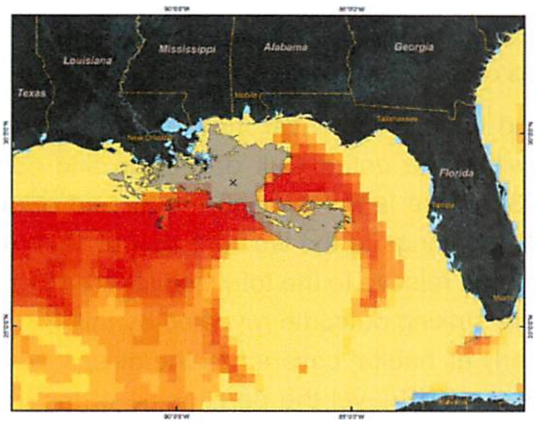
Week 17



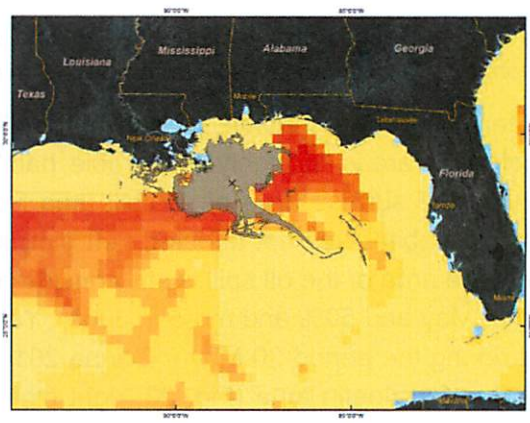
Week 18



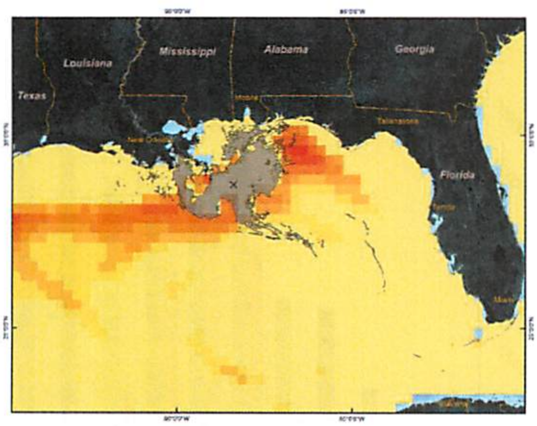
Week 19



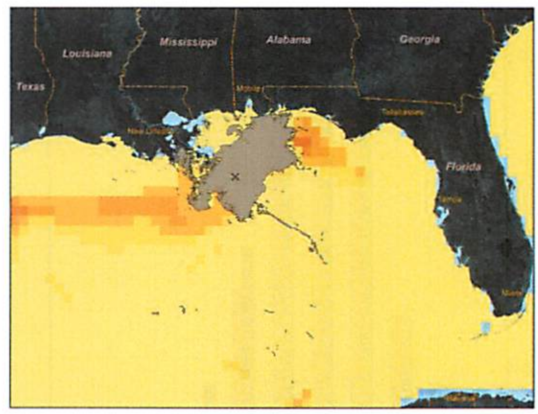
Week 20



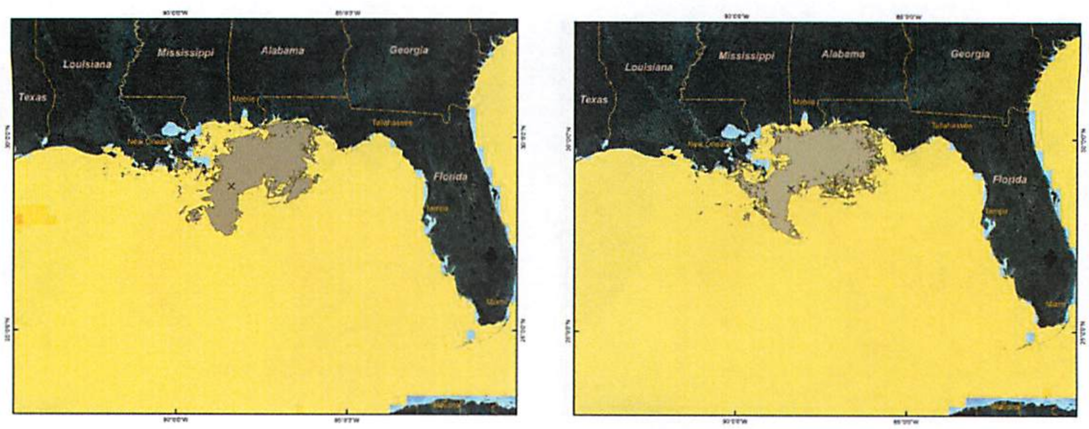
Week 21



Week 22



Week 23



Week 24 Week 25

Figure 22. Maps of potential habitat of bluefin tuna affected by the oil spill. The extent of grey shaded pattern corresponds to the surface oil spill from week 16 to 25 as observed by satellites.

To quantify the interaction of the oil spill and bluefin potential habitat we've calculated characteristic areas of highly favourable habitat within the entire Gulf of Mexico and compared them with the surface area of oil spill (see Fig. 23, on the left). Although the largest area of the favourable habitat was not affected (left plot) since it belongs to the western part of Gulf, one can see that the area of the oil spill is still considerably large relative to the total habitat area (10-24% in month of May and 50% and more in June). Yet more striking outcome revealed by this comparison is that during the period 20 May – 3 June 2010 nearly all habitat covered by the oil spill was highly favourable for bluefin tuna (Fig. 23, right plot). On the EEZ level the percentage of the impacted highly favourable habitat is extremely high, reaching 100% by mid-June (follow the red curve on Fig. 23, right plot).

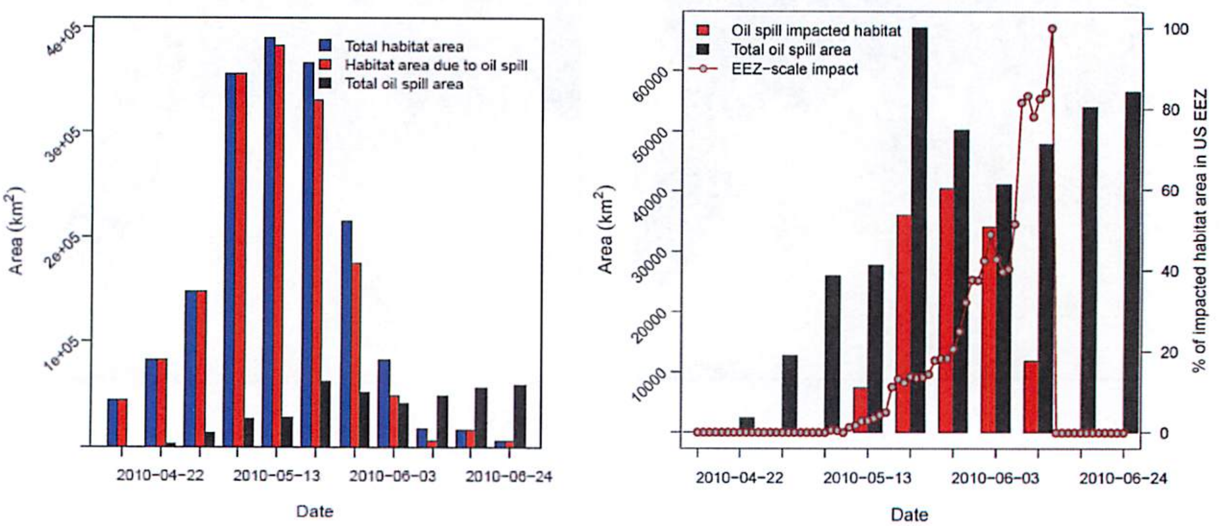


Figure 23. Left: Characteristic areas (weekly means) of total highly favourable (>0.5) habitat in the entire Gulf of Mexico – not taking into account the oil spill (blue) and in the presence of the oil spill (red). The area of oil spill itself is shown by black bars. Right: Area of highly favourable habitat impacted by the oil spill. The dotted line shows daily percentage of impacted habitat area over the total habitat area in the US EEZ.

We also computed the impact on larvae survival using the dynamic component of the SEAPODYM model that simulates the drift of eggs and larvae with currents. We fixed the maximum age of the larvae cohort to 30 days after spawning, simulated occurrence proportionally to the habitat index and then applied natural mortality rates varying as a function of habitat, resulting in 100% mortality the oil spill area. We ran two simulations: S1) releasing the larvae in all non-zero habitat and S2) only in highly favourable habitat (using 0.5 value as a threshold). The example of larvae distributions obtained with or without oil spill in the S1 simulation is shown on Figure 24. For those eggs and larvae that occurred and survived in the western part of the GOM, and hence were not affected by oil spill, the recirculation by currents appears rather favourable since they are not driven to polluted area. Nevertheless computed weekly impacts of the oil on the larvae density in the eastern and central parts of the gulf are still very pronounced (Fig. 24). Furthermore, to quantify the overall impact of the spill on the recruitment in bluefin population one need to compare the amount of larvae reached the juvenile stage with and without the oil spill. According to availability of physical and biogeochemical forcing (January 1 – June 30, 2010) we were able to estimate the level of reduction among juveniles, which were spawned during month of May only. The estimated recruits reduction are 17% and 23% in the simulation S1 and S2 correspondingly; however, assuming that the largest weekly impact on larvae occurs in June (see Fig. 24), one may expect that these numbers will increase if we would take into account larvae during all spawning season.

The difference between integrated spawning index over the domain due to the oil spill is predicted to reach 15-20% at the time of maximum extension of the oil plume visible in surface (Fig. 22) leading to a larvae depletion of 24% compared to a scenario without oil spill.

One essential uncertainty in the measure of the impact of oil spill concerns the relationship with the adult spawning biomass that cannot be included in the modelling of spawning habitat since there is no representation of adult cohorts. In case of a wealthy abundant stock, we could assume that due to density dependence effects the spawning habitat would fit closely to the real distribution of breeding adults. However, it is possible that with a reduced biomass of spawning stock biomass, which is clearly the case for bluefin, the spawning ground would be concentrated in the most favourable habitat. We have tested this assumption by setting a threshold value of 0.5 for the favourable spawning habitat (ranging from 0 to 1). In that case, the impact of oil spill on high quality habitat is much higher and reaches 80% at the end of the spawning season with a corresponding larvae depletion of about 50% (Fig. 24).

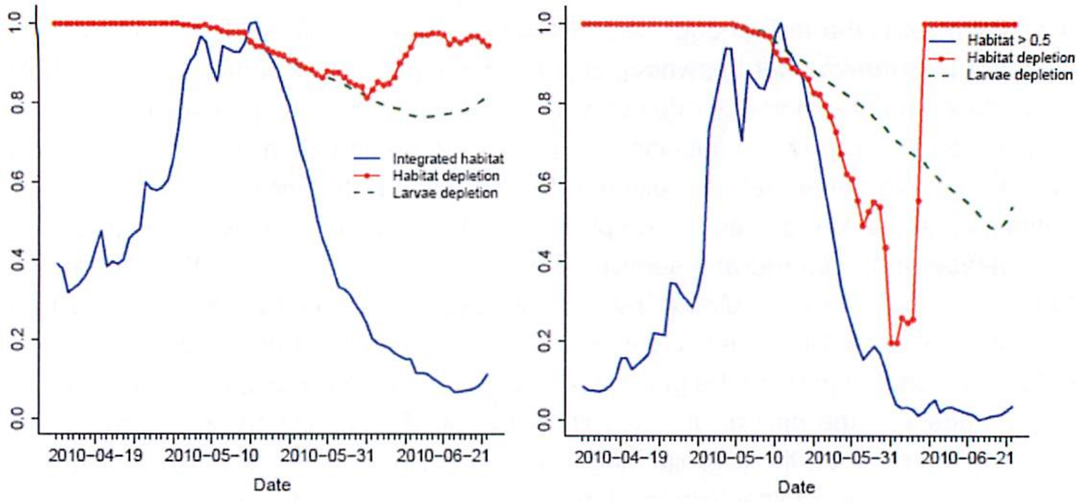


Figure 24. Estimated impact of oil spill on the spawning habitat of bluefin in the GOM: ratio between polluted and clean spawning habitat areas considering all values (left) or only highly favourable habitat with a value above 0.5 (right). The green dotted line shows the same metrics for predicted larvae in the entire GOM.

6 DISCUSSION

6.1 DISCUSSION OF INPUT DATA AND RESULTS

The dimensions of the Deep Water Horizon disaster have been successfully captured from space, providing important information on the location, extent, and temporal evolution of the oil spill and the coastal habitats affected. Beyond the effective monitoring and management of the Earth's resources it was shown that ENVISAT satellite data, acquired immediately after the accident and regularly in the following weeks, can be used to rapidly generate oil spill extent maps and provide an overview of the current state and development of the environment in the Gulf of Mexico. Together with existing oil spill delineations derived from various European and international satellite data (MODIS, RADARSAT, ALOS, TerraSAR-X and SPOT) available through NOAA's NESDIS Satellite Analysis Branch it was possible to derive a consistent chronology of the oil spill caused by the Deep Water Horizon disaster. A summary frequency map developed in this study depicts for each area how often the sea surface was covered by oil in the period between 20th of April and 29th of August 2010. The accumulation of satellite derived oil spill extents allows identification and quantification of areas that have been affected hardest, on the ocean and on the coast.

Oil spill interaction with natural habitats was quantitatively assessed for coastal land cover, turtle nesting sites and the Atlantic Bluefin Tuna (ABFT) spawning habitat.
To determine the oil interaction with coastal habitats the cumulative weekly maps were intersected with NOAA Gulf Coast Land Cover data. In this way, the length of the shoreline affected by the oil spill was identified for each land cover class. The resulting GIS database provides the basis for statistical analyses that have been carried out for the affected shorelines in the states of Louisiana, Mississippi, Alabama and western Florida (Escambia, Okaloosa, Walton, Santa Rosa, Bay, Gulf). Analyses of the satellite data and the shore line land cover revealed that in Louisiana, Mississippi, Alabama and western Florida mainly unconsolidated shores, bare areas (i.e. beaches) and estuarine wetlands were affected by oil landfall. For example, in Louisiana, the percentage of affected wetland shorelines exceeded 15%. These habitats are home for many species and include important breeding sites and nursery grounds of marine animals, such as birds, fishes, shrimps and sea turtles. To understand in how far sea turtles were affected by the oil landfall, a map of sea turtle nesting sites was intersected with the cumulative weekly maps of the oil spill. The statistical analyses revealed for known sea turtle nesting sites how often they were affected by the oil spill, providing important information about the sea turtle populations with regard to conservation efforts.

Besides the impact on the coasts also maritime species, such as the Atlantic Bluefin Tuna were affected by the oil spill. Using various satellite data and models it was possible to get a preliminary estimate of the Deep Water Horizon oil spill impact on the Atlantic Bluefin Tuna (ABFT) spawning habitat and larvae survival. ABFT spawning stock in the western Atlantic has declined by >90% over the past 30 years. One of the management and conservation issues facing ABFT is the need for protection on their GOM spawning grounds. To document the interaction of the oil spill with the ABFT spawning habitat the ABFT spawning index was simulated and intersected with the oil spill evolution as derived from Earth Observation data.

The search for mechanisms that explain the variability in fish larvae survival rate and then the strength of the oldest cohorts recruited in the adult population is one of the major quests in fisheries science. Combining the main proposed mechanism in one model allowed to simulate a spawning habitat sufficiently robust to explain existing observations and general knowledge on Atlantic bluefin tuna reproduction and spawning grounds. Nevertheless, a more rigorous approach to evaluate this model would be to assimilate the satellite and archival tagging data directly in the habitat and movement model to obtain an optimal parameterization. In particular, a shift by one or two weeks in the prediction of the peak of spawning could change drastically the impact of the oil spill.

6.2 ADDED VALUE

It could be shown in this study that large scale disasters can be efficiently monitored from space to identify most impacted areas. ESA satellite data provided valuable input for models and for the direct mapping of oil spill extents as performed on ENVISAT satellite data, allowing a timely, synoptic and precise mapping of the oil spill extent in the Gulf of Mexico (GOM) based on ASAR radar and MERIS optical data. Radar satellite data in particular is very suitable for water surface oil slick mapping, due to its all-weather capability and the strong absorbance of the radar signal by the oil slick. The intersection of satellite derived oil spill extents with various GIS datasets on valuable coastal and maritime habitats allows providing detailed information on the impacts of the oil spill on natural habitats, on the shoreline and in the GOM. This study allowed developing the necessary tools and processing chains to derive in almost near real time products that open the way to the operational management of fisheries.

6.3 OUTLOOK

The initial assessment of the Deepwater Horizon Oil Spill Spatial Chronology and the interaction with natural habitats provides the basis for further analyses of the oil spill impact on the GOM ecosystem. A thorough understanding of the affected habitats is needed to implement future measures to successfully restore the GOM ecosystem. Based on the satellite derived information about the oil spill extent, a synoptic view on the disaster can be provided and affected habitats were identified from space. The results derived in this study also highlight hot spot areas where increased restoration efforts are needed. These hot spot areas will be assessed in a further study (D5). Furthermore, the developed methods can be applied for other natural habitats, such as the ones of birds, shrimps and fishes.

In this study, it was already successfully shown that remote sensing derived oil spill extents can be intersected with modelled fish spawning grounds, here the Atlantic bluefin tuna. The work conducted to simulate the spawning habitat of bluefin requires now a rigorous validation. There are several sources of data that can be used for this, mainly larvae sampling surveys, accurate fishing data, biological sampling and archival and satellite tagging data on large mature bluefin tuna. These tagging data can be integrated in the optimization framework of the model to have a more rigorous estimation of the habitat and movement parameters.

Once evaluated the model prediction could be used in near real time for management, e.g., protecting the spawning ground by limiting accurately the interaction with fisheries. The same approach can be developed for other tuna species. Finally the habitat modelling is part only of the SEAPODYM model that include all the dynamics of the species and a representation of fisheries. Therefore, the work developed to define the spawning habitat of the Atlantic bluefin is providing a key component for a future application of SEAPODM to the whole population dynamics of this valuable but overexploited species.

VB 4/A – DRAFT annotation to ?.