30 YEARS OF BELGIAN NORTH SEA AERIAL SURVEILLANCE

EVOLUTION, TRENDS AND DEVELOPMENTS

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Report MUMM April 2023

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AST GUARD












OAST GU


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Foreword

The North Sea is at the same time a complex ecosystem, an important fishing area, a very busy navigation area, an area where numerous activities takes place and, since Brexit, an external border of the European Union. It is therefore essential to study and monitor it.

Aerial surveillance is obviously a preferred means of covering such an area. First devoted to the prevention of illegal pollution and support in the event of maritime casualties, the missions of the surveillance aircraft have extended over time in two directions: the protection of the marine environment and Coast Guard support.

It is thanks to the seamless collaboration between the ministry of Defence, which provides its expertise in flight techniques above this particular environment, and the Federal Science Policy Office (BELSPO), particularly the Royal Belgian Institute of Natural Sciences, which brings in scientific expertise and has developed a great knowledge of the North Sea ecosystem, that these two functions of surveillance and management have been able to develop over the 30 years, at the service of both the federal and regional departments concerned.

After many years and nearly 10.000 flight hours, and a major contribution to the fight against marine pollution, for the protection of the marine environment, in favour of sustainable management of the sea, for the enforcement of maritime regulations and at the service of the Coast Guard, now is the time to renew the aircraft and modernize and expand the surveillance capability to meet future needs and stay at the cutting edge in terms of technology.

The aircraft is now obsolete, while needs are growing and regulatory and environmental demands are increasing. I will therefore carry the dossier for the renewal of the aircraft with all the necessary energy.

I would like to conclude by congratulating the members of the Scientific Service Management Unit of the North Sea Mathematical Model who produced this report, and by thanking my colleagues Ludivine Dedonder and Vincent Van Quickenborne, and through them the members of their administration who collaborate closely in this essential function both for the environment and for society.

Thomas Dermine,
Secretary of State for Science Policy

List of Abbreviations

A	
AIS	Automatic Identification System
AOH	Aerial Operations Handbook
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas
B	
BAOAC	Bonn Agreement Oil Appearance Code
BC	Black Carbon
BCP	Belgian Continental Shelf
BONNEX	BONN Exercise
C	
CEF	Connecting Europe Facility
CEPCO	Coordinated Extended Pollution Control Operation
CO_2	Carbon Dioxide
COLREG	International Regulations for Preventing Collisions at Sea
COMOPSAIR	(Belgian) Air Component Defence
CRM	Crew Resource Management
CSN	CleanSeaNet service
D	
DZV	*Dienst Zeevisserij* (Fisheries Authority of the Flemish Government Department of Agriculture and Fisheries)
E	
ECA	Emission Control Area
ECGFF	European Coast Guard Function Forum
EEZ	Exclusive Economic Zone
EFCA	European Fisheries Control Agency
EGCS	Exhaust Gas Cleaning System
EGR	Exhaust Gas Recirculation
EMS	Electronic Monitoring System
EMSA	European Maritime Safety Agency
ESA	European Space Agency
F	
FMS	Flight Management System
FSC	Fuel Sulfur Content
G	
GT	Gross Tonnage
H	
HNS	Hazardous Noxious Substances
HUET	Helicopter Underwater Escape Training
I	
ICAL	Intercalibration
ILT	Dutch Human Environment and Transport Inspectorate
IMO	International Maritime Organisation
INBO	Flemish Research Institute for Nature and Forest
IR	Infrared
J	
JDP	Joint Deployment Plan
JFD	Joint Flight Days
L	
LNG	Liquid Natural Gas
M	
MARPOL	International Convention for the Protection of Pollution from Ships
MEPC	Marine Environment Protection Committee
MIK	Maritime Security Center

MMSI	Maritime Mobile Service Identity
MRCC	Flemish Maritime Rescue and Coordination Center
MSP	Marine Spatial Plan
MUMM	Management Unit of the North Sea Mathematical Model
N	
NECA	Nitrogen Emission Control Area
NHTSS	North Hinder Traffic Separation Scheme
NLS	Noxious Liquid Substances
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_X	Nitrogen Oxides
NSN	North Sea Network of Prosecutors and Investigators
O	
OIC	(OSPAR) Offshore Industry Committee
OPERA	Joint Operations between different Coast Guard partners
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
P	
POLEX	Pollution Exercise
PM	Particulate Matter
PPM	Parts per Million
PSC	Port State Control
Q	
QZJR	(Bonn Agreement) Quadripartite Zone of Joint Responsibility
R	
RBINS	Royal Belgian Institute of Natural Sciences
RD	Royal Decree
RPAS	Remotely Piloted Aircraft Systems
RPM	Revolutions per Minute
RoRo	Roll-on-Roll-off Vessels
S	
SAR	Search and Rescue
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communication
SCR	Selective Catalytic Reduction
SECA	Sulfur Emission Control Area
SFOC	Specific Fuel Oil Consumption
SLAR	Side Looking Airborne Radar
SO_2	Sulfur Dioxide
SO_x	Sulfur Oxides
SUMO	Suspended Matter and Seabed Monitoring and Modelling team
SWET	Shallow Water Escape Training
SWOT	Strengths, Weaknesses, Opportunities and Threats
T	
TdH	Tour d'Horizon
TSS	Traffic Separation Scheme
V	
VHF	Very High Frequency
VMS	Vessel Monitoring System
VOC	Volatile Organic Compound
VTMIS	Vessel Traffic Monitoring and Information System
VTS	Vessel Traffic Services
W	
WHTSS	West Hinder Traffic Separation Scheme

EXECUTIVE SUMMARY

This multiannual activity report describes the various missions and results, trends and developments of the Belgian program for aerial surveillance over the North Sea over a period of 30 years, from its start in 1991 up to and including 2021. The report describes how aerial surveillance over sea evolved from the surveillance of marine pollution in the early years to a broader environmental and maritime surveillance above sea, following the extension of the Belgian jurisdiction at sea and the creation of the Belgian Coast Guard structure. The report describes the usefulness and added value of aerial surveillance to combat marine pollution, protect the marine environment, sustainably manage the Belgian marine areas, ensure maritime enforcement and support various other Coast Guard functions.

The major facts of the Belgian North Sea aerial surveillance program since the beginning in 1991 until 2021 can be summarized as follows:

- 9574 flight hours were conducted, of which 7100 hours above sea (approximately 6400 flight hours in national and 700 hours in international context).
- 625 operational oil spills were reported in the Belgian survey area, resulting in an estimated 1013 tonnes of oil pollution.
- 158 operational spills of other harmful liquids (Noxious Liquid Substances, NLS) were observed.
- 51 ships were caught red-handed while performing an illegal discharge.
- While the problem of illegal oil spills nowadays seems to be under control, NLS spills show a slightly increasing trend.
- 35 serious shipping accidents have taken place in or around the Belgian marine areas, with accidental marine pollution or a high risk thereof. In most of these cases (26), the Coast Guard aircraft was effectively activated to monitor the emergency situation from the air and provide air support to response units whenever necessary.
- 24 Tour d'Horizon missions were executed, during which the offshore gas installations and oil rigs in the central part of the North Sea were surveyed, resulting in 430 flight hours and a total of 296 pollution detections (272 mineral oil detections, 9 detections of a harmful substance other than oil (NLS) and 15 contaminants whose nature could not be visually verified).
- There was participation in 10 (Super)CEPCO operations, a regional mission consisting of a series of successive pollution control flights carried out by multiple surveillance aircraft from different North Sea countries.
- The Belgian Coast Guard aircraft participated in a total of 33 pollution response exercises and related experiments at sea, including 16 national POLEX exercises, 9 sub-regional exercises, 2 regional BONNEX DELTA exercises and 6 international Sea Trials.
- 353 emission monitoring flights were conducted with a sniffer sensor since 2015 and 6012 exhaust plumes were sampled. 9% of the monitored ships had a suspicious Fuel Sulfur Content (FSC). Since 2020, when the aircraft was further equipped with a NO_x sensor, 3% of the monitored ships did not comply with the international NO_x regulations.
- In the period 2009 to 2021, 214 flight hours were spent on marine mammal counts (222 hours if the test year 2008 is included). A total of 3223 harbour porpoises were observed during the monitoring campaigns (3 to 404 animals per survey, on average 87 per survey). In addition, 100 seals were seen and sporadically some other species of marine mammals such as white-beaked dolphins, bottlenose dolphins, a minke whale and a humpback whale.
- From 1993 to 2021, 1239 fishery control flights were carried out, leading to a total of 1185 flying hours. This resulted into a total of 7272 monitored and identified fishing vessels.
- Between 2011 and 2021, 112 violations on the use of automatic identification systems (AIS) by ships were observed, together with 148 navigation violations. In recent years there has been a sharp increase in the annual number of observed navigation violations with the highest number in 2021 (36).

Using and interpreting these facts and figures, this activity report also looks to the future, by explaining the recent and still ongoing program evolution from pollution control and environmental surveillance at sea, to

broader maritime surveillance in support of the overall Coast Guard framework, and by outlining that the substantive challenges of aerial surveillance above the sea are and will remain innumerable in the years to come: continuing the fight against sea and air pollution from ships in one of the busiest shipping areas in the world (including accidental pollution), ensuring dedicated airborne support in maritime emergency situations in the framework of the emergency and intervention plans for the North Sea, contributing to the sustainable management of the North Sea and sustainable use of living and non-living natural marine resources, the protection and conservation of marine biodiversity and ecosystems, the monitoring of human activities under a permit regime and/or organized within the framework of the new marine spatial plan, the efficient enforcement of a new European external border (post-BREXIT), promoting maritime security, offering support to search and rescue operations, and much more. Looking into the future, it is finally explained why the medium-term need for renewal of the remote sensing aircraft offers a unique opportunity for the Belgian Coast Guard structure to renew its strategic vision and increase its cooperation on airborne surveillance, and to modernise and expand its surveillance capacity with the aim to effectively deal with current and future needs at sea, in support of the various Coast Guard functions.

1. AERIAL SURVEILLANCE: INTRODUCTION, HISTORY AND EVOLUTION

1.1. Introduction and history

Until a few decades ago, illegal oil discharges from ships were at the root of a serious and chronic environmental problem in the North Sea. Beaches and sea birds covered in oil were an all too common sight[1,2]. Between 1950 and the late 1970s, the southern part of the North Sea was already one of the busiest maritime areas in the world and, consequently, few places saw more operational (intentional) oil spills and shipping accidents. During this period, there were several major shipping accidents causing oil to spill into the sea (like the *Torrey Canyon* disaster), yet chronic oil pollution was killing vastly greater numbers of seabirds on an annual basis[3].

In a joint effort to halt the numerous illegal oil discharges at sea, the various countries around the North Sea came to a unanimous decision during the international North Sea conferences in the late 1980s: there was to be regular surveillance of the sea, by means of specially-equipped aircraft[4]. In addition, these remote sensing aircraft would also be able to provide assistance in the event of accidental marine pollution. This specialized surveillance was organized within the Bonn Agreement (see box 1.2), an agreement by which the North Sea countries, together with the European Union, cooperate in dealing with pollution of the North Sea by oil and other harmful substances (1983)[5].

Following this international decision and after a training of the Belgian flying personnel by the Dutch Rijkswaterstaat, a Belgian programme for North Sea aerial surveillance was launched in 1991. The Belgian aerial surveillance programme became the responsibility of MUMM, the Management Unit of the North Sea Mathematical Model, which was then part of the federal Ministry of Public Health and the Environment but is now a scientific service within the Royal Belgian Institute of Natural Sciences (RBINS), which falls under the Belgian Federal Science Policy Department. From the inception of the aerial surveillance programme, MUMM worked closely with the Ministry of Defence, with the latter providing pilots and an aircraft.

1.2. Evolution of aerial surveillance

Since the early days of the aerial surveillance programme, its core task has been to monitor marine pollution, primarily from ships (see chapter 4.1): tracing illegal marine pollution (in particular infringements of discharge regulations as laid down in the International Convention for the Prevention of Pollution from Ships (MARPOL)[6], which in Belgium was implemented through the MARPOL implementation act[7] of 1995), catching polluters in the act, creating a deterrent effect and providing air assistance in the event of accidental marine pollution, as part of emergency planning at sea.

Although the Belgian observation aircraft mainly supervises the Belgian marine areas and surrounding waters, it also participates in annual international surveillance operations under the Bonn Agreement (see chapter 4.1.3). For example, since the early 1990s, surveillance aircraft belonging to the various North Sea countries have been taking turns monitoring the offshore oil and gas installations in the central part of the North Sea for marine pollution, as part of the annual «Tour d'Horizon" operations (TdH). The North Sea countries also regularly work together, intensively monitoring a specific high-risk area, such as a busy shipping area, for illegal discharges, deploying multiple surveillance aircraft for one or several days during the so-called CEPCO operations (Coordinated Extended Pollution Control Operation). There are also regular international counter-pollution exercises (BONNEX), with the aim of exercising cooperation between countries in combating large pollution incidents at sea.

Since 1993, the surveillance aircraft has an important secondary mission: carrying out fishery control flights on behalf of the Fisheries Authority *(Dienst Zeevisserij, DZV*), belonging to the Flemish Government - Department of Agriculture and Fisheries, systematically monitoring fishing activities from the air, by day and by night (see chapter 6.2).

Since additional satellite surveillance was introduced around 2005, the aircraft is also used

to verify satellite detections of presumed oil pollution in the Belgian marine areas, which are reported via the European Maritime Safety Agency's (EMSA) service "CleanSeaNet".

Belgian maritime policy is largely governed by international treaties and policy instruments, including collaborative partnerships at both European and regional levels. In order to implement the United Nations Convention on the Law of the Sea[a,8] two important laws were adopted in Belgium: (i) the law on the protection of the marine environment and the organisation of marine spatial planning in the marine areas under the jurisdiction of Belgium (Marine Environment Act of 22 April 1999, as amended[9]) and (ii) the law on the exclusive economic zone (EEZ) of Belgium (EEZ Act of 22 April 1999[10]). The Marine Environment Act is the foundation for marine protected areas and the protection of species, the prevention and reduction of pollution and environmental perturbation, the introduction of permits for numerous activities, measures to prevent pollution in the event of shipping accidents, and significant changes to the MARPOL implementation act, which broadened Belgium's powers of enforcement against illegally discharging vessels. In the late 1990s, the EEZ law resulted in an important extension of Belgium's jurisdiction at sea, extending its national waters, which stretch around 85 km off the coast and comprise the territorial sea and EEZ (see chapter 5.2).

This extension of jurisdiction and the greater environmental powers associated with it also caused the aerial surveillance programme to be extended and to include tasks falling within the marine science and environmental policy support remit of MUMM (RBINS), such as the monitoring of licensed activities at sea (including wind farms, aquaculture, sand extraction and energy production), or the monitoring of protected species (like marine mammals), other marine organisms or phenomena (such as plankton blooms) and marine protected areas (see chapters 5 and 6.4).

[a] In 1998, Belgium adopted the United Nations Convention on the Law of the Sea (UNCLOS), the world's leading legal framework for the sea. The treaty confers greater powers to coastal States and port States to act more effectively against illegal discharges from ships, and also determines that coastal States can establish an EEZ adjacent to their territorial sea, where they may exercise their own jurisdiction in different fields.

The Belgian federal government is responsible for most sea-based activities, like environmental policy, shipping and offshore energy, as well as the powers and missions of police, customs and Defence. The Flemish government is responsible for, among other things, fishing, shipping assistance, dredging, pilotage, search and rescue and coastal defence works[11]. With the extension of Belgian jurisdiction at sea, the need arose to establish a structure which allows for the organisation of cooperation between public services with powers at sea. This cooperative structure was established in 2005: the Belgian Coast Guard[12] is responsible for operational coordination and consultation between the 17 Flemish and federal public services who have powers at sea, and the province of West Flanders.

MUMM represents the Federal Science Policy Department within the Belgian Coast Guard. With its environmental and scientific expertise, MUMM makes an important contribution to this body. As a result, the remit of the Belgian aerial surveillance programme was extended further (figure 1). For example, aside from pollution and fisheries control flights, the surveillance aircraft nowadays also provides additional aerial support to several Flemish and federal Coast Guard partners, e.g., monitoring of navigational infringements and various maritime prohibitions, providing support for police operations at sea (to combat illegal trade and transport), and providing second-line assistance for SAR operations and transmigration incidents.

Belgian aerial surveillance continues to evolve and is set to address new environmental challenges. Since 2015, the aircraft has also been monitoring ship emissions at sea, which is a new European priority in the fight against air pollution (see chapter 4.2). MUMM has been able to play a pioneering role internationally in this new enforcement area, by becoming one of the first services to make effective use of innovative sensor technology on board an aircraft.

In the past 30 years, the Belgian surveillance aircraft has evolved from fulfilling a role that was purely about pollution control to a multi-tasking maritime surveillance Coast Guard aircraft, supporting a wide range of government tasks – to the extent possible. This broader concept of maritime aerial surveillance is inherent to the role of the Coast Guard, as it is in other countries, to fulfil national

responsibilities and international obligations as a European coastal State, in accordance with the three main cornerstones of the Coast Guard's mission: maritime safety, maritime security and law enforcement, and protection of the marine environment.

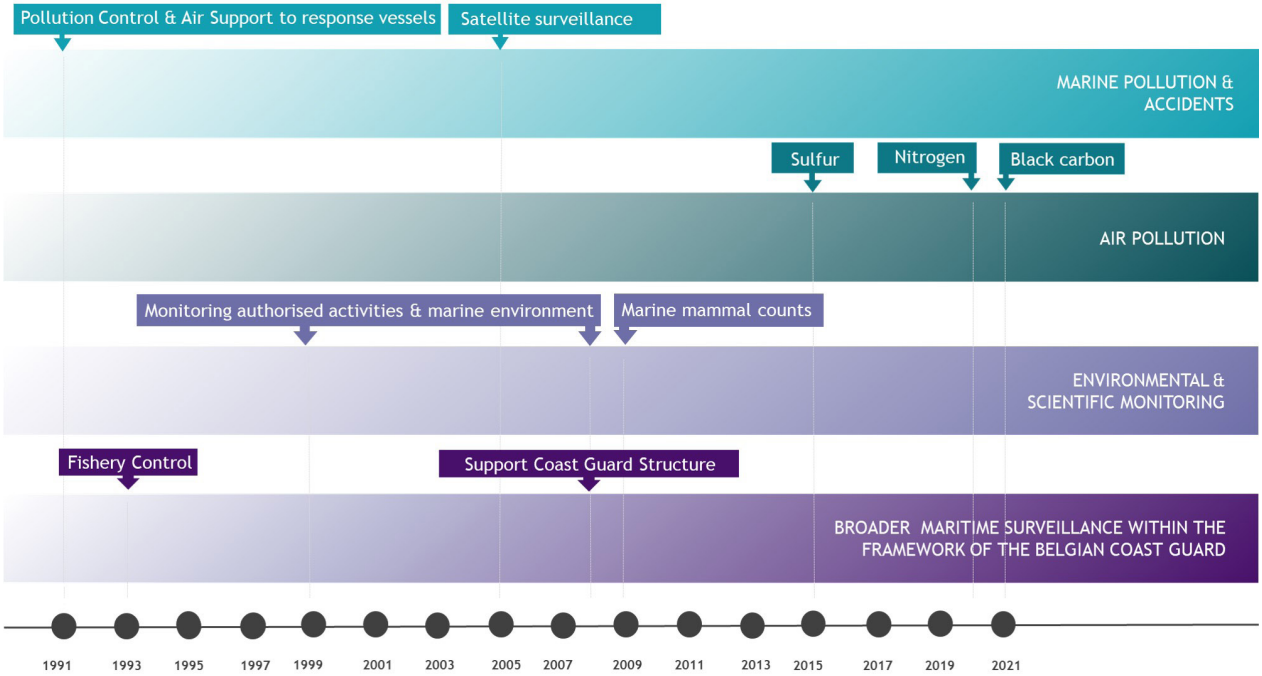

Figure 1. Aerial surveillance in time and by themes. A schematic overview of the various mission types of the Belgian Coast Guard aircraft, from the start of the Belgian aerial surveillance programme (in 1991) to date.

The Bonn Agreement

The sea is a particularly open and dynamic environment, which means that marine pollution can very quickly have cross-border consequences and can threaten the interests of several coastal States in the same marine region. It is therefore in the interest of these countries to cooperate at a regional level in order to protect and preserve the marine environment. The Bonn Agreement, an agreement to prevent and combat pollution from oil and other harmful substances in the North Sea, facilitates cooperation between 10 coastal States (Belgium, Denmark, Germany, France, Ireland, The Netherlands, Norway, Sweden, the United Kingdom, and more recent Spain) and the European Union, in order to effectively deal with pollution in the greater North Sea and its approaches as a result of maritime accidents and chronic pollution from ships and offshore installations. The Agreement was created in 1969, after the *Torrey Canyon* tanker disaster, making it the oldest inter-government regional agreement in the world aimed at dealing with marine pollution. In addition to the pollution control operations (which include responsibilities, procedures, studies and projects), since the early 1990s the Bonn Agreement has also been coordinating regular aerial surveillance by the North Sea coastal States, to prevent illegal pollution and support the fight against accidental pollution in the North Sea. Specially equipped surveillance aircraft are used for this purpose, with the aim of enforcing international discharge standards, creating a deterrent effect, monitoring major marine pollution, and providing air support to pollution combating units at sea.

The North Sea countries regularly carry out national pollution control flights in their designated surveillance areas, their so-called 'Responsibility Zones'. The flights are primarily aimed at tracing pollution from shipping and the enforcement at sea of the MARPOL Convention of the International Maritime Organisation. In addition, the aircraft are used to verify satellite detections of suspected marine pollution, which are supplied by EMSA (CleanSeaNet service - CSN). Apart from the national aerial surveillance programmes, the Bonn Agreement also implements a regional 'Tour d'Horizon' programme for aerial surveillance of marine pollution from offshore oil and gas installations in the central North Sea. Another type of regional flight is CEPCO: a joint intensive surveillance operation over the sea, running for at least 24 hours and up to several days. The surveillance aircraft also regularly participate in sub-regional and regional counter pollution exercises, organised within the framework of the Agreement. These national and regional aerial surveillance operations are carried out in line with the Aerial Operations Handbook (AOH). This manual is part of the Bonn Agreement and contains jointly agreed operational procedures, recommendations and guidelines for the detection, evaluation, documentation and reporting of marine pollution. The AOH ensures that operators on board the various surveillance aircraft follow the same procedures when planning and carrying out control flights, and when collecting and reporting evidence during a pollution incident. The manual also contains a section on the oil volume estimation method developed within the Bonn Agreement, the internationally recognised and used Bonn Agreement Oil Appearance Code or BAOAC (see chapter 2.3). The roles and procedures relating to surveillance aircraft in anti-pollution operations are also discussed in the AOH.

Following the lead of a number of countries like Belgium, Denmark, Germany, the Netherlands and Sweden, which had successfully started monitoring air pollution from sea shipping a few years earlier, the Bonn Agreement Contracting Parties decided in 2019 to extend their surveillance activities at sea with the compliance monitoring and enforcement of the international ship emission standards as set out in MARPOL Annex VI. This makes the Bonn Agreement the first regional agreement in the world aiming to make a significant contribution to the international fight against air pollution from ships. It does so by rolling out surveillance of ship emissions across the whole of the North Sea.

2. AERIAL SURVEILLANCE IN PRACTICE: SURVEILLANCE AREA, RESOURCES, METHODOLOGY & STRATEGY

2.1. The surveillance area and its challenges

2.1.1. Regular monitoring in and around the Belgian marine areas

The surveillance area of the Belgian Coast Guard aircraft is defined in the Bonn Agreement as the "Joint Responsibility Zone". This zone is situated between two northern latitude parallels in the southern North Sea and encompasses the Belgian marine areas and the neighbouring countries' waters. Within this surveillance zone, Belgium, the Netherlands, France and the United Kingdom have the right to conduct regular pollution control flights[5] (figure 2). This part of the southern North Sea is internationally known as one of the busiest sea areas in the world[13,14], making it a high-risk area for operational or accidental spills that could severely affect the four neighbouring coastal States. The majority of the Belgian Coast Guard aircraft's surveillance tasks are carried out over the Belgian marine areas, consisting of the territorial sea and the exclusive economic zone (EEZ). Together they make up an area of almost 3500 km^2, which would be roughly the size of an eleventh Belgian province, but is still only 0.5% of the North Sea. Belgium also has by far the shortest coastline (approx. 65 km) of all the North Sea countries[15]. Nevertheless, the Belgian section of the North Sea is one of the most heavily used marine areas in the world, which makes it highly important and very vulnerable both from an ecological and socio-economic perspective.

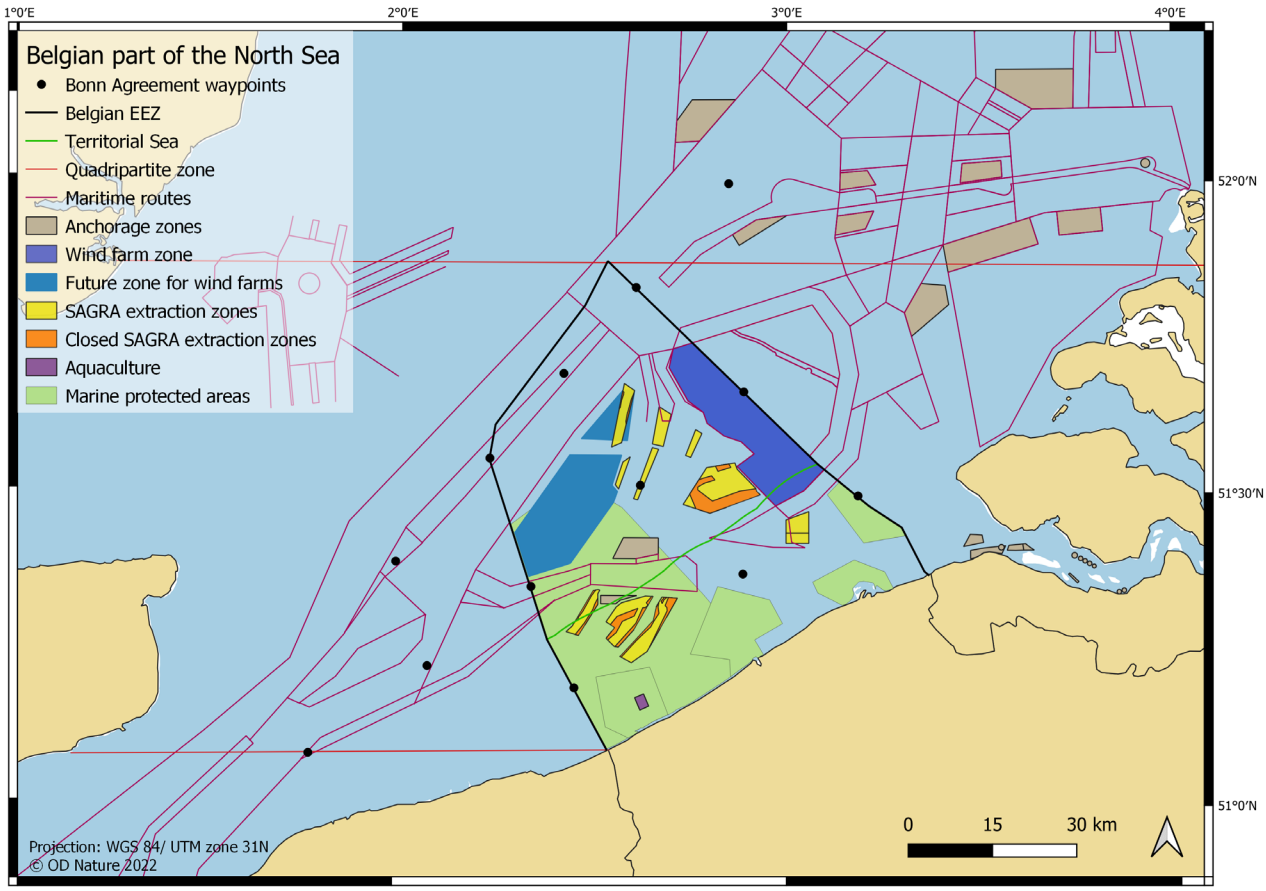

Figure 2. Map of the Belgian Coast Guard aircraft's surveillance area (EEZ: exclusive economic zone, SAGRA: sand and gravel extraction).

The evolution of the Belgian surveillance area over the past 30 years

While the area covered by aerial surveillance has remained almost entirely unchanged since flights commenced in 1991, the legal framework has undergone significant changes. Initially, the sea area where Belgium had jurisdiction was mainly limited to its territorial sea. From 1987, Belgium's territorial sea extended 12 nautical miles off its coast, as opposed to 3 nautical miles before 1987. Prior to 1999, Belgium's jurisdiction included not just its territorial sea, but also the Belgian continental shelf (BCS, the seabed and subsoil of the submarine areas that are adjacent to the coast but which lie outside of the territorial waters), limited to the exploitation of natural resources (mineral and other non-living resources of the seabed and subsoil, together with living organisms belonging to sedentary species). The joint responsibility zone, which was established under the Bonn Agreement, was smaller than it is today, comprising only part of the French, English and Belgian waters (the so-called 'tripartite' zone) (figure 3A).

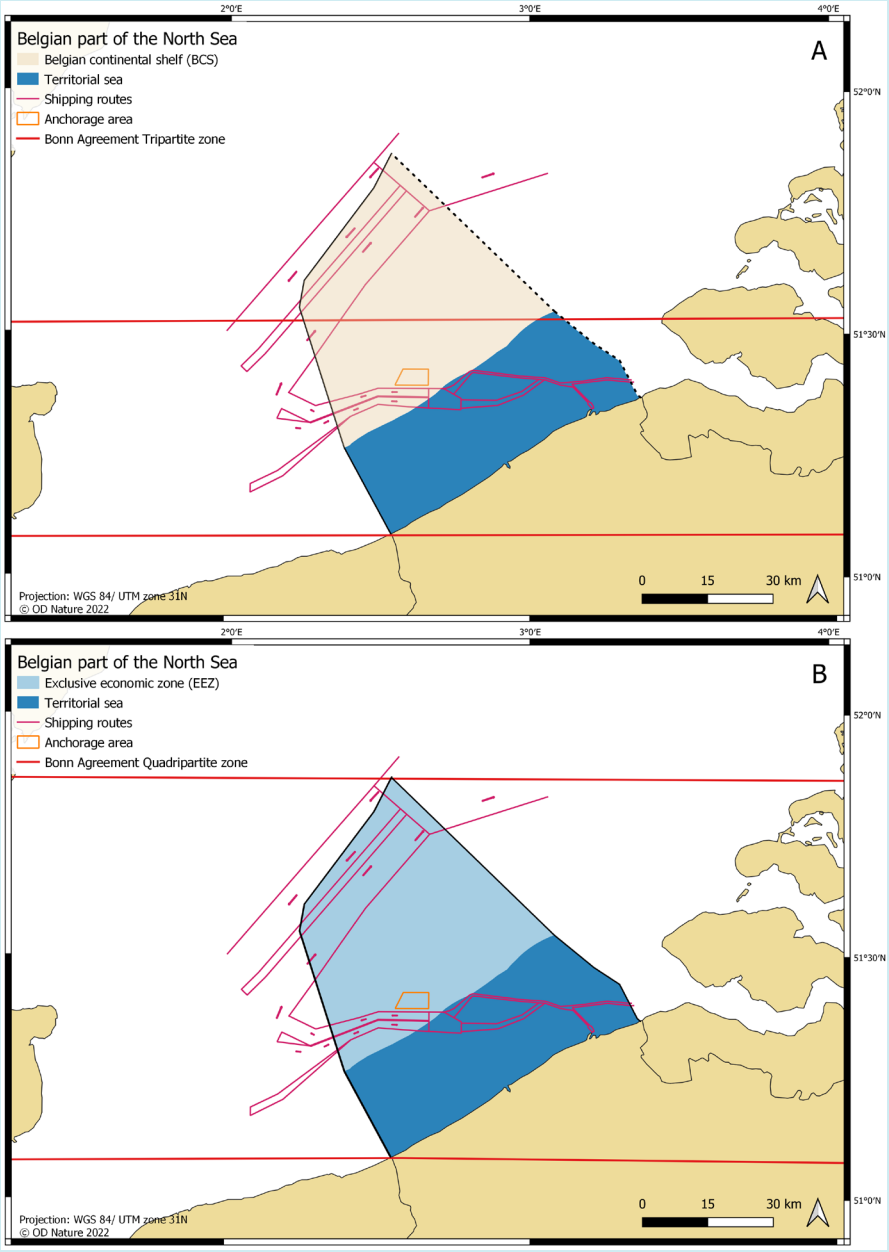

*Figure 3. Maps presenting an overview of the Belgian Coast Guard aircraft's surveillance area. **A**. Before the turn of the century. **B**. After the turn of the century, with the extension of Belgium's jurisdiction after the establishment of the EEZ (in 1999) and the extension of the Bonn Agreement joint responsibility zone up to the degree of latitude which crosses the northernmost point of the Belgian EEZ (changing from a tripartite to a quadripartite zone in 2003). In the 1990s, there was no established maritime border with the Netherlands (the dotted line represents the hypothetical sea border).*

Following the expansion of Belgian jurisdiction at sea in the late 1990s, Belgium has become responsible for both the territorial sea and the EEZ. The EEZ corresponds to the BCS in terms of area, and includes both the seabed and the water column above it. Changes were therefore also made at Bonn Agreement level. The previous tripartite zone covered only part of the EEZ, moreover, it was perfectly logical that also the Netherlands should be able to carry out regular surveillance in this joint responsibility zone, given the fact that a marine pollution incident occurring in the tripartite zone would often threaten Dutch waters as well. In 2003 it was therefore decided to extend the borders of the joint responsibility zone as defined by the Bonn Agreement, extending it as far as the northern border of Belgium's EEZ, and adding the Netherlands to the zone. Consequently, the tripartite zone became a four-party or quadripartite zone[16] (figure 3B).

2.1.2. Ecological importance of the Belgian waters and coastline

The Belgian waters are situated in the southern part of the North Sea and are very shallow. The average depth is 20 m, gradually increasing to the north-west to a maximum depth of 40-45 m. The seabed is characterised by a complex system of elongated sandbanks, up to 30 m high compared to the trenches, with a length of 15 to 25 km and a width of 3 to 6 km. This dynamic marine environment of sand and gravel beds, as well as banks of sand mason worms (*Lanice conchilega*), is a real biodiversity hotspot. This system of sand banks, with its rich soil full of life, is also an important feeding and nursery area for higher trophic levels such as fish and birds[17]. The Belgian coastal waters are very important spawning and nursery areas for, among others, economically important fish species like sole (*Solea solea*)[18], as well as a haven for endangered species such as dead man's fingers (*Alcyonium digitatum*) and mermaid's glove (*Haliclona oculata*)[15]. Belgium's waters are also an important wintering and feeding area for seabirds, as they are situated on annual migration routes used by millions of birds[19,20].

In order to sustainably maintain these valuable marine habitats and marine bird areas, a number of marine protected areas have been created: the 'Vlaamse Banken' ('Flemish Banks') in the west, (protecting shallow sandbanks, gravel beds and banks of sand mason worms, harbour porpoises, and common and grey seals), three bird protection areas along the coast and a new protected area stretching along the Dutch border: the 'Vlakte van de Raan'. The Belgian coastline consists mainly of fine sandy beaches and dunes. There are also three important intertidal areas of salt marshes and mud flats: the 'Zwin', the 'IJzermonding' and the 'Baai van Heist': a nature reserve made up of a coastal and a marine part[17].

This rare combination of a shallow sandbank system with an important spawning and nursery function, with numerous wintering, migrating and foraging seabirds, and the silty, low-oxygen soils of the neighbouring salt marshes and mud flats, unfortunately also makes the Belgian marine and coastal areas particularly vulnerable from an ecological point of view, especially from all kinds of marine pollution.

2.1.3. Socio-economic importance of the Belgian waters and coastline

The Belgian marine areas also have a vital socio-economic role to play. They are situated to the north-east of the Dover Strait, between Calais and Dover. Maritime transport is by far the most important economic activity in our waters. The two most important ports in Europe - Rotterdam and Antwerp - are a stone's throw away, and the Belgian marine areas serve as the gateway to all Belgian seaports (Zeebrugge, Ostend, Ghent and Antwerp). It is one of the busiest shipping areas in the world, with over 150,000 ships passing through every year - or about 400 a day[21]. Two major shipping routes run through the area: (i) the North Hinder Traffic Separation Scheme (NHTSS), which is the central traffic separation scheme forming the main link between the Dover Strait and the greater North Sea; and (ii) the West Hinder TSS (WHTSS), branching off the NHTSS in French waters and running through Belgian waters in the direction of Zeebrugge and the Scheldt ports[22].

Apart from shipping, there are other important activities taking place at sea. In order to allow ships to sail smoothly through the fairways, they need to be dredged; sand and sludge need to be removed.

The Belgian Coast Guard structure

In view of the increase in human activity in the Belgian marine areas and the many challenges that exist in terms of maritime safety, maritime security, enforcement, and the protection and sustainable management of the marine environment, a Coast Guard structure was established, based on the Coast Guard Collaboration Agreement of 8 July 2005[12]. This Coast Guard structure facilitates collaboration between the 17 different federal and Flemish services charged with specific tasks at sea - including the federal Science Policy Department.

The Flemish services involved in the Coast Guard are the Department of Agriculture and Fisheries (Fisheries Authority), the Port and Water Policy Division, the Flemish Fleet and Pilotage Services, the Coastal Division, the Shipping Assistance Division, the International Policy Division and the Maritime Access Division. The Federal partners are FPS Interior, FPS Foreign Affairs, Foreign Trade and Development Cooperation, FPS Health, Food Chain Safety and Environment (DG Environment), FPS Mobility and Transport, FPS Finance, FPS Economy, Defence, Federal Science Policy Department (BELSPO) and the Federal Institute for Sustainable Development. The governor of West Flanders is also represented in the Coast Guard.

The Coast Guard structure is made up of an administrative branch, consisting of three administrative elements (the Policy-making body, the Consultation body and the Secretariat), and an operational branch, i.e., the Coast Guard Centre. The Coast Guard Centre is made up of two complementary parts: the Maritime Rescue and Coordination Centre (MRCC) in Ostend, which is in charge of safety at sea and coordinates rescue operations, and the Maritime Security Centre (MIK) in Zeebruges, which takes charge of security at sea and monitors compliance with applicable regulations at sea (enforcement).

The dredging spoil is subsequently dumped at the specific dredging dumps designated for this purpose. In our North Sea, 2 to 3 million tonnes of sand is extracted every year. This is mainly used in the construction industry, as a basic component of concrete. Several sand extraction areas were designated for this purpose. To protect our coast from storms and floods, beaches are regularly raised with huge volumes of sand[23]. The Belgian waters are also important fishing grounds, due to the presence of various commercially interesting species like sole, plaice, dab, flounder, cod and brown shrimp[24]. Aquaculture and passive fishing have the potential to become important new activities for fish production and fishing in Belgium. The North Sea also offers space for wind farms, for the generation of renewable energy. Pipelines for gas, electricity and telecommunications cables are bundled, to the extent possible, in established corridors. The Belgian maritime area is also regularly used for military activities and exercises, mainly shooting practice from land towards the sea and exercises to defuse mines. The Ministry of Defence carries these out in specific areas, where no other activities are permitted during the exercises[15]. The Belgian coast is the country's most popular holiday destination, especially during the summer months. In 2019, the year before COVID-19 severely affected tourism, the region recorded almost 28 million overnight stays and there were also nearly 18 million day trippers[25]. The sea offers its many visitors plenty of leisure opportunities.

For all these activities to take place safely, in accordance with existing regulations and in balance with nature, monitoring, surveillance and enforcement at sea is an absolute necessity. This is a significant challenge for the Coast Guard (see box), with aerial surveillance over the North Sea as a crucial operational and supporting link.

2.2. The aircraft, instrumentation and personnel on board

2.2.1. The aircraft

From the very start of operations in 1991, MUMM has cooperated closely with the Ministry of Defence on the implementation of the aerial surveillance programme. The army, specifically the School of Light Aviation in Brasschaat, initially supplied a twin-engine military 'Britten Norman

Islander' aircraft and several military pilots to enable MUMM to carry out surveillance flights over the North Sea (figure 4A). MUMM equipped this military aircraft (call sign B-02) with analogue instrumentation for remote sensing of marine pollution, navigation and communication.

When the army retired all 'Britten Norman Islander' aircraft in late 2004, the cooperation between MUMM (which by this time was part of RBINS) and the Ministry of Defence was adapted. The specially equipped military aircraft B-02 was transferred to the RBINS, where it was re-fitted in 2005-2006, painted in new livery and adapted to the standards of civil aviation (figure 4B). In accordance with the Protocol Agreement of 31 May 2005 between the RBINS and the Ministry of Defence, Defence (COMOPSAIR) has continued to supply military pilots. In 2006, the RBINS launched a renewed programme, taking on the management of the aircraft, now with call sign 'OO-MMM', but leaving the flight controls in the capable hands of military pilots who were already familiar with the project. Deurne airport became the aircraft's base, and remains so to date.

In 2012, after 20 years of aerial surveillance, the aircraft was fitted with a modernised cockpit and equipped with a new, fully integrated and digital mission management system, which made documenting and reporting a growing number of different observations and findings much quicker - also speeding up the follow-up on shore. Since the aircraft was repainted in 2017, it is also clearly identifiable as a Coast Guard aircraft, with the typical oblique stripes, as well as the Coast Guard's name and logo (figure 4C).

2.2.2. The instrumentation on board

A full overview of instrumentation on board can be found in Annex 1. The aircraft is equipped with remote sensing instruments or sensors to detect, analyse and document marine pollution at both short and long range. The SLAR (Side Looking Airborne Radar) is the aircraft's most important sensor. It actively scans the sea surface over a lateral distance of 20 km to the left and right of the aircraft (long-range sensor). The antennas, the 2 black tubes underneath the aircraft, transmit radar waves and receive the reflected signals (figure 5). A black line or spot on a SLAR image, visible in high contrast with the surrounding seawater (which appears on a SLAR image in an even-grey colour) indicates possible marine pollution (figure 6). The smoothing effect of oily substances on the waves, preventing radar signals from bouncing back, is what underpins this form of remote sensing. Mineral oil slicks, or other floating liquids with a similar damping effect, can therefore be detected at great distances both during the day and at night, in good as well as poor visibility. The additional infra-red (IR) camera on board the aircraft is a passive sensor that detects temperature differences on the surface of the water, either between a slick and the surrounding water or between the thicker and thinner parts of the slick itself.

In 2015, an innovative 'sniffer' sensor was added to the Belgian Coast Guard aircraft (figure 7), which allows to determine the sulfur content of ship fuel by analysing the smoke plume of a sailing vessel[26]. These monitoring flights were initiated as part of the European pilot project 'CompMon' (EC/CEF Compliance Monitoring pilot for MARPOL Annex VI)[27], with the aim of

*Figure 4. **A**. The military aircraft B-02 in the period 1991-2006. **B**. OO-MMM in the period 2006-2016. **C**. OO-MMM since 2017, with the typical block colours and the Coast Guard name and logo.*

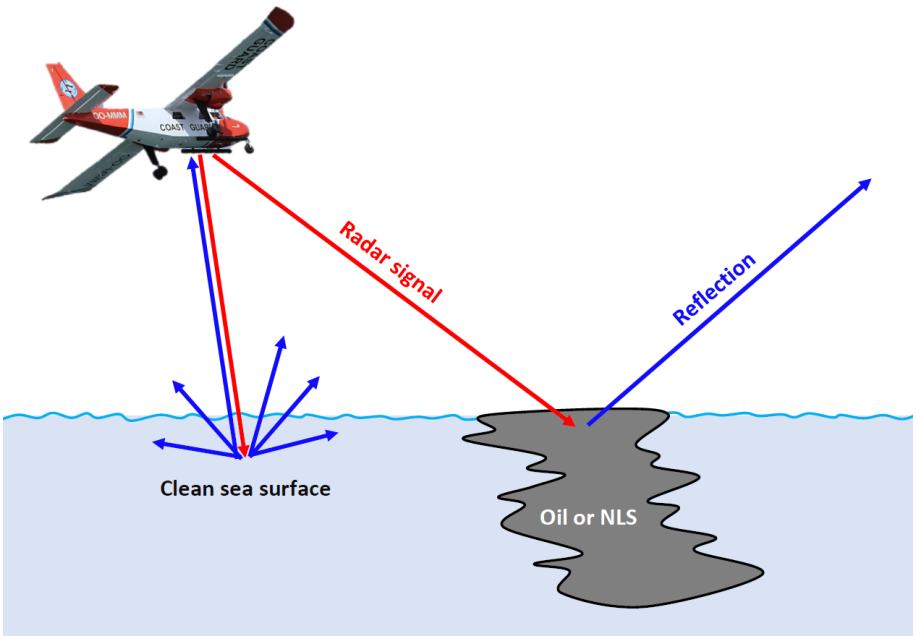

Figure 5. Schematic representation of how a Side Looking Airborne Radar (SLAR) works.

contributing to the enforcement of the strict sulfur emission standards for ships that are in place, in addition to the Port State Control inspections (PSC) – in Belgium executed by the Directorate-General Shipping. The project demonstrated that monitoring sulfur emission from individual ships at sea with 'remote sensing' techniques can very effective be used for targeted ship inspections in port. The sniffer sensor, that was acquired with the support of the European Commission, was developed by Chalmers University (Gothenburg, Sweden) and marketed by FluxSense (Sweden). The sniffer consists of a set of different scientific gas analysis instruments[26]. The measurement is carried out by flying through the emission plume, following a specific procedure (figure 8, figure 9).

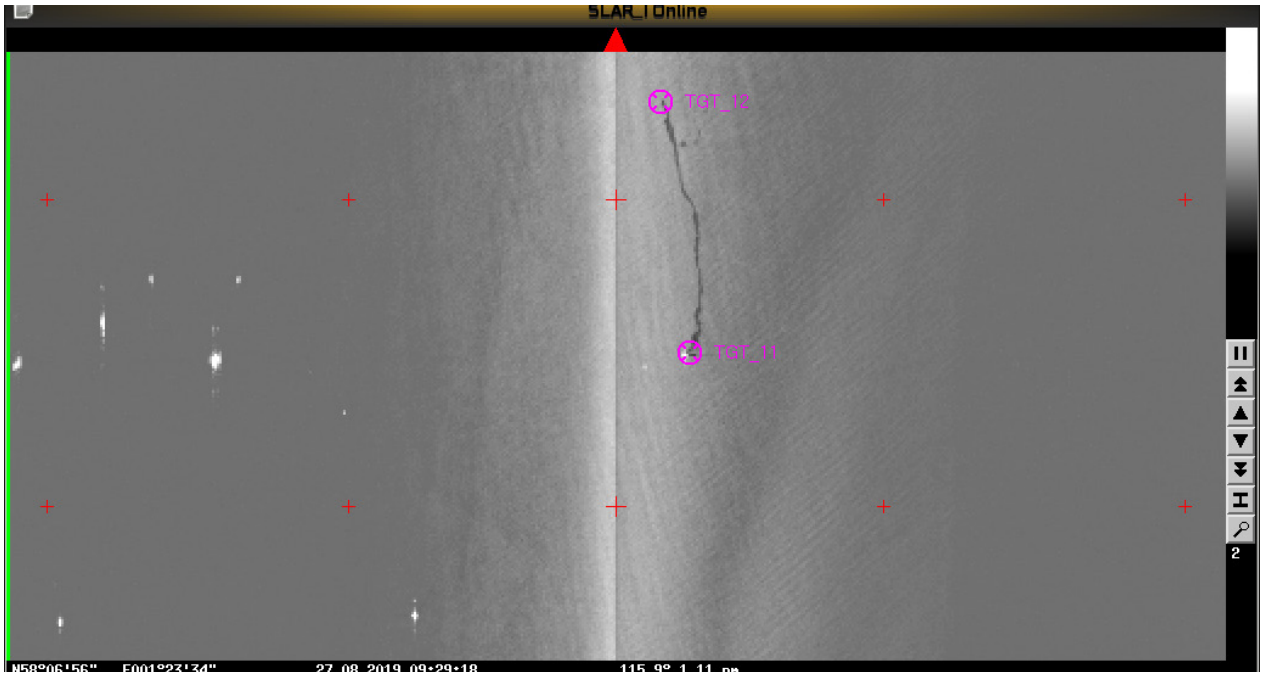

Figure 6. SLAR image of an oil slick (dark grey line) linked to an oil rig (white dot), captured during the 2019 Tour d'Horizon mission.

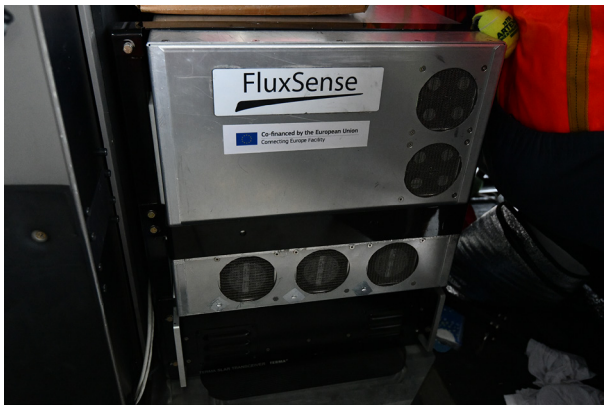

Figure 7. The sniffer sensor on board the Coast Guard aircraft.

Via a probe on the bottom of the plane outside air is continuously pumped through the sensors of the sniffer, which is immediately analysed (figure 10A-B). This monitoring can be carried out throughout the year and in most weather conditions. In order to ensure accurate measurements, the instruments are calibrated before each flight. Supporting expertise was found in Belgium, at the Brussels Environment department (Leefmilieu Brussel/Bruxelles Environ-nement (BIM/IBGE)) and the Flanders Environment Agency (VMM). This method not only allows for more efficient monitoring of the impact of shipping on air quality above the sea, but also allows for identification of potential offenders and reporting to the competent port inspection services.

In 2020, the initial sniffer sensor was extended with an NO_x sensor, which allows the Belgian Coast Guard aircraft to monitor the latest NO_x emission standards from the air, in addition to the sulfur measurements it was already carrying out[28]. The latest addition to the sniffer system took place in 2021 and was a black carbon (BC) sensor, which measures the emission of black carbon (soot). With this new BC sensor, MUMM hopes to generate new insights on black carbon emissions from global shipping over the next few years, with a view to possible future regulations to reduce ship emissions. BC measurements only started in 2021, so there is not yet enough data to discuss the results in the current activity report. These will certainly be reviewed in future, however.

The aircraft is also equipped with a digital video camera and two digital reflex cameras, used to document observations and findings. The GPS and the Flight Management System (FMS) allow for exact localisation, but also the registration of time, date, wind speed and direction, and the course and speed of the aircraft. The central

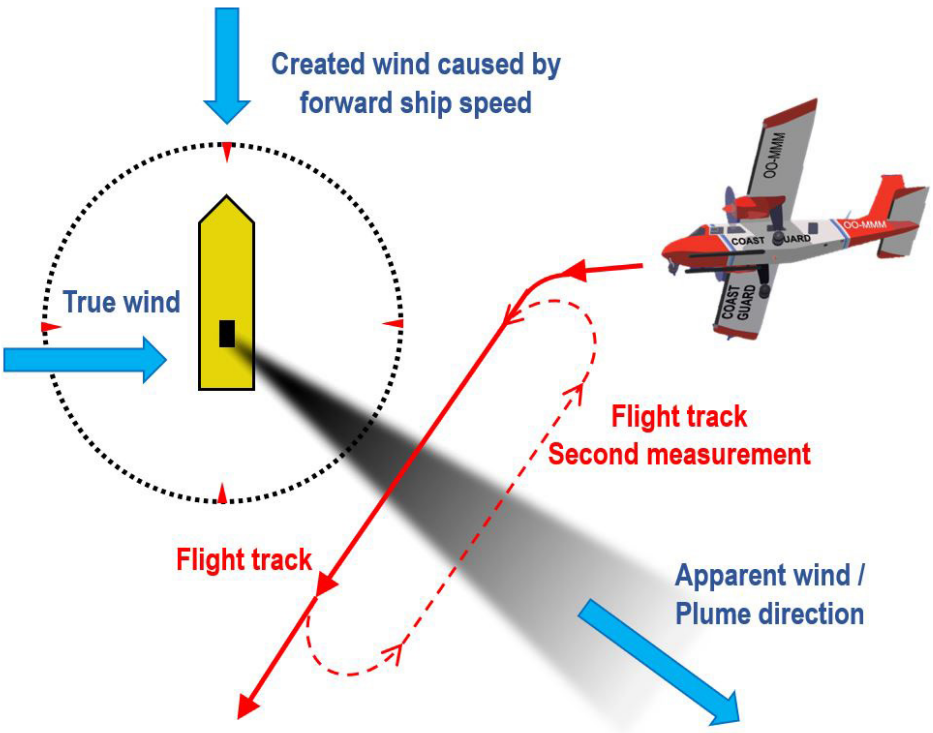

Figure 8. Schematic representation of a ship approach for emissions monitoring.

Figure 9. Approaching a ship to measure its emissions.

A

B

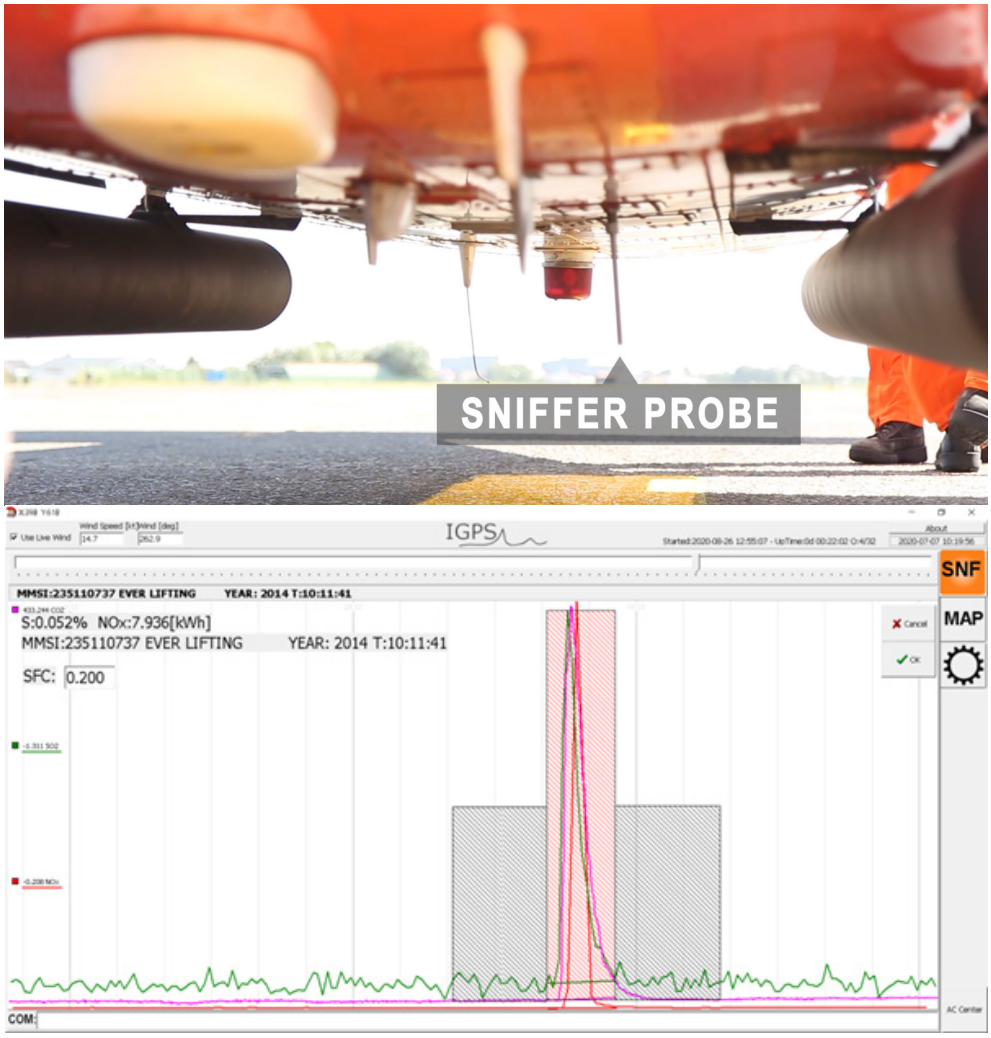

Figure 10. ***A****. A probe on the outside is connected with the sniffer sensor on board through the belly of the plane.* ***B****. The air of the smoke plume is immediately analyzed by the sensors and displayed on the graph, with a clear peak in the* SO_2 *and* NO_x *values.*

digital MEDUSA control unit integrates the various sensors and sensor images (figure 11). In addition, the aircraft is equipped with all the necessary communication tools (VHF radio and 'SATCOM' satellite communication) to ensure that its mission can be performed as efficiently as possible. Lastly, the aircraft is also equipped with Wi-Fi, to enable flight reports and any photographic or video evidence to be sent to relevant partners immediately after the flight.

2.2.3. Qualified and trained personnel

The Belgian Coast Guard aircraft is flown by military pilots and crewed by MUMM operators with a scientific background. Just like the BELGICA, Science Policy's oceanographic research vessel, the national aerial surveillance programme enjoys all the benefits of the intrinsic strengths of both Defence and Science Policy, specifically the efficient combination of operational and scientific expertise. Over the years, this synergy has produced some remarkable results, as discussed further on in this report.

MUMM's operators are legally authorised to carry out environmental monitoring and surveillance under the Marine Environment Act[9], and to monitor ship discharges in accordance with the Belgian Maritime Code[29]. When identifying operational or accidental pollution, the crew adheres to the internationally-agreed procedures entailed in the Bonn Agreement. For other Coast Guard surveillance tasks, which MUMM personnel may not be expressly authorised to carry out, the operational procedures agreed with the Coast Guard partners are adhered to (see box 2.1.3 and chapter 6.1).

Figure 11. The MEDUSA console on board the Coast Guard plane.

When detecting or observing a potentially serious marine pollution incident, the information gathered by the aircraft can quickly be relayed and linked to other marine scientific disciplines represented at the RBINS, such as mathematical models, chemical analyses, scientific monitoring and impact assessments, use of satellite detection, and so on. This internal pooling of scientific expertise to arrive at a solid, scientifically rooted evaluation of a (potential) marine pollution incident provides valuable additional support for the Belgian government's intervention and decision-making. This includes the substantiation and presentation of the burden of proof in criminal cases, or in compensation claims resulting from accidental marine pollution.

Air safety is, of course, central in the aerial surveillance operations. This is why the pilots and operators regularly have joint training sessions, to ensure they are able to deal with unexpected situations such as an accident, fire or crash. SWET (Shallow Water Escape Training), COLD SWET or HUET (Helicopter Underwater Escape Training) training sessions are conducted every year. During these training sessions, the crew are placed in a cage that is toppled into the water (figure 12a, b). The aim for the crew is to free themselves, according to a specific safety procedure, and get to the surface as quickly as possible. Whereas a regular SWET exercise takes place in an indoor heated pool, the COLD SWET is done in the winter months in an unheated outdoor pool. The HUET also takes place in an indoor pool, but with the added difficulty of simulated waves, darkness and lightning. There are also regular training sessions around First Aid, CRM (Crew Resource Management) and firefighting, to ensure the crew can respond appropriately in emergency situations. Every six years, the crew also takes part in Sea Survival training. All of this safety training is part of a professional Safety Management System. MUMM really benefits from the extensive safety expertise available within the Ministry of Defence, as provided for in the Protocol Agreement of 2005. Airborne staff also regularly participate in substantive training, both at a national (internal MUMM training, training provided by the Fisheries Authority (DZV), counter pollution

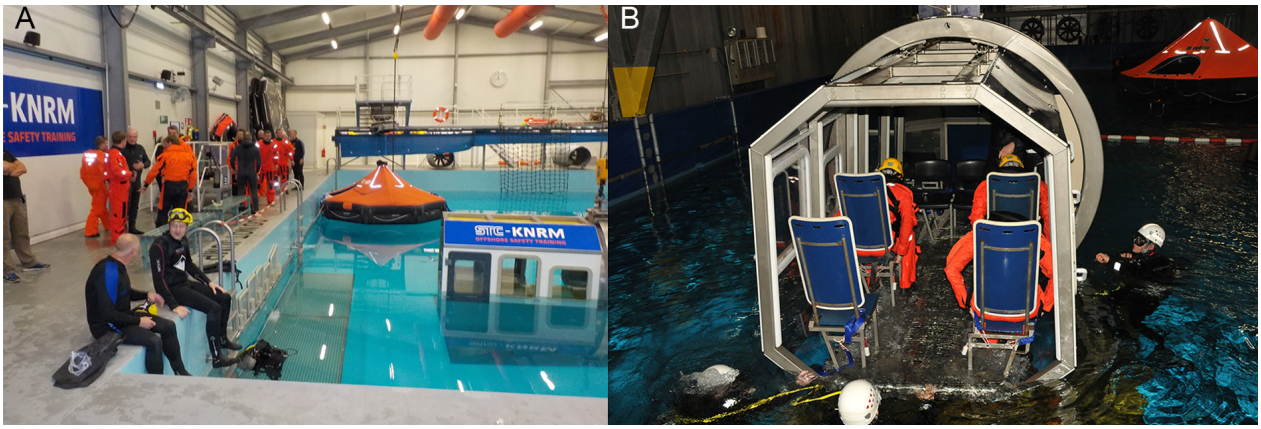

*Figure 12. **A-B**. The HUET training is intended to train pilots and operators to escape an upended cabin (representing the plane) as quickly as possible. Other sea survival techniques are also trained.*

exercises, etc.) and a European level (specialised European surveillance training and workshops, mainly organised by EMSA).

2.3. Methodology and flight strategy

The Belgian Coast Guard aircraft operates over the sea several days a week, both during the day and at night, during the week and at the weekend, throughout the year. The aircraft's robustness and on-board instrumentation enable it to operate in fog and bad weather. Given the nature of the assignment, flight planning is strictly confidential. A long-term schedule (drawn up on a monthly and annual basis) aims to combine the various tasks as efficiently as possible, while ensuring the plane's regular presence at sea. The planning takes into account the number of flight hours available annually, the frequency required for different tasks, any seasonal or spatial variations in natural phenomena or activities at sea, as well as maintenance of the aircraft and other factors. Since 2007, the monthly planning has also been taking into account the passes of the satellites used as part of EMSA's CleanSeaNet service (see box)[30]. This enables a quick response when a satellite detection requires visual verification. MUMM operators perform the initial evaluation of the reported satellite detections to determine whether a flight is required (figure 13).

When the Coast Guard aircraft is temporarily grounded for inspection, maintenance or repairs,

EMSA's CleanSeaNet (CSN) Service

The European Maritime Safety Agency (EMSA) helps the European Member States to identify and detect illegal discharges and polluters through the CleanSeaNet satellite service. The service was launched in 2007 following a pilot project called MARCOAST, which was financed by the European Space Agency (ESA) and was able to demonstrate the capability for a pan-European oil pollution detection system. The radar technology used for this satellite surveillance (SAR or Synthetic Aperture Radar) is similar to the technology used on board the aircraft (Side Looking Airborne Radar – SLAR). Using the SAR satellite images, the exact locations and dimensions of potential oil slicks on the sea surface can be detected, and suspected polluters can be traced[30].

In recent years, there has been a huge increase in the number of planned satellite passes per month. As a result, the annual number of detections increased as well. In 2009, the year CleanSeaNet was launched, there were 13 satellite detections of potential marine pollution. By 2021, the number of detections had risen to 48. The record year for the Belgian surveillance area was 2018, with 65 detections alerts. Satellite detections are systematically followed up by MUMM operators. Where needed, the Coast Guard aircraft is deployed to perform verification at sea. The results of this verification effort are already included in the figures for operational marine pollution (see chapter 4.1.1.1).

another plane (not equipped with sensors) is used to ensure continuity in aerial surveillance. In this case, basic portable equipment is brought on board, consisting of navigational instruments, communication devices and photography equipment.

In addition to the monthly and annual planning, a daily schedule is drawn up for each flight day, aligning the flight's duration and route with the task at hand and the target area (priority zone). During each surveillance flight, a pre-planned and continuously varying route is flown between fixed waypoints (figure 2). During a flight, depending on the observations made at sea, it is always possible to deviate from the planned flight path. If a pollution is detected, the operators follow the procedures set out in the Bonn Agreement to estimate the size of the polluted area and, in the case of an oil slick, the volume as well[31]. The maximum length and width of the pollution can be read from the SLAR image or on the digital nautical chart, by placing an imaginary rectangle around the pollution. Next, the coverage of the slick within the rectangle is estimated. The estimated polluted area then corresponds to length (km) × width (km) × % coverage = (km^2). In the event of oil contamination, an estimated volume can also be calculated based on the Bonn Agreement Oil Appearance Code (BAOAC). To do this, it is necessary to determine the appearance of the slick (sheen, rainbow, metallic, discontinuous true colour, and continuous true colour), and the percentage coverage of each level. For each observed appearance, the minimum and maximum thickness of the oil layer has been scientifically demonstrated. When the polluted surface area and the ratio of the different colours are known, the minimum and maximum volume can be calculated quite easily:

Oil volume = ∑ oiled area (km²) × area covered with specific appearance (%) x min./max. thickness (µm)

Between 1991 and 2003, oil volume estimations were based on a previous Bonn Agreement colour code. After a transition year in 2004, the old code was replaced by the BAOAC. Results from 1991-2003 were converted using a method defined in Lagring et al. (2012)[32]. Whereas the minimum oil volume is the most important thing to calculate in the event of illegal operational oil pollution (to enable reporting of the minimum amount discharged), in case of accidents it is vital to look at the worst case scenario and therefore the maximum volume.

The Coast Guard aircraft is the only manned aerial platform within the Coast Guard structure regularly carrying out surveillance missions over and around the Belgian marine areas. It operates according to multi-tasking principles at the service of the Coast Guard (see chapter 6.1). This allows a wide range of possible observations to be reported to the

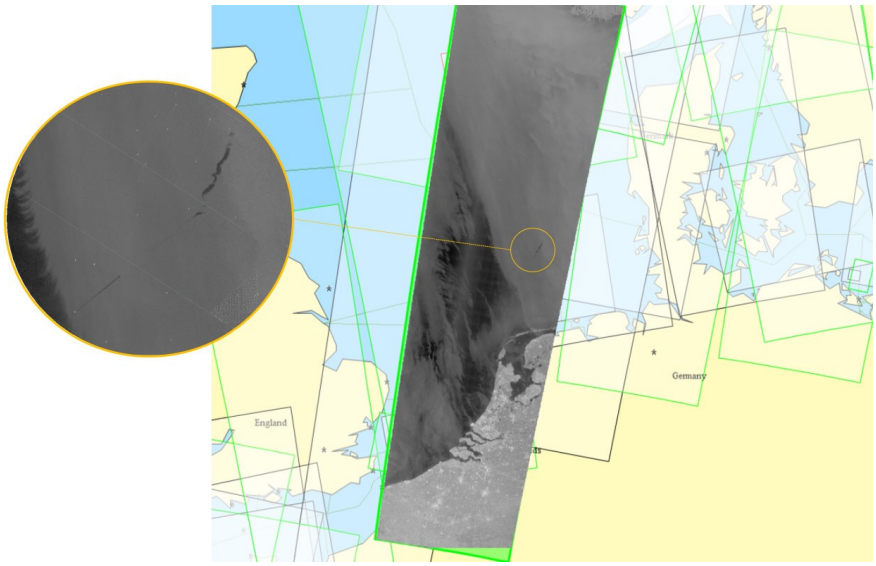

Figure 13. Detection of a pollution (dark line) and polluter (white dot) by a satellite operated by the European Maritime Safety Agency (EMSA).

various competent Coast Guard partners, either for their information or to enable further action. Flight reports are drawn up and sent either to the MIK (Maritime Security Centre), the 24/7 Coast Guard centre responsible for law enforcement in Belgian marine areas, or the national contact points of other coastal States in the event of detection in their waters or an international flight. A list of 40 flight-reporting scenarios was drawn up in consultation with the competent Coast Guard partners. It contains references to the recipients of various flight reports and a code agreed with the MIK to indicate the level of priority and confidentiality.

3. OPERATIONS AND MISSIONS: AN OVERVIEW OF THE LAST 30 YEARS

Throughout the year, the Belgian Coast Guard aircraft carries out various national and international missions and assignments. The primary tasks are part of the flight plan, with the effort and time spent on them tracked over the years. Secondary tasks are carried out alongside the main missions, taking a multi-tasking approach.

For each flight, the daily schedule will determine the main assignment, the flight route and the flight time. In practice, the crew is able to switch from one task to another very easily, for example if a navigational infringement is spotted during a fisheries control flight, or if an oil slick is detected during a ship emissions monitoring flight. An overview of all the main tasks of the Coast Guard aircraft and the total flight time spent on them across the whole period can be found in Table 1. For a detailed overview, please refer to the table in Annex 2.

In the past 30 years, there were a total of 9574 flight hours, 7100 of which were over the sea. Of those, 6403 hours were flown over the Belgian surveillance zone, and 697 hours (about 10% of our total flight time at sea) were spent on international missions in the greater North Sea area. Annually, that is an average of 309 flight hours, of which 229 hours above sea. The remaining 80 flight hours are transit time, i.e. the time needed to fly from the airport to the sea and vice versa, as well as pilots' training hours and technical flights. This transit time is not discussed further in this report, as there are no results or goals associated with it. On average 11% of the annual Belgian flight hours on behalf of the Coast Guard take place at night (in darkness).

Table 1 – Overview of the period and the total flight hours per mission type of the Belgian Coast Guard aircraft.

Missions	Period	Total flight hours	
National surveillance flights		6138:10	Total BE surveillance area 6403:24 hours
Routine aerial surveillance - Marine pollution	1991-2021	4282:12	
Air pollution	2016-2021	426:47	
On call	1991-2021	244:21	
Fishery control flights	1991-2021	1184:50	
Scientific monitoring		**221:54**	
Marine mammals counts	2008-2021	221:54	
National Training		**43:20**	
Pollution Exercises (POLEX)	1991-2021	43:20	
International missions		**672:22**	Total international 697:02 hours
BONN		**577:57**	
Pollution Exercises (BONNEX)	1991-2021	24:40	
Tour d'Horizon	1992-2021	430:35	
(Super-)CEPCO	1997-2021	110:17	
ICAL	1991-1993	12:25	
Bilateral		119:05	
Air pollution (NL)	2016-2021	119:05	
Transit	1991-2021	2473:37	
Total		**9574:03**	

3.1. National surveillance missions

Since the start of the aerial surveillance, the aircraft's core task has been to monitor marine pollution, like oil, harmful liquids or waste, in Belgian marine areas and the surrounding waters (see chapter 4.1) (figure 14). While searching for marine pollution, by systematically scanning the sea surface with sensors ('pollution control' flight mission), the Coast Guard aircraft also multi-tasks by monitoring aquaculture activities, wind farms, sand and gravel extraction, navigational infringements, safety perimeters around wind farms, masts and measuring posts, the use of the automatic identification systems (AIS) by vessels and any suspicious vessel movements. Flight operators also report *ad hoc* observations of striking natural phenomena, like plankton or jellyfish blooms, dolphins or whales, floating macro-algae, notable turbidity plumes or wintering seabird groups. The aircraft also participates in joint enforcement operations (OPERAs) at sea every year, organised by the Coast Guard. The plane's role in those operations is to provide air support to the patrol units on the water. This multi-tasking approach to aerial surveillance is generally adopted for all the core missions of the programme, but the limited amount of flight time spent on these (secondary) tasks falls under the wider category of 'routine aerial surveillance'. Over the last 30 years, 4282 flight hours were spent on this routine aerial surveillance, with 'marine pollution/pollution control' as its main mission. This is an average of 138 flight hours per year.

Since 2015, there have been regular ship emissions monitoring flights (so-called 'sniffer flights'), in an effort to combat air pollution. Initially the plumes were only checked for sulfur concentrations (SO_2), but as of 2020 the amount of nitrogen (NO_x) emitted by the ships is also being measured. A total of 427 flight hours have already been spent measuring ship emissions in and around the Belgian marine areas, which is an average of 61 hours per year (see chapter 4.2).

Figure 14. The Belgian Coast Guard aircraft during a surveillance flight over Belgian marine areas.

If an emergency situation develops at sea, the aircraft can be called up and mobilised for so-called "on call" flights, most likely in the event of a maritime accident or when severe marine pollution is reported. As part of the Coast Guard cooperation the surveillance aircraft, if requested, also helps in Search and Rescue (SAR) operations in the North Sea. It may happen that the aircraft participates in a search for missing persons at sea, as an additional flying resource to support the SAR helicopters of the Koksijde Air Force Base and MRCC's SAR coordination. The aircraft can also be mobilised to locate a whale, or large floating objects that pose a danger to shipping. However, most of these "on call" flights were carried out as part of the activation of North Sea emergency and intervention plans, as a result of a maritime emergency. In total, some 244 flight hours were performed "on call" in the period 1991-2021, or an average of eight hours per year.

Even before the Coast Guard was founded in 2005, there was a long-standing cooperation with the Department of Agriculture and Fisheries (Fisheries Authority, DZV) for the monitoring of sea fishing activities from the air. In the period 1993-2021, there were 1185 flight hours on behalf of DZV, representing an average of 40 hours per year (see chapter 6.2).

In total, between 1991 and 2021, there were around 6138 surveillance flight hours with the aim of enforcement in the Belgian surveillance area, in the framework of the Belgian Coast Guard. This is an annual average of 198 flight hours.

3.2. National flights for scientific monitoring

In addition to surveillance flights (for enforcement), the aircraft also performs flights for scientific monitoring and observation (scientific purposes), specifically related to marine mammal counts, which have been taking place several times a year since 2009. A total of 214 flight hours have been spent counting harbour porpoises and seals (222 hours if the test phase in 2008 is included

in the tally), as well as less common species like bottlenose dolphins and white-beaked dolphins (see chapter 5.4.1).

3.3. National training missions

The Coast Guard aircraft regularly participates in national counter pollution exercises, alongside the other competent Coast Guard partners (Pollution Exercises – POLEX). These exercises have been happening since the inception of the aerial surveillance programme, to practice cooperation between the various services involved in responding to large (and potentially cross-border) accidental marine pollution incidents. In the past 30 years, there were 43 flight hours as part of national counter pollution exercises (POLEX), in order to prepare crews to assist in the event of a controllable marine pollution incident (see chapter 4.1.2.3).

3.4. International assignments

The Coast Guard aircraft also participates in (sub-) regional exercises, in order to improve cooperation between the different countries (BONNEX-BONN Exercise), and in other international surveillance operations, primarily surveillance operations under the Bonn Agreement, both at a regional and bilateral level. Over the last 30 years, a total of 578 flight hours have been dedicated to Bonn-related international assignments (see chapter 4.1.3), including 25 flight hours for (sub)regional counter pollution exercises and 553 flight hours for surveillance assignments (TdH, (Super)CEPCO and ICAL – see further in this report).

One of those international assignments is the monitoring of the offshore oil and gas installations in the central part of the North Sea for oil pollution, as part of the annual "Tour d'Horizon" operations (TdH). At different times throughout the year, the surveillance aircraft of the various North Sea countries take turns carrying out this international mission. In the past 30 years, Belgium's Coast Guard aircraft contributed 430 flight hours to the TdH mission. Another international mission Belgium regularly participates in are the (Super) CEPCO operations (Coordinated Extended Pollution Control Operation), in which over the course of one or several days, the North Sea countries deploy several surveillance aircraft to intensively monitor a specific area with heavy shipping traffic from the air, looking for illegal discharges. Since 1997, the Coast Guard aircraft spent 110 hours in the air for this regional surveillance operation.

Belgium is an international pioneer in the monitoring of ship emissions at sea, using innovative sniffer sensors on board an aircraft, which recently resulted in a few years of bilateral cooperation between the Netherlands and Belgium. MUMM was commissioned by the Dutch Human Environment and Transport Inspectorate (ILT), to carry out a number of sniffer flights over the Dutch sea areas. This happened in 2016, 2018, 2019 and 2021, for a total of 119 international flight hours (see chapter 4.2.3).

Taking into account the limited size of the Belgian marine areas (< 1% of the North Sea), our country makes a proportionately sizeable contribution to regular aerial surveillance compared to other North Sea countries, and more than bears its part of the joint responsibility for monitoring the greater North Sea under the Bonn Agreement. These Belgian efforts have much - if not entirely – to do with the particularly busy shipping traffic in and around Belgian waters, and the associated environmental risks.

Past international missions

Some types of assignments were phased out over the years. In the early 1990s, there were so-called 'Intercomparison Exercises'[33]. These were international calibration flights (ICAL flights; accounting for 12.5 flight hours) with the aim of comparing the different aircraft and instruments on board the North Sea countries' surveillance aircrafts, evaluate detection techniques and discuss possible improvements or new developments in remote sensing techniques. It was also a way of harmonising operational procedures for detection, documentation and reporting. After 1993, these types of flights were no longer carried out, but this does not rule out the possibility of such flights being resumed at some point in the (near) future. In 2019, the Contracting Parties of the Bonn Agreement made the decision to include Annex VI of the MARPOL Convention in the Bonn Agreement scope of work[33], which relates to more stringent sulfur and nitrogen rules for ship emissions (see chapter 4.2). At this time, it was agreed to actively work together in the coming years, to develop joint guidelines, strategies and procedures for the monitoring of compliance to MARPOL Annex VI regulations in the greater North Sea.

There were also Joint Flight Days (JFD) in the 1990s, which meant that the different North Sea countries carried out simultaneous surveillance flights over their own zones, in order to obtain a snapshot of pollution in the entire North Sea at a given moment. The final JFD flight took place in 1998. JFDs were later replaced by CEPCOs (which generated more results and greater public attention) and satellite surveillance, as satellite images can cover large parts of the greater North Sea in a single snapshot. In spite of the international context in which these JFD flights were operated, their 37 flight hours were added to the (national) routine aerial surveillance tally, because the flights took place over the Belgian surveillance area. Any pollution that was observed was also recorded as part of national pollution observations.

4. POLLUTION MONITORING

Aerial surveillance of operational marine pollution has been the primary task of the Coast Guard aircraft since it came into operation. It is carried out in accordance with the commitments made by Belgium, together with the other North Sea countries, under the Bonn Agreement, to prevent pollution from oil and other harmful substances in the North Sea (see box chapter 1.2)[34]. This surveillance is performed at sea to monitor compliance with the international discharge regulations for ships, as laid down in the International Maritime Organisation's MARPOL Convention[6]. The MARPOL Convention stipulates strict provisions for operational discharges by ships, for oil (as specified in MARPOL Annex I), for other harmful liquids (as specified in MARPOL Annex II) and for solid substances (MARPOL Annex V). It also prescribes technical measures for the construction and equipment of ships in order to prevent marine pollution. Following a test phase in 2015, the Coast Guard aircraft now also monitors air pollution from ships. The MARPOL Convention entails regulations for these too, as specified in Annex VI.

In addition to the general regulations, the MARPOL Convention also defines certain maritime areas as 'Special Areas', where stricter standards apply for reasons relating to specific oceanographic and ecological conditions and intense maritime traffic, in order to create a higher level of protection against marine pollution. The North Sea, which the Belgian marine areas are part of, is one of those Special Areas as defined in MARPOL Annex I, MARPOL Annex V and MARPOL Annex VI[35] (see below).

The MARPOL Convention was ratified by Belgium in 1984, and was followed by the MARPOL implementation act of 6 April 1995 on the prevention of marine pollution from ships[7]. The implementation act charged the maritime police and inspectorate with monitoring compliance with MARPOL regulations and the implementation act provisions in ports. The maritime police, maritime inspectorate and harbour masters would henceforth be responsible for detecting and establishing infringements of the discharge provisions. MUMM agents were tasked with the detection and identification of illegal discharges at sea.

4.1. Marine pollution

4.1.1. Operational marine pollution from ships in and around the Belgian marine areas

The Belgian surveillance area is a very interesting area for studying trends around illegal operational discharges from ships: there are no offshore oil and gas installations and any pollution observed in this very busy shipping area is almost entirely caused by those (illegal) operational discharges. The aerial surveillance data collected in and around the Belgian marine areas over the years has been collected with the same aircraft, over the course of a relatively stable annual number of flight hours (on average ca. 200 routine aerial surveillance flight hours per year, both during the day and at night). This has created an excellent data set to monitor long-term trends in terms of operational discharges.

4.1.1.1. Liquids

4.1.1.1.1. MARPOL Annex I – Operational oil discharges from ships

Operational oil discharges from ships (figure 15A-B) were a long-standing environmental problem in the North Sea and had an unacceptably severe impact on seabird populations and vulnerable coastal areas[36,37], among other things, including in Belgium[1]. The most polluting type of operational oil discharges, with observed volumes often exceeding 10 m³ (metric tonnes), were the result of tank washing by oil tankers. This type of discharge occurred regularly in the Belgian waters well into the 1990s[38]. Another serious form of operational oil discharge is the discharge of the oil sediment from a ship's sludge tank, which can amount to more than a tonne of oil. The ship's bilge water - polluted water that accumulates in the deepest part of the ship - can also be discharged into the sea. This type of discharge often involves smaller volumes (less than 1 m³)[39,40]. Whereas tank washing is only done by oil tankers, the discharge of sludge and bilge water can involve any seagoing vessel. The average volume of oil per discharge of bilge may be relatively small, its environmental impact should not be underestimated, as this is by far the most common type of discharge at sea and therefore

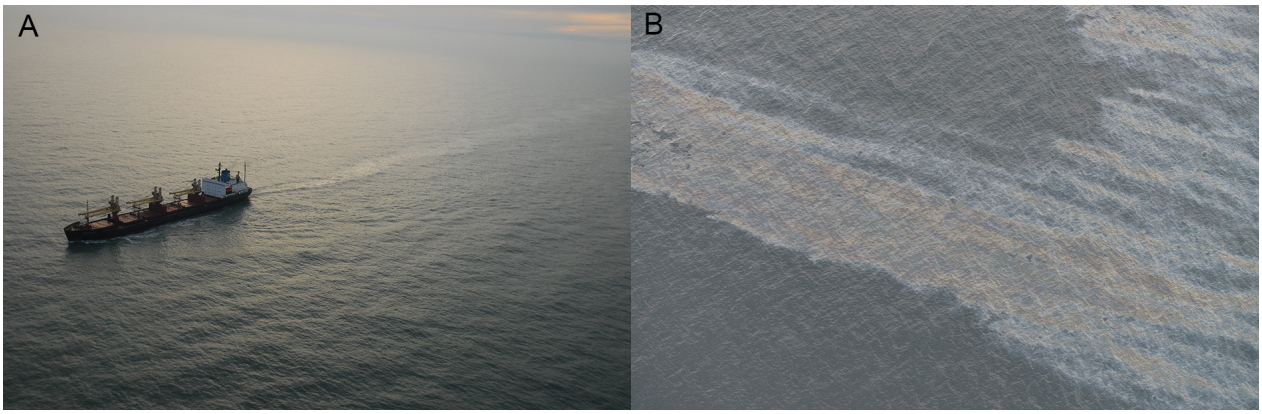

*Figure 15. **A**. Oil slick in the wake of a ship. **B**. Detail of a mineral oil slick on the sea surface, identified by its typical colours.*

an important contributor to the chronic pollution pressures caused by illegal oil discharges[32].

Because the number of operational discharges remained unacceptably high, the Contracting Parties of the Bonn Agreement decided in 1989 to enforce international regulations on oil pollution at sea by intensifying aerial surveillance[4,5]. Since the subsequent launch of the Belgian aerial surveillance programme in 1991, there have been regular pollution control flights, systematically documenting oil slicks on the sea surface in accordance with the standard procedures laid down in the Bonn Agreement. As soon as an oil slick is visible to the naked eye, it can be assumed that the permitted concentration limit of 15 ppm, which has been in force since the North Sea became a 'Special Area' for MARPOL Annex I in 1999[35], has been exceeded and the discharge is therefore illegal. In most cases, an oil slick will be observed without an obvious polluter being present. Discharging oil at sea can be done very quickly, and in only 5 to 10% of marine pollution incidents that are observed can the pollution be linked to a suspect vessel. This is not just the case in Belgium, but in all the North Sea countries (hence the importance of effective prosecution if a ship is caught in the act – see chapter 4.1.1.3).

The table in Annex 3 shows the number of oil slicks (operational oil discharges) detected by the Belgian Coast Guard aircraft in and around the Belgian marine areas between 1991 and 2021. Over this period, 625 oil slicks were documented and reported, representing a total of 1013 m^3 of oil pollution. The highest number of oil pollution incidents in a single year was observed in 1994, when 65 slicks were recorded. This contrasts sharply with the more recent years 2015 and 2021, when not a single operational oil spill was identified. The number of slicks detected per flight hour filters out the variation in the number of hours flown each year. This shows that 1992 was the year with the highest relative frequency of oil slicks being detected, with an average of 0.28 slicks per hour in the air.

This downward trend[32,38] is remarkably consistent with two key policy measures that have had the most perceptible impact in the field. Firstly, the North Sea was recognised by the International Maritime Organisation as a Special Area for oil spills from ships in 1999, which meant that from then on, the strictest international discharge standards applied[35]. This led to a significant drop in the average number of pollution incidents observed (figure 16) and the average total volume of oil pollution (figure 17) after 1999. A second important policy measure was the adoption of the European Port Reception Facilities Directive (2000)[41,42], which was only fully implemented in European ports around 2004-2005[43,44]. Since the introduction of this EU Directive, all seagoing vessels calling at European ports are required to unload their waste oil in port reception facilities, making it very difficult for ships to illegally discharge large volumes of oil into the sea. The flight data demonstrates that this later and crucial policy measure primarily had an effect on the volume of oil observed, and not so much on the number of oil pollution incidents, with the latter showing a more extinguishing effect and gradual decline after the Special Area designation came into effect.

Figure 18A-C shows the evolution in the spread of the number of operational oil spills in the periods 1991-2000 (a), 2001-2010 (b) and 2011-2021 (c) in the Belgian surveillance area. These spatial

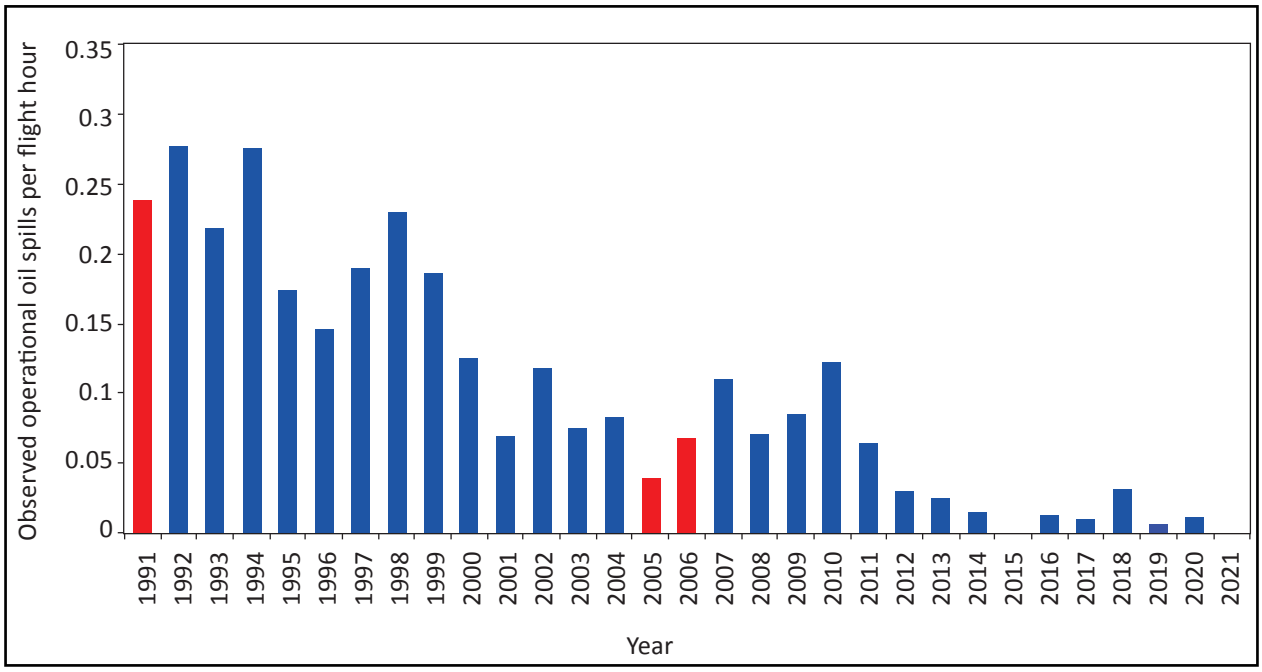

Figure 16. The number of operational oil discharges observed in the Belgian surveillance area per flight hour from 1991 to 2021 (1991, 2005 and 2006 are transitional years with a reduced number of flight hours: 1991 was the year surveillance was launched; in 2005-2006 the plane was transferred and refitted).

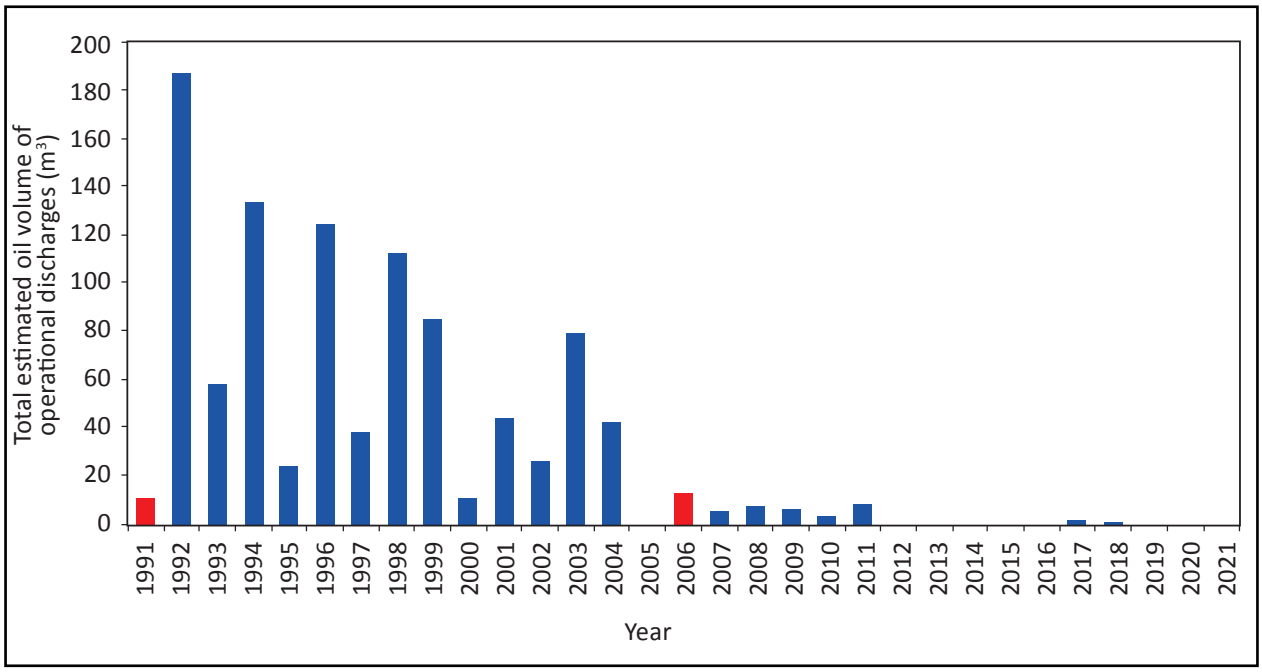

Figure 17. Total estimated volume of the operational oil discharges observed in the Belgian surveillance area per year (1991, 2005 and 2006 are transitional years with a reduced number of flights hours: 1991 was the year surveillance was launched; in 2005-2006 the plane was transferred and refitted). Total oil volumes observed in 2005, 2012-2016 and 2019-2021 were under 1 m³ and therefore not visible in the figure.

maps are of a more qualitative nature because they only show the location of the oil slicks in the surveillance zone over the years, and do not provide any information about the variation in flight frequency in the area. Despite this, they still visualise well the chronic oil pollution pressure: the broad SLAR coverage (20 km either side of the plane, 40 km in total) means that almost the entire Belgian sea area will be scanned over the course of each flight. The positive effects of designating the North Sea as a Special Area in relation to MARPOL Annex I and the approval of the European Directive on port reception facilities can be clearly seen in figure 18B, with a huge reduction in the number of oil pollution incidents. There is also a clear spatial shift over the last 30 years. In the first period (1991-2000), most oil slicks were found along the primary shipping routes (Dover Strait, North Hinder TSS, West Hinder TSS). In the second period, 2001-2010, this is much less pronounced, whereas on the third map, covering the most recent period 2011-2021, the opposite appears to be true: the remaining oil slicks were more likely to be found away from the primary shipping routes, near the secondary routes that are used for short sea shipping (mainly ferries, smaller merchant ships and fishing vessels) between the United Kingdom and continental Western Europe, or between coastal ports[38]. This shift in the spatial distribution of oil slicks in the Belgian surveillance area is probably a result of a particular exception to the waste disposal obligation, which was initially included in the European Directive on port reception facilities (Art 7.2.)[41]. In situations where there was deemed to be sufficient storage capacity for all ship waste to be held until the ship's next port of call, which was usually the case for short sea shipping, there was no obligation for the waste on board to be disposed of in the current port. This created an opportunity for the crew to discharge oil into the sea after all. The Directive was amended in 2019 to exclude different interpretations and applications of this exception[45].

There is little doubt that these two important legislative measures would not have had the same effect had they not been adequately monitored and enforced[32]. In reality, all policy measures have contributed to the downward trend, including the deterrent effect of aerial surveillance, thorough on-board inspections in European ports of call, and international cooperation in terms of prosecution and prioritisation - see chapter 4.1.1.3).

An equally significant downward trend is also evident in the number of oiled birds found on the Belgian coast[2]. Research by INBO (the Flemish Research Institute for Nature and Forest) showed that trends in the oil rates of beached seabirds are consistent with the temporal and spatial patterns of chronic oil pollution at sea: recent analysis of a multi-annual data set on beached birds along the Belgian North Sea coast in the period 1962-2017[46] indicates that the number of birds affected by oil has dropped to historically low levels, while there is still intense shipping in the area. This points to a significant decrease in chronic oil pollution. Better still, the OSPAR Ecological Quality Objectives (EcoQO) were achieved for the proportion of oiled guillemots, which was defined by OSPAR as less than 20% of the total number of dead or dying animals found on the beach during the winter months (November-April) over a period of five years, by 2020[47].

Of course, the Belgian aerial surveillance data only represents a fraction of the full picture of oil pollution in and around its waters, as it is based on detections from around 200 surveillance flight hours per year over the sea. The actual pollution level has probably been a lot higher for all these years. Nevertheless, the aerial surveillance figures are statistically relevant and the trends are reliable[48]. All this points to chronic oil pollution in the North Sea being under control, although surveillance and enforcement remain necessary to provide a deterrent effect.

4.1.1.1.2. MARPOL Annex II – Operational discharges of other harmful liquids from ships

In addition to illegal oil spills, the Coast Guard aircraft also regularly observes discharges of other dangerous and harmful liquids, known as Noxious Liquid Substances (NLS). Unlike oil, which is present on board each ship in some form (engine oil, fuel, or as cargo in the case of oil tankers), NLS are only transported by tankers (mainly chemical tankers and gas and oil tankers specifically adapted for NLS). NLS discharges are often referred to as "chemical discharges", but this term is not entirely correct: other products, like vegetable oils and biodiesels, are also considered to be NLS.

Unlike oil spills, many of the operational NLS discharges from ships observed by the aircraft are legally permitted at sea. However, some of these discharges do still constitute an infringement

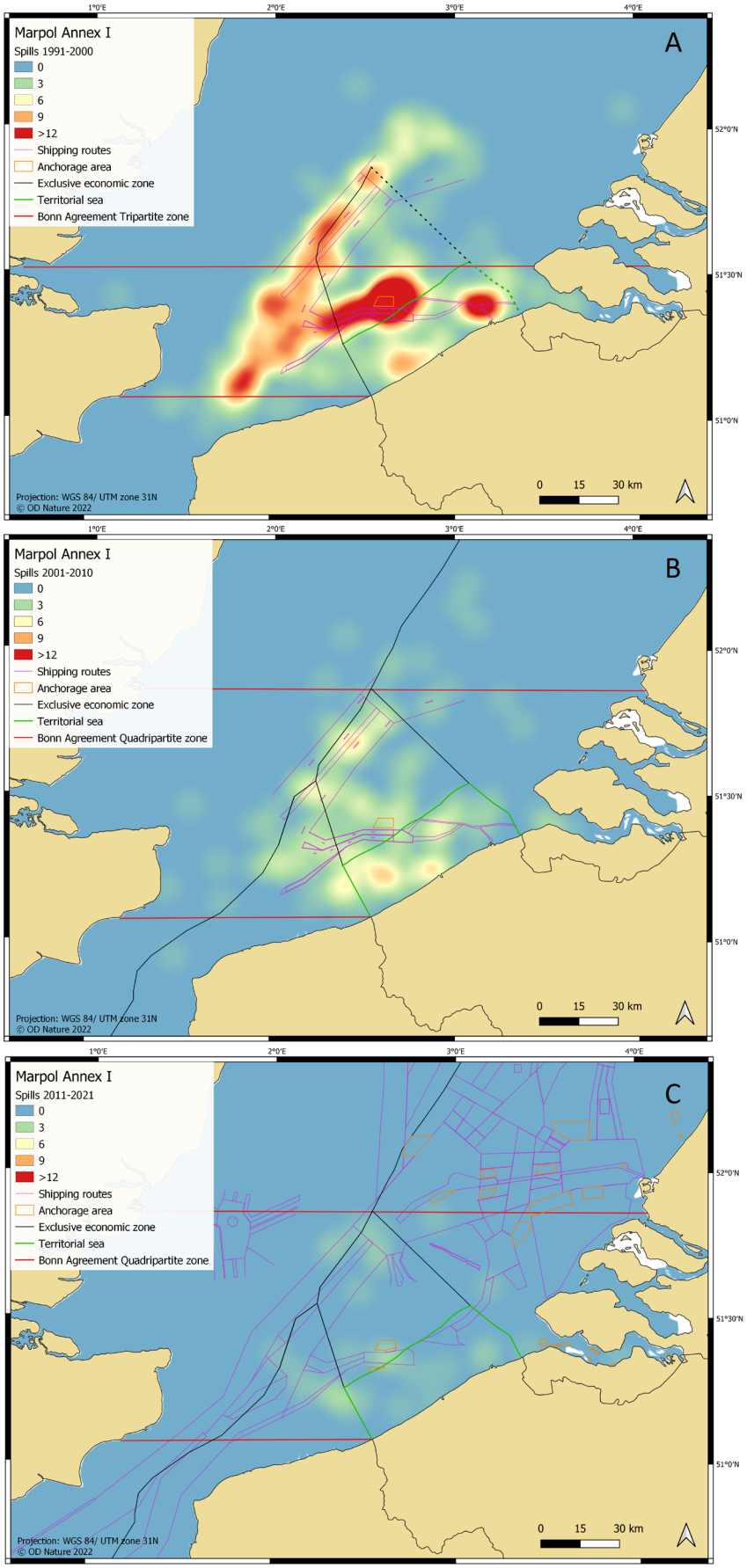

*Figure 18. Distribution maps showing operational oil pollution in the Belgian surveillance area. **A**. 1990-2000. **B**. 2001-2010. **C**. 2011 to 2021.*

of international standards for Noxious Liquid Substances, as set out in Annex II of the MARPOL Convention[6]. Whether or not such discharges are legal depends on the type of liquid (see box page 41), but also how and where the discharge takes place.

Discharges of Category X, Y and Z liquid substances must be carried out outside the territorial sea (i.e., at least 12 nautical miles away from the coastline), where the water has a minimum depth of 25 metres. The ship must be proceeding 'en route' at a speed of at least 7 knots. The discharge must be made below the waterline (figure 19), unless the vessel was built before 2007 and the substance discharged falls under category Z, in which case the discharge may also be carried out above the waterline[6].

When NLS discharges from ships at sea are detected or observed, a thorough port investigation is often required to determine whether or not the discharge was legal. For this reason, when an NLS discharge is detected from a ship at sea, it is systematically documented and reported to the competent authorities in the affected coastal State, who usually then request a technical inspection and/or police investigation at the suspect vessel's next port of call (figure 20).

In the period 1991-2021, a total of 158 operational NLS spills were reported, with the highest number (13) being identified in 2014 (Annex 3). The number of spills detected per flight hour normalises the number of hours flown each year. A gradual increase can be seen in the annual number of operational NLS discharges, with the highest number being recorded in 2021 (on average 0.07 NLS spills per flight hour) (figure 21). The trend analysis for NLS discharges is limited to numbers,

Figure 19. An illegal MARPOL Annex II discharge of palm oil (Cat. Y), above the waterline inside the Belgian EEZ.

as it is not possible to estimate NLS volumes from the air (as opposed to oil spills).

On the one hand, these figures indicate that on average, the number of NLS discharges is considerably lower than the number of oil discharges, and that the general problem of operational discharges from ships off the Belgian coast is no longer as significant as it was before the turn of the century. On the other hand, they show that the number of NLS discharges has not seen the same downward trend over the years as oil spills, rather the opposite. This can be partly explained by discrepancies in applicable discharge standards. The increase in NLS discharges in and around the Belgian marine areas is also largely in line with the increase in maritime traffic, including bulk transport[50]. At the same time, the strikingly upward trend from 2011 coincides with the period following the global banking crisis, which also had a significant impact on the maritime sector. The years with the highest number of NLS pollution incidents – 2020 and 2021 – coincide with the COVID crisis,

Figure 20. MARPOL Annex II discharge of palm oil (Cat. Y), with a clearly visible trail in the wake of the discharging ship.

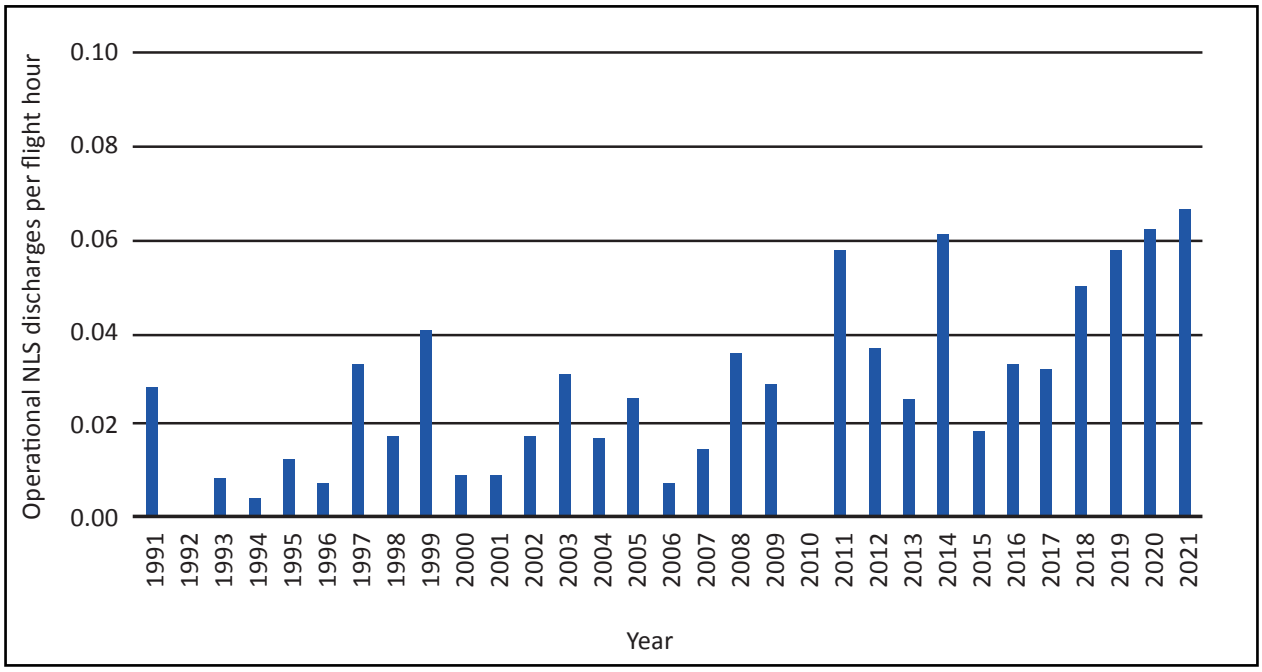

Figure 21. Number of operational discharges of Noxious Liquid Substances (NLS) observed per flight hour in the Belgian surveillance area from 1991 to 2021.

which in turn may have generated an additional adverse side effect on the North Sea. Other North Sea countries found a similar upward trend in the number of NLS pollution incidents in their waters[51], as can be seen in the Bonn Agreement's annual statistics. Nonetheless, the problem is particularly pronounced in the Belgian surveillance area. This is due to the very busy shipping traffic in the area and its proximity to the two largest European ports: Rotterdam and Antwerp-Bruges. The port of Antwerp-Bruges is also internationally renowned as the largest integrated (petro-)chemical cluster in Europe, and the second largest in the world[50].

When looking at the location of the different discharges across the periods 1991-2000, 2001-2010 and 2011-2021, the increase in discharge is most marked in the NHTSS area (figure 22A-C). This is not surprising, since the NHTSS area sees a large concentration of ships that are 'en route', well outside the territorial sea and in sufficiently deep water. This also indicates that most of the NLS discharges that were observed were likely to be legally permitted, in accordance with the general MARPOL Annex II standards[6], although in most cases only a port inspection investigation can determine this.

However, just because probably most MARPOL Annex II discharges are legal, that does not mean that there is no cause for concern. After all, these are still substances which can cause varying degrees of harm to the marine environment. The main worry is the gradual increase in the number of discharges over the last decade. Coastal States, and particularly Belgium due to the high incidence in its surveillance area, must continue to monitor these discharges. Aerial surveillance not only creates a deterrent effect, it can also help to identify problems at sea and provide the impetus for a change in the law. For example, following a joint request by the North Sea coastal States, the IMO amended Annex II of the MARPOL Convention in 2019, adding a new category called 'Persistent Floaters' which was to be subject to stricter conditions[52] (see box 'NLS categorisation system' page 41).

As NLS discharges are often permitted outside the territorial sea, the average length of the spills (and therefore the discharge time) is often more than twice as long when compared to oil slicks in the last 30 years (approx. 3.0 km for oil compared to approx. 6.5 km for NLS). Looking specifically at the last decade, they were over three times as long on average (see Annex 3).

Discharges of other harmful liquids remain a not inconsiderable problem in the North Sea, which requires further close monitoring and enforcement,

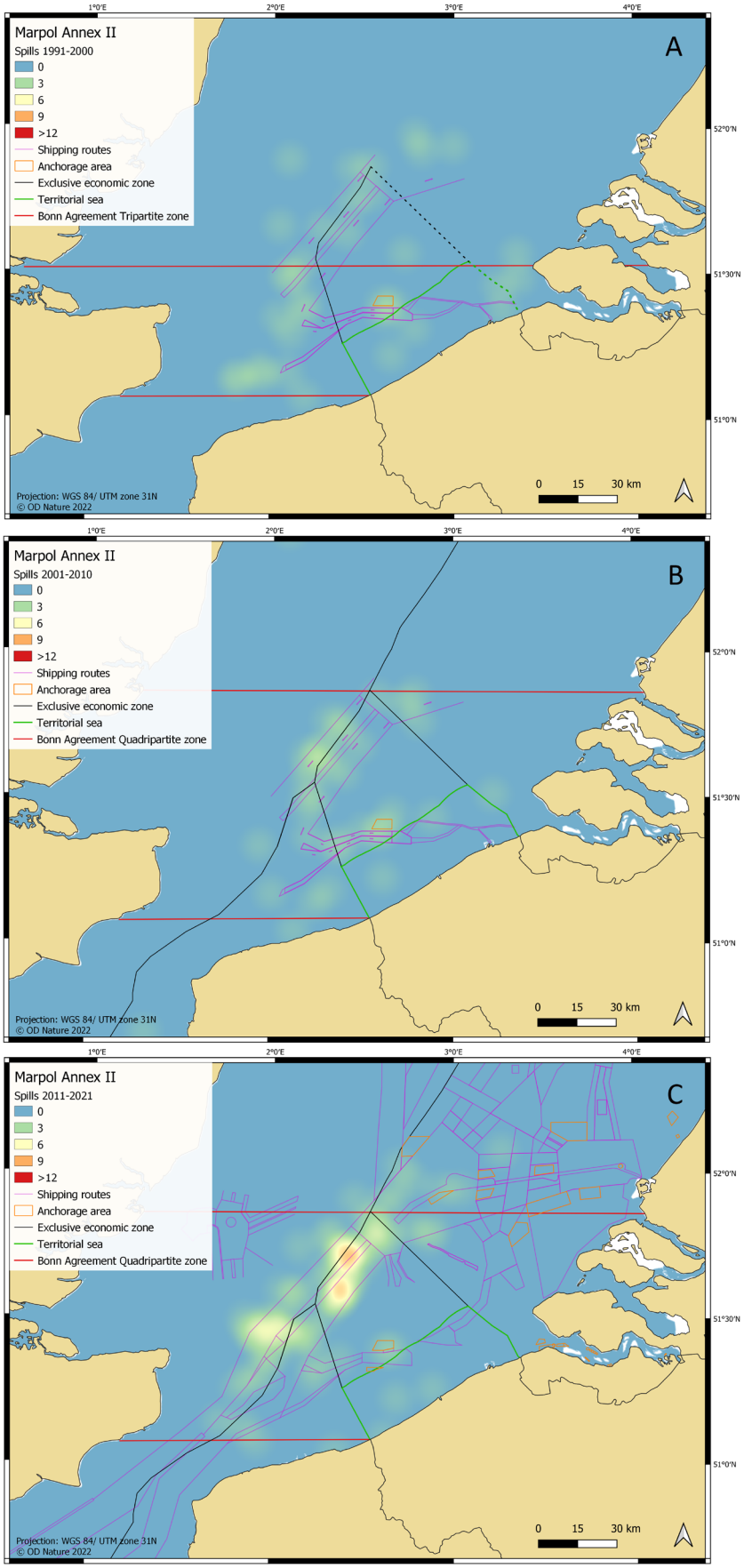

*Figure 22. Distribution maps of operational discharges of Noxious Liquid Substances (NLS) for the period 1991-2021 or the partial periods in the Belgian surveillance area. **A**. 1991-2000. **B**. 2001-2010. **C**. 2011 -2021.*

NLS categorisation system[49]

Annex II of the MARPOL Convention divides hazardous and harmful liquids (Noxious Liquid Substances, NLS) into 4 categories, based on how harmful they are to the environment:

1. Category X: these are substances which are deemed to present the greatest danger to the environment and public health if discharged into the sea, and discharge of this category of substances is therefore prohibited. Ship tanks from which a category X liquid has been removed must be prewashed before the vessel is allowed to leave the port. As a result, any tank-washing carried out at sea afterwards should not produce any more traces of the harmful liquid previously transported.
2. Category Y: these are substances which are deemed to present a danger and/or cause damage if discharged into the sea, and which therefore justify certain discharge restrictions. This category including vegetable oils, Fatty Acid Methyl Ester (FAME) and biodiesels. In the case of very viscous or solidifying liquids, the ship tanks may need to be prewashed under certain conditions, depending on the temperature at the time of unloading. For persistent floating liquids ('Persistent Floaters', for example paraffin), a systematic prewash requirement has been in place since 2021, regardless of the temperature at the time of unloading.
3. Category Z: these are substances which are deemed to present a minor hazard and therefore justify less stringent discharge restrictions (e.g., Urea Ammonium Nitrate (UAN) solutions.
4. Other Substances (OS): these substances fall outside the categories X/Y/Z above, because they are not considered to cause any damage. These substances are not subject to discharge provisions at sea.

both at sea and on shore. In particular, the recently tightened provisions for the discharge of 'Persistent Floaters' are a priority for aerial surveillance in the coming years.

4.1.1.1.3. Non-visually verifiable marine pollution

If the SLAR detects a marine pollution at night or when visibility is poor (e.g., fog), operators cannot visually verify whether the substance is oil (with its typical appearances) or another harmful liquid. Such spills are routinely catalogued as 'unknown', to indicate visual verification was not possible. If the discharge is in progress and the SLAR shows a clear link between the spill and a ship, the marine VHF radio on board of the aircraft will be used to contact the suspect vessel to try and obtain information about the nature of the substance that is being discharged. If no visual verification was possible, port inspections are crucial to verify if an infringement has occurred.

During the period 1991-2021, the precise nature of 59 spills could not be verified: an average of just under two per year. The data shows a downward trend in this type of observations, despite an increase of the proportion of flight hours over the sea taking place at night (figure 23).

The drop in the absolute number of 'unknown' spills is negligible, however, as the proportion of all observed spills being categorised as 'unknown' has remained more or less the same over the years (figure 24). Whereas oil pollution incidents were dominant in the statistics in the 1990s, they have seen a gradual decrease in the past 30 years, with the share of NLS discharges clearly increasing. This is where the future challenges lie in terms of the monitoring and enforcement of marine pollution.

4.1.1.2. Solids – MARPOL Annex V

The discharge provisions for (solid) waste from ships, including rubbish, fishing nets and solid cargo residues, are laid down in Annex V of the MARPOL Convention[6]. MARPOL Annex V also considers the North Sea to be a Special Area[35] with stricter regulations. In effect, this means that with the exception of ground food waste discharged outside the territorial sea and fishing by-catch, there is an almost blanket prohibition on discarding any solid waste from ships.

In the first few years after the conclusion of the Bonn Agreement, the emphasis was on illegal oil discharges, and later on MARPOL Annex II discharges. It was not until 2008-2009 that the potential of aerial surveillance was realised when

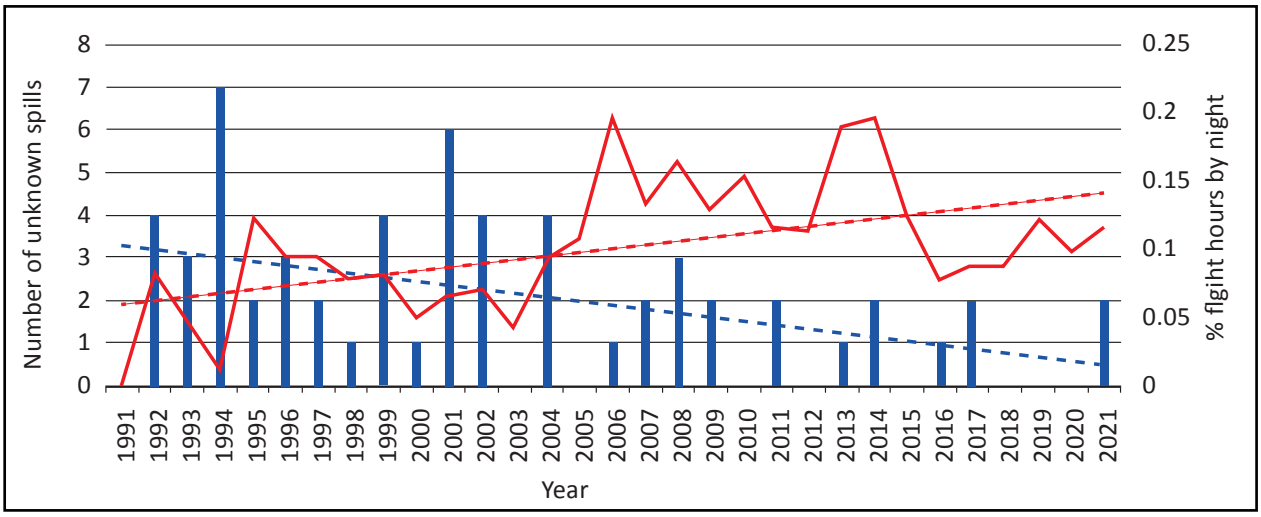

Figure 23. Evolution of the number of unknown discharges observed between 1991 and 2021 (blue bars) and the percentage of night flights out of the total number of flight hours spent actively monitoring for marine pollution (red line). The dotted lines show linear regression.

it came to MARPOL Annex V[53], even if there was a slim chance of catching offenders in the act, since throwing waste overboard often takes very little time. This makes it difficult to ensure compliance with this legislation from the vantage point of the Coast Guard aircraft. There is currently no on-board sensor to help the operator detect this type of pollution, and they can only monitor and verify incidents visually. Nevertheless, the North Sea coastal States have shared their experiences with MARPOL Annex V monitoring at sea, and aligned their operational procedures[31]. Air operators look out for ships sailing or lying at anchor with open hatches, ships sailing with a discoloured trail in their wake that is not showing up on SLAR, ships surrounded by concentrations of floating debris, or any sign of anything that might be thrown overboard. For example, if a ship is observed with refuse bags on deck (figure 25), and there is no immediate sign or presumption of any infringement of the law, the aircraft will always try to contact the ship, enquire what their intentions are regarding the waste and remind the crew that the North Sea is a designated Special Area. This approach both increases awareness and creates a deterrent effect.

Since 2010, 13 reports have been made of MARPOL Annex V violations or potentially suspicious observations related to MARPOL Annex V, which established a clear violation or led to a strong suspicion that a violation had occurred. These mainly concerned observations of solid cargo residues on the deck of a ship (usually bulk carriers), sometimes with visible traces on the hull (figure 26). In a few cases, traces of cargo residues could be seen in the wake of the ship (figure 27) or a fishing vessel was caught in the act of dumping old nets, see chapter 4.1.1.3. Such a small number

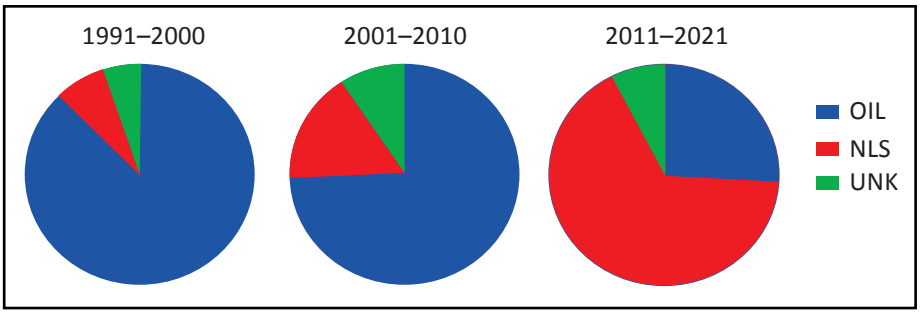

Figure 24. Pie charts for the periods 1991-2000, 2001-2010 and 2011-2021, showing the proportion of oil slicks, Noxious Liquid Substances (NLS) slicks and unknown slicks (UNK).

of reports being made over the course of 30 years does not in any way reflect the seriousness of the problem - it merely illustrates how unlikely perpetrators are to be caught. Despite the general impression that most of the waste in the seas and oceans comes from land, some recent studies have ascribed much of the problem to international shipping[54-56]. To date, this cannot be confirmed for Belgian waters: in terms of waste monitoring on Belgian beaches and the seabed, it has proved very difficult to identify the source (except for fisheries and aquaculture waste), because in most cases an object (e.g., plastics) may come from a variety of different sources[46]. Nevertheless, in calm seas, operators sometimes observe a significant amount of floating waste, often along and near the major shipping routes. This indicates the problem of marine waste is far from being resolved.

4.1.1.3. Detection of illegal discharges from ships (infringes of MARPOL Annex I, II and V)

As mentioned earlier in this chapter, the chances of catching a ship in the act of illegally discharging at sea - i.e. committing an infringement of the discharge provisions in MARPOL Annex I, II or V - are very low, as a discharge can occur very quickly, the surveillance area is large and there are only a limited number of flight hours available on an annual basis. Nevertheless, in the period 1991-2021, the Belgian Coast Guard aircraft caught a total of 51 ships in the act of an illegal discharge at sea, resulting in an official statement, additional investigations by competent authorities (on-board inspections in a subsequent port of call, police investigation, etc.) and compilation of the findings in a MARPOL file.

Figure 26. Coal cargo residue on deck and traces on the hull of a ship.

Of these 51 incidents of MARPOL violations, 40 were related to MARPOL Annex I (illegal oil discharges), 8 fell under MARPOL Annex II (illegal discharges of Noxious Liquid Substances (NLS) other than oil), and 3 were related to MARPOL Annex V (the illegal dumping of waste by a ship). The number and nature of these MARPOL cases show similar trends with the numbers of pollution incidents from oil, NLS and waste discharges observed over the period 1991-2021. In the period 1991-2000, MUMM reported 21 MARPOL offences, all of them of ships illegally discharging oil. In the period 2001-2010, the surveillance aircraft reported a total of 20 MARPOL offences: 16 illegal oil discharges, 3 illegal NLS discharges and 1 incident of illegal dumping of ship waste. In the last decade (2011-2021) there were only 10 cases: 3 illegal oil discharges by a ship, 5 illegal NLS

Figure 25. Observation of large refuse bags on the deck of a ship.

Figure 27. Trail of rinsed-off cargo residue (coal) in the wake of a ship.

discharges and 2 incidents of illegal dumping of ship waste.

In less than half (24) of these MARPOL cases, a Belgian court or body was the primary competent authority. In other words, in most cases (27) a foreign court or body was competent to prosecute the ship suspected of a MARPOL infringement, in accordance with international maritime law. There are several reasons for this. Firstly, the Belgian aircraft's surveillance zone covers not only Belgian waters, but also the adjacent British, French and Dutch waters, as defined within the Bonn Agreement. Secondly, Belgium only extended its jurisdiction up to and including the EEZ in 1999[10]. Until 1999, Belgium's jurisdiction as a coastal State was limited to the territorial sea, while most of the infringements were observed outside the territorial sea, and offences were usually passed on to the ship's Flag State. Today, Belgium does have jurisdiction within its marine areas, but not the same as in its sovereign territory. In accordance with international maritime law[8], Belgium does not have exclusive - and in some cases not even primary - jurisdiction, as is the case with certain discharges into the EEZ. Our country must take into account the rights of the flag States and port States. This is not always to our disadvantage: cooperation with European port States has often resulted in a faster and more efficient investigation of suspect vessels.

Between 1991 and 2021, MUMM passed a total of 18 files to competent French, Dutch and British authorities (as neighbouring coastal States) and nine files to other competent States, three inside and six outside the European Union. Because of this complex international dimension to the prosecution of polluters, as well as the low number and technical nature of MARPOL cases, in the 1990s these were often dismissed with no further action being taken (both in Belgium and abroad) or MUMM did not receive any feedback about what happened with the cases. Other North Sea countries also faced this problem when it came to prosecuting offenders. This has gradually changed over the years, thanks to the extension of the countries' jurisdiction at sea and the improved national and international cooperation between the various competent services and authorities. For example, the Bonn Agreement Contracting Parties worked together to promote the mutual acceptance of evidence, and in 2002 the North Sea countries jointly set up the North Sea Network of Prosecutors and Investigators[57], who work with the Bonn Agreement to facilitate effective prosecution of MARPOL offenders[58,59]. The European Union issued Directive 2005/35/EG on ship-source pollution and on the introduction of penalties for infringements, also known as the Ship-Source Pollution (SSP) Directive[60]. Several countries, including Belgium, have committed to a zero-tolerance policy, which has given MARPOL cases a higher level of priority for prosecution. All these measures have ensured that more and more ships are actually prosecuted after being caught in the act, resulting in out of court settlements, administrative fines and criminal penalties that can amount to hundreds of thousands of euros. The largest fine imposed by a Belgian court on a MARPOL offender to date was 1.5 million euros, for a large illegal oil discharge in Belgian waters. Thanks to the international cooperation between competent authorities, Belgian reports have also led to convictions, fines and penalties in France, the UK, the Netherlands, Germany, Sweden, and as far afield as the Bahamas.

Despite all these measures, a total of 51 official reports over the course of 30 years seems a poor result when seen in the context of global shipping. This is of course largely related to the limited likelihood of offenders being caught in the act at sea, which is a problem not limited to Belgium: all North Sea and European countries face the same issue. At the same time, the comparison cannot be made from a purely national perspective: it should be viewed within a regional or European context. Belgian aerial surveillance covers only a small fraction (about 0.5%) of the entire North Sea. Other North Sea countries also carry out aerial surveillance over their particular part of the North Sea, under the regional Bonn Agreement. As far as the North Sea is concerned, this has already led to a large number of official reports, subsequent investigations and prosecutions. The Baltic Sea countries, as well as various Mediterranean countries, also regularly carry out aerial surveillance over their waters. EMSA further complements these national surveillance efforts in the various European marine regions by providing satellite images with pollution detections and, more recently, unmanned monitoring platforms[61]. In addition to sea surveillance, there are also numerous MARPOL inspections on board ships in European ports. All of these regional and European efforts combine to make a substantial difference and create a clear deterrent effect.

4.1.2. Shipping accidents and risk of accidental marine pollution

4.1.2.1. The Belgian waters as a high-risk maritime area

The greater North Sea is one of the busiest and most heavily-used maritime regions in the world[13,14]. The ever-increasing competition for space at sea, the growing number of ships and the trend in shipping of increasingly large vessels (maritime gigantism) unfortunately also lead to a greater risk of shipping accidents, which in turn may result in accidental marine pollution[62].

Despite its relatively short coastline of only 65 km, and the limited size of its sea area, Belgium by no means escapes the risk of shipping accidents. The Belgian waters are situated in the southern North Sea, with the immensely busy Dover Strait to the south and the two largest European ports - Rotterdam and Antwerp-Bruges - close at hand. The shallow system of sand banks off the Belgian coasts forces the numerous seagoing ships into narrow routes. All of this means that Belgian and surrounding waters are internationally known as a high-risk maritime area. This is evident both from numerous national and international risk analysis studies, and from the history of maritime incidents in and around the Belgian marine areas[38,62-65]. In addition the Belgian waters have a very high ecological sensitivity to marine pollution: there are huge numbers of wintering seabirds, vulnerable benthic habitats, spawning grounds and nursery areas in the shallow parts of the territorial sea, as well as a number of particularly vulnerable coastal conservation areas, like the Zwin, IJzermonding and Baai van Heist (see chapter 2.1.2). The Belgian part of the North Sea is also highly vulnerable to marine pollution in a socio-economic sense, for example in terms of the possible impact on fishing activities, coastal tourism and recreation, or relating to other human activities at sea like wind farms and aquaculture (see chapter 2.1.3). With a high risk of shipping accidents and any resulting pollution on the one hand, and the significant ecological and socio-economic vulnerability of the

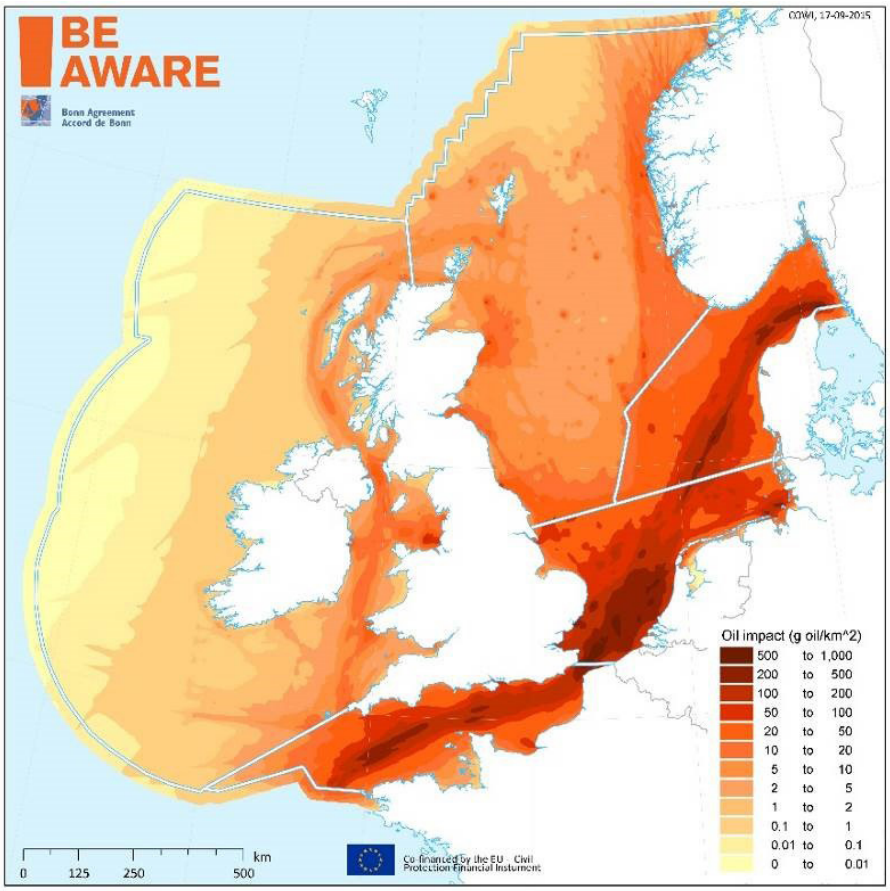

Figure 28. Scenario developed by BE AWARE II in 2015[65], which predicts the distribution of oil impact for 2020. The impact is expressed in g oil/km², representing the amount of oil from accidental discharges present on average in each km² of the North Sea.

area on the other, the Belgian and surrounding sea areas are considered to be the single most high-risk area for incidental oil impact in the greater North Sea, and one of the highest risk areas for total oil damage[65] (figure 28).

The environmental impact of accidental marine pollution is different to the impact of operational discharges, which occur frequently in all seas and all seasons. Despite smaller volumes of oil being released, operational discharges (from ships or other human activities at sea, such as the offshore oil and gas industry) lead to more chronic, cumulative pressure on the marine environment, stretching across entire marine regions[3]. Accidental marine pollution, on the other hand, tends to be the result of a sudden, usually much larger release of harmful substances, in one particular place and one specific season. Depending on the spatial and seasonal vulnerability of the area affected, a single severe incident of accidental marine pollution can potentially cause many years of extensive environmental damage.

4.1.2.2. Emergency planning and government action in the event of emergencies at sea

In accordance with the International Convention on the Law of the Sea (UNCLOS)[8], coastal States have an obligation to protect and preserve the marine environment, including from accidental pollution. That is why coastal States draw up emergency plans and work together to ensure preparedness, to be able to deal quickly and efficiently with a maritime disaster. Belgium, too, has developed a detailed emergency plan for the Belgian part of North Sea in the framework of its Coast Guard structure, the General Emergency and Intervention Plan North Sea. With its associated monodisciplinary and operational sub-plans, it is not just aimed at environmental disasters – it covers all kinds of potential emergency situations at sea, including search and rescue missions, maritime safety and security incidents and environmental emergencies. The General Emergency and Intervention Plan North Sea consists of a dual crisis management structure, ensuring consultation and cooperation between competent federal and Flemish government departments, both at operational and higher management levels. Operational coordination is in the hands of an operation command post (CP-OPS), based at the Maritime Rescue and Coordination Centre (MRCC) in Ostend. Higher crisis management takes place within the provincial coordination committee (CC-PROV), which is also set up at the MRCC Ostend, or at the provincial crisis centre in Bruges. The General Emergency and Intervention Plan North Sea also involves a significant coordinating role for the Governor of West Flanders, who is responsible for the coordination of crisis management (CC-PROV) and acts as the competent authority for the accommodation of ships in need of assistance. Emergencies at sea quickly trigger a number of coordinated actions from the Coast Guard, including information gathering, alerting the different emergency services through the Coast Guard centre, activating the marine emergency plan, joint evaluation of the event, and a coordinated government response, which may involve the launch of search and rescue and counter-pollution operations at sea, the activation of intervention means, the establishment of a safety perimeter, ensuring ongoing shipping safety, a police investigation, and so on.

4.1.2.3. Role of the Coast Guard aircraft in the event of accidental marine pollution

In the event of a maritime disaster involving (a risk of) accidental marine pollution, the Coast Guard aircraft is scrambled as quickly as possible to assist in the emergency interventions, with a dual role:

1. Monitoring of accidental pollution from the air, including determining the extent, severity and combatability of the pollution and estimating the volume that has been discharged (in the case of oil) (figure 29A);
2. Providing air support to units combating the pollution at sea, by locating thicker, combatable areas of pollution and guiding response vessels (figure 29B).

Both tasks are essential to deal efficiently with accidental marine pollution. Aerial surveillance is the quickest way to get a good picture of the scale and severity of a marine pollution incident, even across a large and cross-border maritime area. The information gathered from aerial surveillance is also used as inputs for advanced mathematical models, like the RBINS's OSERIT model[66], which is able to quickly and reliably simulate the behaviour and drift of pollution at sea for several days following an observation in the field. The combination of aerial

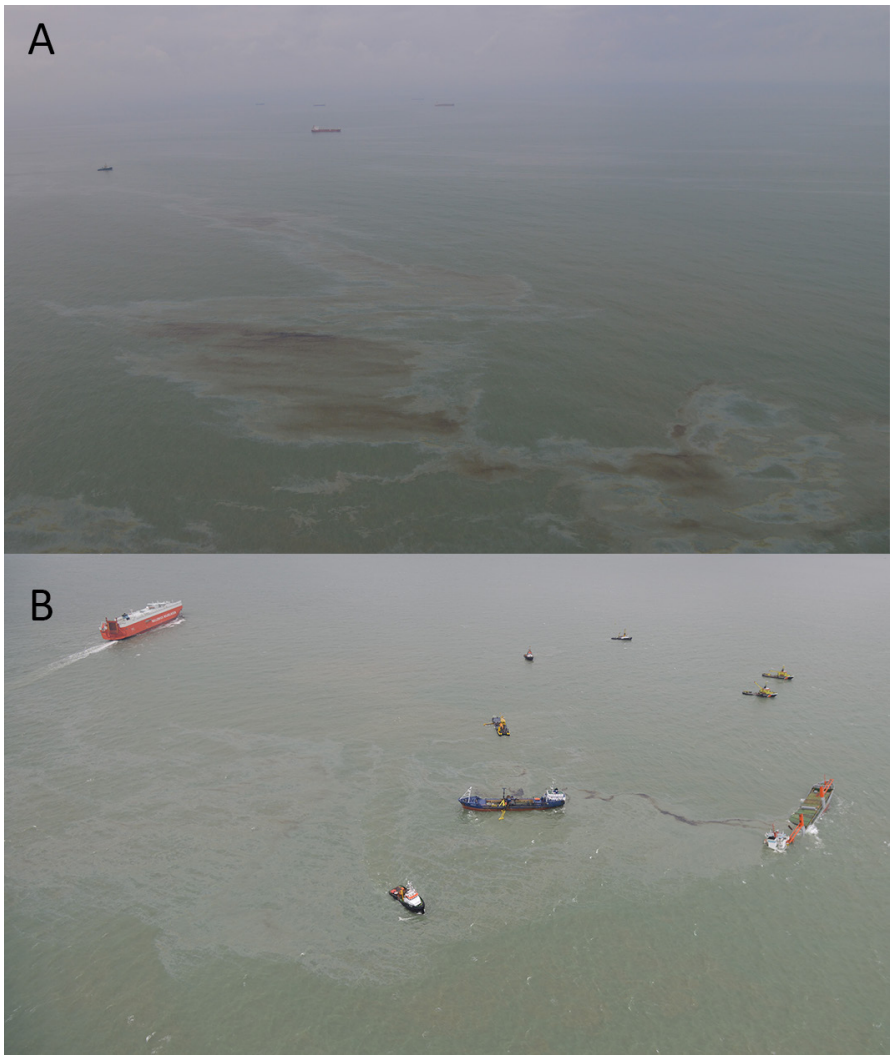

*Figure 29. Flinterstar accident. **A**. After the accident, large quantities of oil ended up in the sea, which were closely monitored by the Coast Guard aircraft. **B**. Guidance of the oil combat vessels by the Coast Guard aircraft to the thickest oil layers (October 2015).*

surveillance and modelling makes a significant contribution to creating a reliable overall picture of the situation, which lies at the basis of sound decision-making. Air support for response units is also crucial for pollution response operations to be effective. Personnel on the water will rarely be able to get a good overview of an accidental marine pollution – which can often spread quickly across several square kilometres – and which parts of it may or may not be combatable. MUMM makes a significant contribution to pollution response operations at sea. They work closely with and support those public authorities who are responsible for the emergency response at sea or along the coast, specifically the Directorate-General for the Environment of the FPS Health, Food Chain Safety and Environment (who coordinate pollution response operations at sea), the Ministry of Defence, The Flemish Service Fleet, Civil Protection, the coastal Fire Brigades, and any other units that have been activated to combat the pollution, such as foreign, private or European response vessels.

In order to practice for its role of aerial monitoring and support in case of accidental marine pollution in and around Belgian waters, the Coast Guard aircraft regularly participates in national and sub-regional exercises called POLEX – Pollution Exercises. Over the period 1991-2021, the aircraft participated in 16 POLEX events (figure 30) and four sub-regional counter pollution exercises that took place in Belgian waters (see Annex 4 and chapter 4.1.3.3 for more information).

Figure 30. A patrol vessel practises using dispersants on an oil simulant (straw) during the 24 June 2021 POLEX. The Coast Guard aircraft monitors the pollution incident and offers support to units on the water.

4.1.2.4. Incident history since 1990

For decades, MUMM has been keeping a list of maritime accidents in and around the Belgian marine areas that either led to accidental marine pollution or presented a significant risk of pollution. Looking at this incident history for the period between 1991 and 2021, we can see some remarkable statistics:

- Since the start of the Belgian aerial surveillance programme in 1991, 35 serious maritime accidents have occurred in or around Belgian marine areas, either resulting in or presenting a significant risk of accidental marine pollution from oil or other harmful substances. A total of 55 ships were involved in these accidents.
- In most of these cases (26), the surveillance aircraft was actually scrambled to monitor the emergency from the air and to provide air support where appropriate. The shortest intervention period was one day. The longest intervention period was 1.5 years and related to the *Tricolor* incident (from the initial collision in December 2002 until the recovery of the wreck was completed in August 2004 – see box page 50).
- By far most accidental pollution incidents, or most of the high-risk situations, were caused by collisions between ships (19 cases). Less frequent causes include capsizing, loss of cargo in bad weather, overflow during bunkering operations or fire/explosion (figure 31). Although ships are very frequently stranded in Belgian waters[b], these types of incidents rarely lead to environmental damage, because of the naturally sandy seabed in and around the Belgian marine areas;
- Over half of the ships involved in these incidents (30 ships, or 55%) were of a type that carried oil or Hazardous Noxious Substances (HNS) as cargo, besides oil for fuel: i.e., tankers, container ships and RoRo (roll-on/roll-off) vessels (figure 32).
- In 26 cases, the incident resulted in an accidental oil spill (22) or a serious risk thereof (4). In one case, there was a violent fire (*British Trent* incident, 1993 - see box). Out of these 26 emergencies, 2 presented a major risk of explosion or fire. The largest volume of oil accidentally discharged into the sea was 7000 m³ (accidental release of unleaded petrol from a ruptured tank of the *Bona Fulmar*, 1997 - see box).
- Despite the significant risk of accidents involving harmful substances other than oil or HNS in and around Belgian waters, which is clearly stated in multiple risk analysis studies, Belgium has fortunately been spared major incidents of this kind in the period 1991-2021. Nevertheless, our country has dealt with 9 HNS incidents at sea, which resulted in HNS being released in the marine environment (5), or a serious risk thereof (4) (including the passage of the damaged container ship '*MSC Flaminia*' in 2012 – see box).
- In only 16 of the 35 shipping incidents involving (serious risk of) accidental pollution - which is fewer than half - the initial accident occurred in the Belgian marine area. In 14 cases, the accident happened in surrounding French, Dutch or British waters. There were also two accidents that occurred even further away, which nonetheless caused (a serious risk of) accidental pollution in the Belgian part of the North Sea. In the remaining three cases, the accidental pollution originated in one of the Flemish coastal ports (Ostend and Zeebrugge). This is not entirely surprising, because the North Sea is a very dynamic and open environment, and marine pollution can very quickly cross sea borders under the influence of the wind and tide. There are also some significant maritime traffic

[b] As can be seen from the annual maritime incident statistics compiled by MRCC Ostend. MRCC's incident statistics also indicate that collisions are more common than MUMM's incident history suggests, which means that many collisions - fortunately - result in only minor damage.

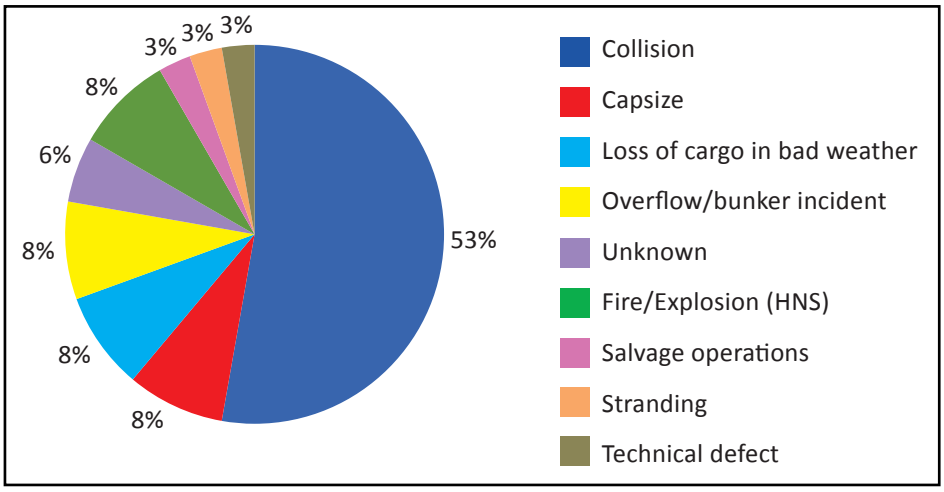

Figure 31. Pie chart showing the distribution (%) of the various causes that have led to (a significant chance of) accidental marine pollution in and around the Belgian marine areas.

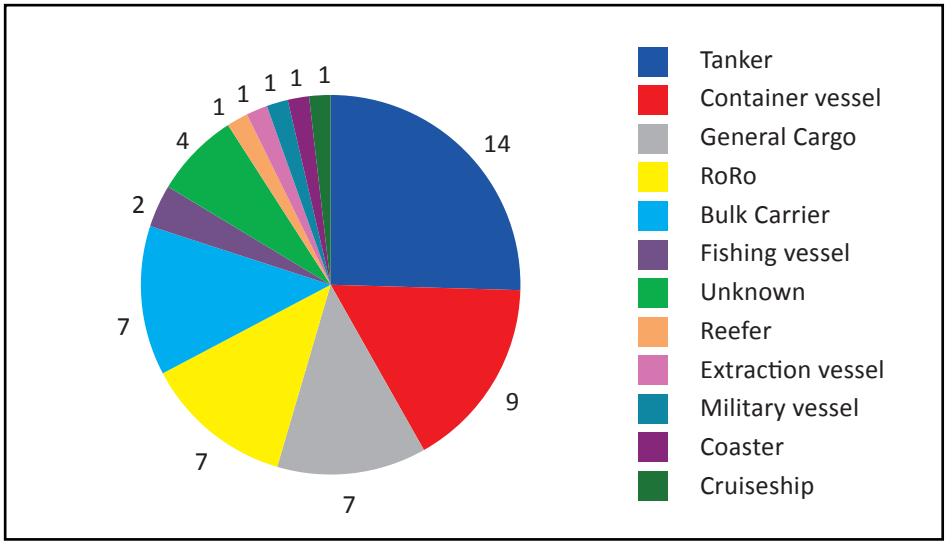

Figure 32. Pie chart showing the distribution of the different types of vessels involved in collisions that have led to (a significant chance of) accidental marine pollution in and around the Belgian marine areas.

routes just outside the Belgian marine area: the Sandettie junction and the Dover Strait in nearby French-British waters and the North Hinder junction in Dutch waters. The Belgian waters themselves also include several high-risk areas for maritime accidents, like the West Hinder anchorage area, the central route North Hinder TSS (at the northern edge of the Belgian EEZ) and the route to and from the Western Scheldt (West Hinder TSS, Scheur). A maritime accident in this part of the southern North Sea could very easily affect the sea areas of 4 coastal States: Belgium, France, the UK and the Netherlands.

4.1.3. International assignments under the Bonn Agreement

Although the Coast Guard aircraft's main area of operation is in and around the Belgian marine areas, it has also been participating in international surveillance and cooperation missions since the early '90s, as part of the Bonn Agreement. These international assignments mainly consist of the "Tour d'Horizon" (TdH) missions, the (Super) CEPCO operations (Coordinated Extended Pollution Control Operation), (sub-)regional exercises (BONNEX) and sea trials.

Examples of important incidents

***British Trent* (1993)**[48,67]

On 2 June 1993, the oil tanker '*British Trent*' (loaded with 24,000 tonnes of petrol) and the ore ship '*Western Winner*' collided near the West Hinder anchorage area, a little over 12 nautical miles off Ostend. The collision caused a major fire on board the tanker, with very heavy smoke. The incident claimed a heavy human toll, taking the lives of nine crew members on the *British Trent*. Thanks to the professional fire-fighting operation, however, only one-fifth of the tanker's cargo was consumed in the fire. The accidental oil discharge into the marine environment was relatively limited: the MUMM surveillance aircraft observed as little as 10 m³ of oil on the sea surface.

Figure 33. Firefighting at sea during the accident with the British Trent.

***Bona Fulmar* (1997)**[68,69]

On 18 January 1997, in thick fog, the product tanker '*Bona Fulmar*' (loaded with 60,000 tonnes of petrol) collided with the chemical tanker '*Teoatl*', around 19 nautical miles north-west of Dunkirk. A tank on the *Bona Fulmar* ruptured, and 7,000 tonnes of petrol flowed into the sea. Fortunately, the damage suffered by the *Teoatl* was minor enough for it to sail on to Rotterdam. Most of the petrol that was released into the sea evaporated within a day. The intense petrol odour still reached inland areas of England. Passing ships were warned about a potential risk of fire and explosion. As petrol is a non-persistent oil, its impact on the marine environment was relatively limited, despite the significant volume that was discharged.

***Tricolor* (2002-2004) and *Vicky* (2003)**[70-72]

During the night of 14 December 2002, the RoRo vessel '*Tricolor*' collided with the container ship '*Kariba*' at the Sandettie junction, within the French EEZ but close to the Belgian EEZ. The *Tricolor*, carrying 1,988 tonnes of heavy fuel oil, sank right in this busy shipping route (figure 34), where it posed a major navigational hazard. Despite extensive safety measures, two other ships collided with the wreck: on 16 December, a small ship called the '*Nicola*', struck the *Tricolor*, and on 1 January 2003, with 66,000 tonnes of diesel on board, so did the tanker '*Vicky*'. On 22 January 2003, the wreck was further damaged by an incident during salvage operations. Although the *Tricolor* lost little oil after the first collision, the accidental oil discharges increased dramatically as the structural condition of the wreck deteriorated, resulting in frequent leaks. Later in 2003, while the wreck was being cut into sections and lifted out of the water, multiple large volumes of oil (10 m³ to >100 m³) were discharged into the sea. The accidental discharge of heavy fuel oil from the *Tricolor* was finally estimated at approx. 500 m³. Additional heavy fuel oil pollution from a ruptured tank on the *Vicky* was thought to be around 200 m³ (figure 35). The incident took a heavy toll on the seabird populations overwintering in the area: over 18,000 oiled birds were found on the beaches of Northern France, Belgium and the Southern Netherlands. Along the Belgian coast, 9,177 oiled birds were collected, belonging to 32 different species. The surveillance aircraft continued to operate regular surveillance flights around the *Tricolor* site from

mid-December 2002 until recovery was completed in October 2004. This amounted to about 190 passages and 80 flight hours.

Figure 34. RoRo Tricolor, which sank in the middle of the busy shipping route after a collision on 14 December 2002.

Figure 35. Accidental oil pollution by tanker Vicky, after striking the Tricolor on 1 January 2003.

Sapphire (2007)

On 4 December 2007, the bunker ship '*MS Sapphire*' started to leak after a wrong manoeuvre during a bunkering operation. This released some 100 tonnes of heavy fuel oil into the tidal dock at the port of Ostend (figure 36). The Civil Protection, the Directorate-General for the Environment and the local fire brigade were quickly on site and were able to confine and mechanically recover most of the oil floating on the surface. The Coast Guard aircraft was deployed in order to check the spread of the oil, as there was a risk of the heavy fuel oil flowing into the vulnerable coastal waters nearby. On 4 and 5 December, several oil slicks were observed from the aircraft within the tidal dock, the Zeewezendok and the port channel in the Ostend outport. Many quay walls were covered in sticky oil. Fortunately, the nearby coastal waters were spared: no oil flowed towards the sea. The *Sapphire* incident demonstrated that a real risk of accidental pollution exists in the Flemish seaports as well, and that emergency plans for the seaports are also essential to be able to act quickly and efficiently, limit the impact on the port and prevent further spread of pollution to vulnerable areas nearby.

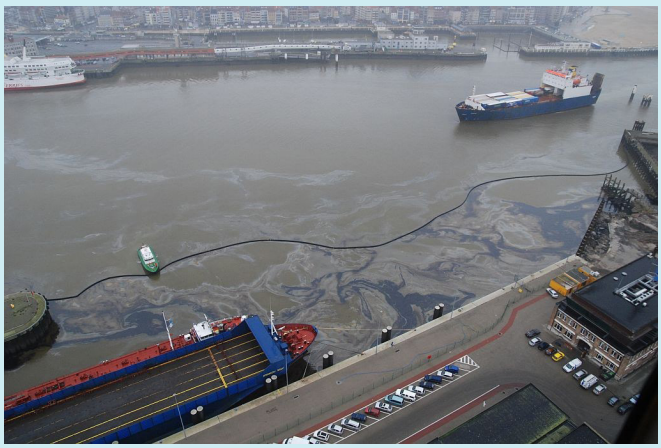

Figure 36. MS Sapphire bunker incident in the port of Ostend (4 December 2007).

MSC Flaminia (2012)[73-77]

On 14 July 2012, while sailing from Antwerp to Houston on the Atlantic Ocean, the container ship '*MSC Flaminia*' suffered a powerful explosion and subsequent fire on board (figure 37). One crew member died, a second was missing and three others were injured. After the crew evacuated and abandoned the ship, it was left drifting in the mid-Atlantic. A second explosion occurred four days later, and the fire raged on for nine days. Salvage ships raced to the scene, first putting out the fire and then towing the *Flaminia* towards Europe. Before the ship could be permitted to enter a European port, an international team of experts boarded the *Flaminia* on 23 August for an inspection to evaluate the vessel's stability and the risk of further fires or explosions. Analysis of the cargo lists revealed that 153 of the containers on board contained a huge variety of HNS. Many of those containers were located in the fire-ravaged central part of the ship, indicating that the water

left on board after firefighting operations was potentially heavily contaminated. After consultation with several European coastal States, including Belgium, the ship's flag State Germany eventually offered Wilhelmshaven as a place of refuge for the *Flaminia*. This meant the *Flaminia* needed to be towed to Germany through the Channel. During the night of 5 to 6 September 2012, the convoy passed through the Belgian EEZ, with a Coast Guard escort. Sometime before this journey took place, Belgium (MUMM) had activated the European MAR-ICE network to conduct a thorough HNS risk analysis. During its journey through our EEZ, the *Flaminia* was closely monitored from the air by the Coast Guard aircraft. No loss of cargo or contaminated water was detected. On 9 September, the *Flaminia* finally arrived in Wilhelmshaven, without further incidents.

Figure 37. The severely damaged container ship 'MSC Flaminia', after two explosions and a fire (July 2012) .

***Flinterstar* (2015)**[78,79]

In the night of 6 October 2015, the gas tanker '*Al Oraiq*' collided with the cargo ship '*Flinterstar*' on the coastal shipping route Scheur, in the eastern coastal waters of the territorial sea. The tanker suffered minimal damage, but the *Flinterstar* was pushed onto a sandbank, just 8 km north-west of the port of Zeebrugge. The General Emergency and Intervention Plan North Sea was activated immediately and the *Flinterstar*'s crew was evacuated within a few hours. Unfortunately, the wreck of the *Flinterstar*, which was carrying around 430 tonnes of heavy fuel oil and 115 tonnes of gas oil, was steadily leaking oil into the sea (figure 38). The coastal waters where this took place are considered to be particularly vulnerable given the proximity of the Zwin, Baai van Heist, Western Scheldt and rich fishing grounds. A fast response was absolutely vital, and specialist counter-pollution ships were called in from the Netherlands. The Belgian Coast Guard aircraft was also scrambled very quickly, and performed its first surveillance flight early on the morning of 6 October. Between that first morning and the end of oil recovery operations on 2 November 2015, the aircraft operated around 40 consecutive flights, amounting to over 55 flight hours at sea, to provide both aerial monitoring and air support for the response vessels at sea. After that, the aircraft regularly flew over the site until the wreck was fully recovered in the summer of 2016. Based on data from aerial surveillance and the amount of oil pumped out of the vessel's tanks, it was concluded that approximately 200 tonnes of oil (mixtures of heavy fuel oil and gas oil) entered the marine environment in the first month. Around 50 tonnes of this was recovered from the sea.

Figure 38. The cargo ship 'Flinterstar' was involved in a collision on the Scheur coastal route in the eastern coastal waters of the territorial sea, leaking oil into the sea for months (October-December 2015).

4.1.3.1. Annual surveillance of the offshore oil and gas installations – Tour d'Horizon

Tour d'Horizon is an important regional surveillance programme that has been taking place every year since the start of aerial surveillance under the Bonn Agreement. TdH missions entail surveillance flights carried out in turn by the various North Sea countries' aircraft, to monitor and detect marine pollution from offshore oil and gas installations in the central and northern parts of the North Sea. Any pollution detected during TdH flights (including any incidents spotted while flying to and from the relevant offshore areas) is systematically evaluated, documented and reported to the competent authorities for the coastal State in question, regardless of whether the pollution has originated from a drilling platform (figure 39) or a ship.

Belgium has been carrying out this annual regional mission since 1992. In the past 30 years, there were only six occasions when our country has been unable to participate (in 2003, 2005, 2007, 2011, 2015 and 2016). Between 1992 and 2021, a total of 430 hours were flown for TdH missions. During these TdH flights, 296 pollution detections were reported (an average of 12 per year), 272 of which consisted of mineral oil, nine were harmful substance other than oil, and 15 could not be visually verified (the type was recorded as unknown, because of poor visibility in fog or low clouds) (Annex 5). The vast majority of the oil detections - 240 of them - were connected to an oil or gas installation. The distribution of these different types of slicks across the waters of the different North Sea countries is shown in figure 40. The locations of most of the oil detections are consistent with the locations of the largest oil fields in the North Sea, while pollution incidents involving other substances are more scattered across the whole area. The reason for this is that spills of other harmful liquids usually originate from shipping, rather than from the offshore industry. The detections that were recorded as being of an 'unknown' nature were also found around rigs, which suggests that they almost certainly consisted of oil, even if this could not be confirmed through visual verification. The table in Annex 6 shows the distribution of oil detections connected to rigs across the EEZs of the four North Sea countries involved in oil and gas production in the North Sea. Figure 41 shows the distribution of all oil detections on the map, indicating that most of the oil pollution incidents detected are in UK waters. That is logical, as UK waters are home to more oil-drilling platforms than all the other North Sea countries. The largest drilling-related volumes of oil detected and reported by the Belgian Coast Guard aircraft were also primarily found in British and Norwegian waters. After all, the largest oil fields - and with them the greatest concentration of platforms - can be found in the north.

Figure 39. An oil detection linked to an oil rig observed by the Belgian Coast Guard aircraft during the TdH mission in 2020.

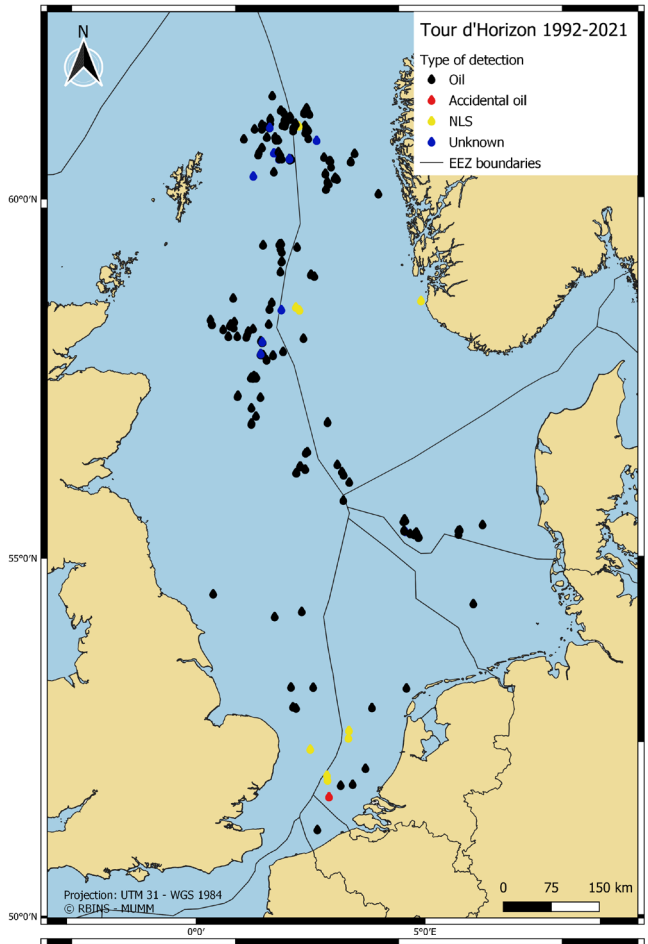

Figure 40. Distribution of the different types of detections (oil, NLS and unknown substances) during TdH missions in the waters of the different North Sea countries in the period from 1992 to 2021.

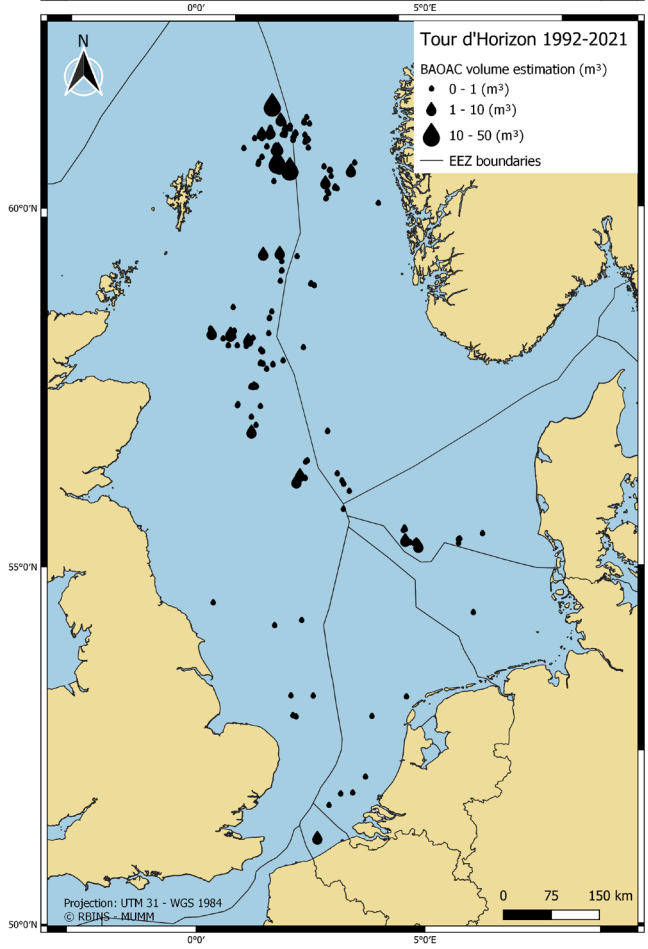

Figure 41. Distribution of the oil detections during TdH missions in the waters of the different North Sea countries in the period from 1992 to 2021.

The 272 oil detections reported during Belgian TdH missions had an estimated combined volume of at least 194 m^3. After 2001, a significantly smaller volume of oil was observed compared to the 1990s (although 2008 was an outlier), but this has been increasing again in the last few years (figure 42). The same trend is also noticeable in the number of major oil detections (over 1 m^3) observed during the annual Belgian TdH mission (figure 43). Most of the slicks observed are found to be permitted operational produced water discharges from drilling platforms. This is (polluted) water that is pumped up from the oil reservoir along with the oil, either because the water was already naturally present in the oil reservoir or because the water was pumped into the reservoir to force the oil upwards. A small minority of the slicks are the result of non-permitted discharges by drilling platforms, for example due to technical defects. In many of those cases, the volume of oil is greater than 1 m^3.

The increase in the total oil volume after 2013 can be partly explained by ageing infrastructure. The older the rigs, the more water will need to be used for oil production, and the greater the risk of leaks in the infrastructure[47]. Another important aspect that creates variation in TdH results over the years is the weather: in calm weather, an oil slick will remain on the surface longer than it would in a storm. In the 1990s, the Belgian surveillance aircraft occasionally carried out TdH missions during the winter period, but since 2009 these flights have only taken place in the summer season, as MUMM learned from experience that the Belgian Coast Guard aircraft does not have sufficient autonomy to carry out an entire TdH mission in adverse weather conditions with enough safety margin.

After each TdH flight, all observations are reported to the coastal States concerned and any reported observation is systematically followed up by the inspection services of the competent coastal State. This creates a significant deterrent effect for the operators of oil and gas installations in the North Sea. The results and findings of the annual TdH missions are also shared with the Offshore Industry Committee (OIC) of the OSPAR Commission[80]. As part of the OSPAR Convention of 22 September 1992 (Convention for the Protection of the Marine Environment of the North-East Atlantic)[81], the OIC is responsible for the inclusion and coordination of work to prevent and remove pollution from offshore activities, including monitoring and evaluating the impact of the offshore oil and gas industry on the marine environment and the review of OSPAR measures and actions on pollution from offshore activities.

4.1.3.2. Coordinated monitoring of a sea area by different countries ('CEPCO')

A regional CEPCO surveillance operation consists of a number of consecutive pollution control flights by several surveillance aircraft from different North Sea countries. The aim is to create permanent surveillance from the air over a period of at least 24 hours, in a zone that is at high risk of illegal vessel discharges. Every few years, there is a 'Super CEPCO' operation (figure 44), a campaign of near-continuous aerial surveillance over a high risk area, over several days (up to max. 10 days).

The Belgian Coast Guard aircraft took part in CEPCO operations in 1997, 1998, 2000, 2001, 2007-2010, 2012 and 2021. The campaigns in 2007, 2010, 2012 and 2021 were so-called Super CEPCOs (see box page 57). The data generated by the Belgian Coast Guard aircraft alone can be found in Annex 7. As part of this regional surveillance operation, Belgium's aircraft spent a total of 110 hours in the air, across 34 separate flights, making 17 observations. CEPCO operations, and especially Super CEPCOs, always generate plenty of attention in the countries where they take place. They emphasize the North Sea countries' desire to work together to put a stop to illegal discharges at sea, and serve to strengthen the deterrent effect of aerial surveillance.

4.1.3.3. Sub-regional and regional counter-pollution exercises (BONNEX etc)

Another form of international cooperation on aerial surveillance is assisting one or more coastal States that are affected by serious accidental marine pollution, with air monitoring and air support. In order to maintain this level of international cooperation and preparedness, it is important that as well as national counter pollution exercises, there is also regular sub-regional or regional training at sea which includes aerial surveillance. The North Sea coastal States also carry out occasional pollution-related sea trials, to gain more and new knowledge related to specific forms of marine pollution and response techniques.

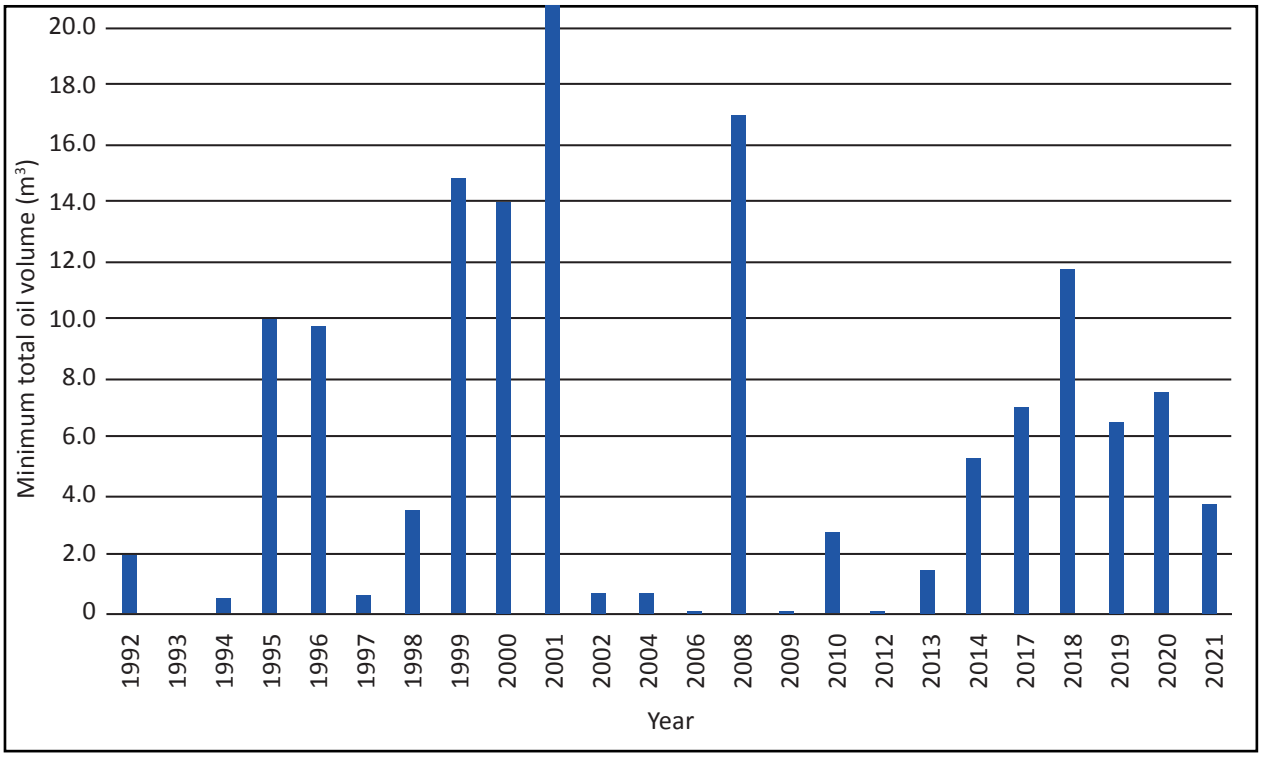

Figure 42. Estimated minimum total volume (m³) of reported oil detections per year in the period 1992-2021 during the Belgian TdH missions. The years in which the TdH campaign was not carried out have been omitted. A total oil volume of 74.3 m³ was reported in 2001.

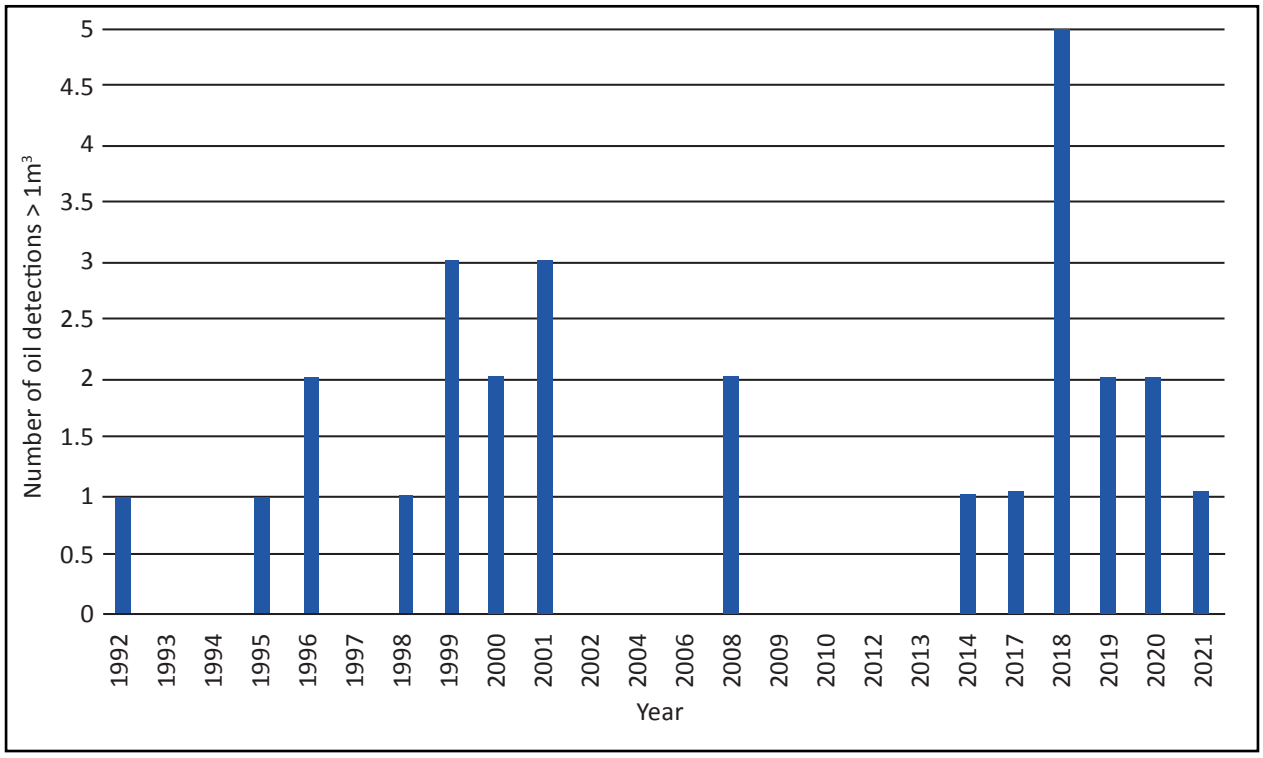

Figure 43. Number of oil detections with a minimum estimated volume greater than 1 m³ in the period 1992-2021, as reported during the Belgian TdH missions. The years in which the TdH campaign was not carried out have been omitted.

The 2007 Super CEPCO created a stir

The very first Super CEPCO operation took place in 2007. It was organised by Belgium from the Koksijde Air Force Base, with financial support from the European Commission. During this Super CEPCO, there were 10 days of continuous aerial surveillance over the southern North Sea, the northern Channel and the Dover Strait. All of the countries that were part of the Bonn Agreement at the time took part in the operation. Belgium, the Netherlands, the United Kingdom, France, Denmark and Germany supplied a total of seven aircraft for this large-scale campaign, while Sweden and Norway provided operators.

Over the course of those 10 days, there were 225 flights hours, resulting in 51 reports of marine pollution (36 of mineral oil, one of fish oil, one of vegetable oil and 13 whose nature could not be verified). Five ships were caught in the act of discharging oil into the sea. Their details were immediately passed to the judicial authorities, who were also involved in the operation. The European Maritime Safety Agency (EMSA) provided significant operational support, in the form of additional satellite surveillance: their CleanSeaNet service supplied 20 satellite images, showing 27 potential pollution detections. Ten of these were verified at sea by a surveillance aircraft.

This large-scale international surveillance operation generated a great deal of both national and international media attention[82], including in specialised maritime magazines. With this 10-day effort, Belgium and the other North Sea countries sent out a joint and very clear message: they were determined to put a stop to illegal oil pollution in the North Sea and would be pursuing a zero-tolerance policy.

Under the Bonn Agreement, there are three types of regular exercises which may include aerial surveillance:

- A sub-regional pollution combating exercise (BONNEX CHARLIE) aims to test the cooperation at sea between combating units from two or more North Sea coastal States, with respect to both communication and equipment.
- BONNEX DELTA is a regional, large-scale pollution response exercise, which is organised once every few years by the Bonn Agreement. It involves all aspects of counter-pollution, including communication, coordination, surveillance and response at sea, based on a realistic pollution scenario that continues to develop during the exercise. All of the North Sea countries are invited to participate in a regional BONNEX. Flying and seafaring personnel from the participating countries can meet and take part in the briefing together. A BONNEX DELTA exercise runs for around 24 hours and is followed

Figure 44. The surveillance aircraft of several North Sea countries, including Belgium, are ready to participate in the 2021 Super CEPCO at Oslo Airport (Gardermoen), Norway.

by a joint debriefing session. Occasionally, there are also some additional workshops. Due to the scale of the exercise, the European Commission usually makes a contribution towards its costs.

- Some of the North Sea countries regularly carry out sea trials, and the surveillance aircraft from other Bonn Agreement countries can often make a useful contribution to these. Sea trials are usually organised as part of European or national research projects, aimed at gaining more insight into certain forms of marine pollution and response techniques.

During the period 1991-2021, the MUMM surveillance aircraft participated in five sub-regional exercises that took place in neighbouring waters, two regional BONNEX DELTA exercises, and six international sea trials (3 sea trials were combined with national POLEX exercises (2) and a regional BONNEX DELTA exercise (1)) (see Annex 4).

4.2. Air pollution from ships

The adverse effects of air pollution on land have long been recognised, and stringent regulations for e.g., power plants and transportation have led to a significant decrease in harmful emissions. By contrast, the regulation of emissions from shipping has long remained substandard. Shipping is one of the main sources of SO_x and NO_x emissions worldwide[83]. In the period 2007-2012, SO_x and NO_x emissions from ships represented 12% and 13% of global anthropogenic emissions respectively, but only 3.1% of CO_2 emissions[84]. A series of international measures was clearly required in order to drastically reduce air pollution from ships. Those international environmental standards for air pollution by ships have been laid down in Annex VI of the MARPOL Convention[85]. This Annex is primarily aimed at gradually reducing emissions of sulfur oxides, particulate matter and nitrogen oxides (SO_2, PM and NO_x, as stated in Regulations 14 and 13 respectively) and introduced Emission Control Areas (ECAs), where stricter emission standards for air pollutants apply (figure 45).

In 1999, stricter standards were agreed for the sulfur content of shipping fuels in specific Sulfur Emission Control Areas (SECAs)[86]. Like the Baltic Sea before them, The North Sea and the English Channel became a SECA area in 2008[85]. From January 2015, the emissions limits were tightened further: ships would only be allowed to use fuel with a maximum sulfur content of 0.1%. Before 2015, the limit was set at 1.0%, and before 2010

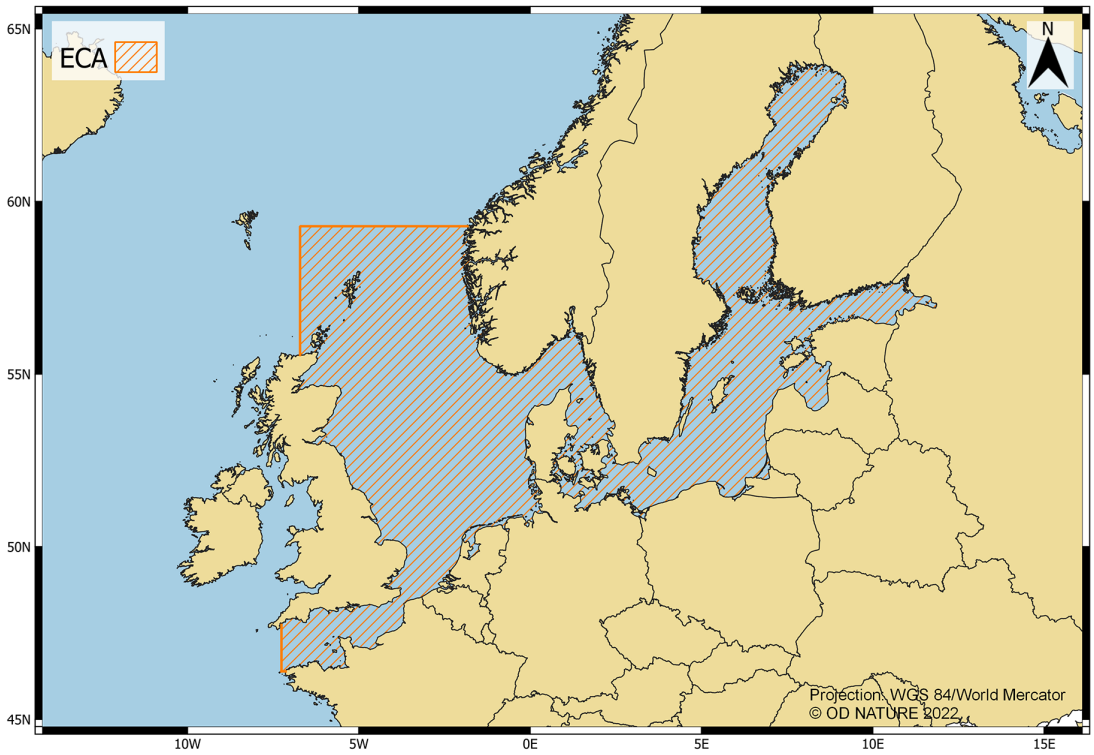

Figure 45. The North Sea and Baltic Sea ECA area. The coordinates of the boundaries as shown are based on IMO guidelines.

it was 1.5%. On 1 January 2020, maximum sulfur levels were reduced outside the SECAs as well, when the Global Sulfur Cap in MARPOL Annex VI - previously set at 3.5% - was lowered to 0.5%[87] (figure 46). The European Union considers Regulation 14 of MARPOL Annex VI on air pollution by sulfur oxides as a top priority, which is why the international emission restrictions for SO_x were implemented in European regulations, directives and[88] and implementing decisions[89]. At a national level, Belgium implemented MARPOL Annex VI and the relevant EU Directive with the Marine Environment Act[9] and a Royal Decree[90].

To comply with the regulations, ships entering SECA areas must either switch to fuels with a lower sulfur content, or use an approved after-treatment system (Exhaust Gas Cleaning System - EGCS, also known as a scrubber) to "wash" sulfur compounds from exhaust gases, allowing them to achieve the same low emission levels. By using natural gas (usually Liquified Natural Gas or LNG) as fuel ships can meet MARPOL Annex VI regulations as well.

Regulation 13 of MARPOL Annex VI lays down limits for NO_x emissions from marine diesel engines. In 2021, the SECA zone in the North Sea and the Baltic Sea was extended with a Nitrogen Emission Control Area (NECA) and subsequently referred to as an Emission Control Area (ECA)[87, 91, 92]. Emission limits for NO_x are expressed very differently to those for sulfur: for sulfur, it is the proportion of sulfur in fuel that is subject to control, whereas for NO_x, what matters is the amount of NO_x per unit of engine power (g NO_x/kWh). Limits apply to any engine with an output of more than 130 kW, depending on the optimum Engine Rated Speed as expressed in Revolutions per Minute (RPM). Three emission levels, called Tiers, were defined based on the ship's construction date. Ships built between 2000 and 2011 must comply with the Tier I standard (9.8-17.0 g/kWh), ships constructed after 2011 must comply with Tier II (7.7-14.4 g/kWh), and those built after 2021 should comply with Tier III (2.0 – 3.4 g/kWh) within the NECA (figure 47). Ships built between 1990 and 2000 with an output greater than 5000kW or cylinder displacement over 90 litres are also subject to Tier I. No standards were laid down for older ships. Unlike EU sulfur regulations, NO_x emissions from ships have not been regulated by an additional EU directive, which unfortunately means there are no common European rules and procedures for monitoring.

The IMO has recently started to review emissions of soot particles or Black Carbon (BC) in greater detail. Attempts have been made to perform measurements and thus investigate the impact of BC emissions from shipping, and to reach an agreement on the most appropriate ways to reduce BC emission from ships. However, there is currently little data available on BC emissions from ship engines, and knowledge of reduction technologies and measures is still limited, especially in comparison with BC emissions from road transport running on diesel. Several experimental campaigns have shown that BC emissions from ships are a major contributor to air

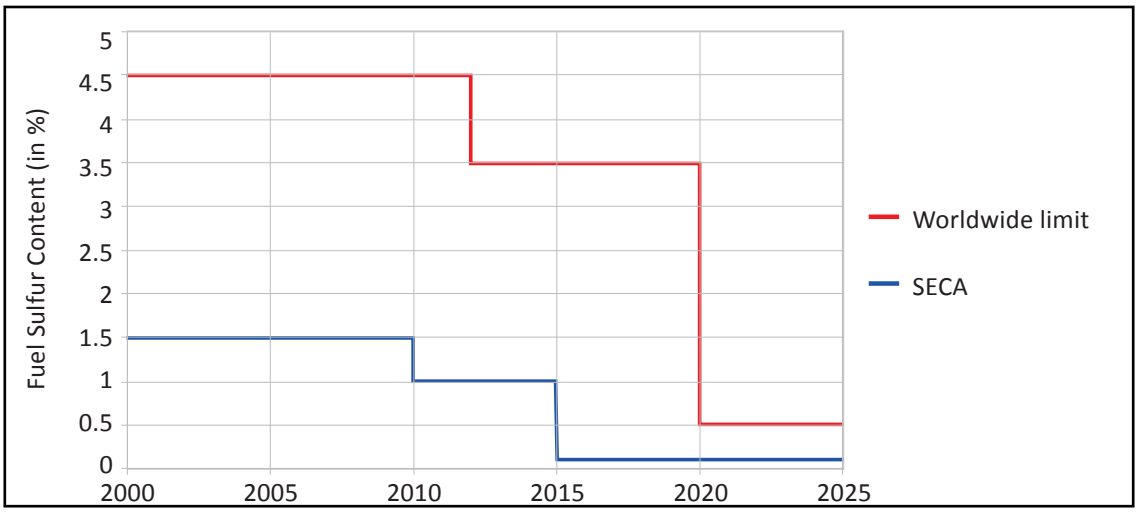

Figure 46. : Evolution of MARPOL Annex VI sulfur limits for ship fuel in the SECA areas (blue) and worldwide (red). Graph based on IMO guidelines.

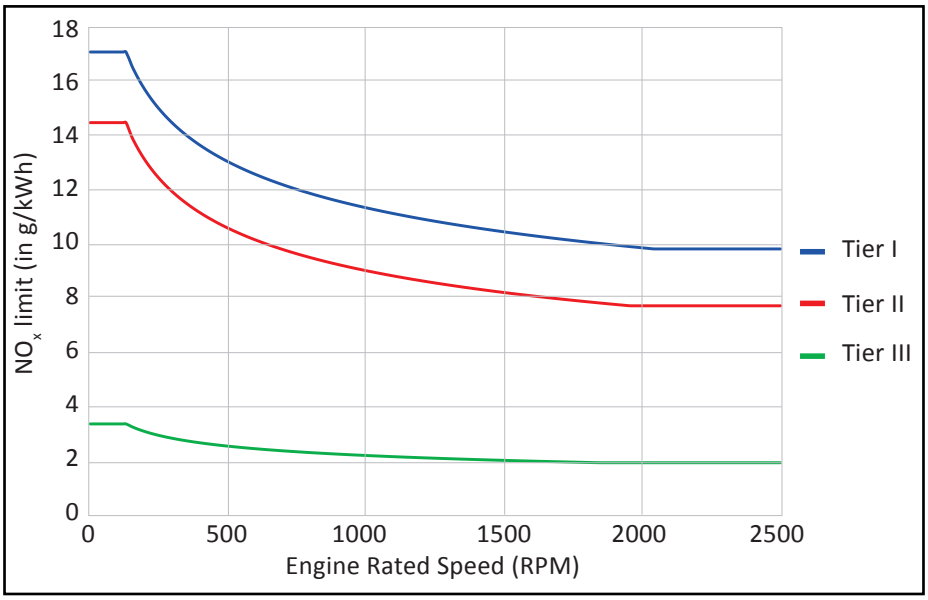

Figure 47. NO_x Tier standards: Tier-I applies to ships constructed from 2000, Tier-II to ships constructed from 2011 and Tier-III to ships constructed from 2021. Whereas Tier-III standards apply only in the NECA area, Tier-I and Tier-II apply worldwide.

pollution and climate change. The IMO has called on the various Member States to provide reliable data on BC emissions from shipping[93].

4.2.1. Locating vessels with suspect sulfur values

Cooperation and communication with the European Port State Control (PSC) network is a crucial aspect in the use of aerial surveillance to enforce MARPOL Annex VI. PSC is responsible for carrying out and coordinating port inspections to implement the EU Sulfur Directive[88,89]. Before sniffer measurements were carried out at sea, the selection of ships for inspection and sampling was mostly random. Only a small number of the ships calling at a port can ever be inspected. Identifying suspect vessels through aerial surveillance allows port inspections and sampling to be conducted in a more targeted and efficient way. With that in mind, any findings from suspect sniffer measurements at sea are reported to the competent inspection services in the next European port of call immediately after the flight. In addition, all other measurements results are collated in Thetis-EU via an automated protocol, forming a database managed by EMSA and accessible to all EU Member States. The data also includes those ships that were found to be compliant with the rules, further contributing to more efficient port inspections throughout the European Union. The ability to accurately target inspections reduces the time lost on ships that conform to the rules. Before aerial monitoring, ships leaving EU ports and leaving the ECA area, or ships that sailed across the ECA without calling at an EU port, could not be inspected by PSC. This meant that PSC compliance data did not paint an entirely accurate picture of reality.

For the time being, official reports cannot be made based purely on sniffer measurements at sea. Infringements can only be officially recorded if sufficient evidence is found during a port inspection with fuel sampling. In Belgium, port inspections and fuel sampling on board ships are carried by the FPS Mobility (DG Shipping). Sulfur measurements at sea with the sniffer sensor therefore mainly serve as a targeting system to make port inspections more effective.

4.2.2. Emission measurements

In the period 2015-2021, MUMM carried out 353 sniffer flights for a total of 545 flight hours.

4.2.2.1. Sulfur content of marine fuel

Since 2015, the sulfur emissions in no fewer than 6012 exhaust plumes from 3811 different ships have been checked (figure 48) in both Belgian and neighbouring waters - an average of 11 ships per

Figure 48. Ship with notable smoke plume.

flight hour. About 91% of the ships off our coast were found to be compliant with the strict sulfur standards. However, that also means that around 9% of them, or 405 of the vessels monitored at sea, were probably in breach of the rules (figure 49). It is absolutely vital that these potential offenders are dealt with efficiently if we want to enforce emission limits, create a level playing field in the shipping sector and ensure good air quality.

As part of the European pilot project 'CompMon'[27] following the start-up of sniffer flights, a system of colour codes was developed for reporting alleged MARPOL Annex VI violations to the port inspection services, which was further refined based on experience gained in the field. Each flight report using this system indicates the degree of probability of a ship being non-compliant:

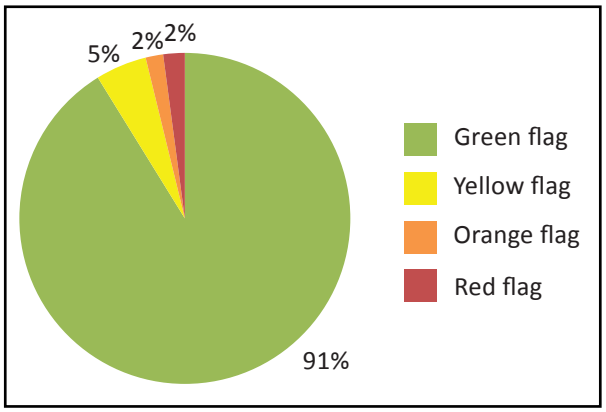

Figure 49. Pie chart showing the results of the sniffer campaign from 2015 to 2021, monitoring sulfur limits for ship fuel (yellow, orange and red flags are used to indicate the severity of the infringement, the green flag indicates the percentage of ships that were found to comply with sulfur regulations).

- Green flag: Fuel Sulfur Content (FSC) below 0.13% (considered to comply with the 0.1% SECA limit, taking into account an error margin in sniffer measurements);
- Yellow flag: FSC between 0.13% and 0.2% (i.e., non-compliant with the 0.1% SECA limit with a 68% confidence interval);
- Orange flag: FSC between 0.2% and 0.3% (i.e., non-compliant with the 0.1% SECA limit with a 95% confidence interval);
- Red flag: FSC over 0.3% (i.e., non-compliant with the 0.1% SECA limit with a 99% confidence interval).

Over the past few years, the number of ships found suspected of non-compliance has decreased significantly (figure 50), as has the severity of the infringements. However, more violations were found to take place further out at sea, which once again emphasises the importance of monitoring at sea (figure 51). Despite these encouraging results, new problems are now emerging on ships equipped with scrubber systems. These vessels are still allowed to use sulfur-rich fuel, but are equipped with an after-treatment system that washes sulfur from the exhaust fumes in order to achieve the targeted emission standards. Unfortunately, several ships with scrubbers were found to not respect the emission standards. What's more, when ships equipped with scrubber installations were found to be in breach of emissions standards, the values measured were significantly higher than those observed from ships that did not have scrubbers installed and were using low sulfur fuel. In addition, when inspecting ships in port it is difficult to ascertain whether or not the systems were correctly used at sea. That is why sniffer measurements are a great way to monitor scrubber vessels at sea.

Analysis of the number of violations recorded by port inspection services shows that the measurements and flight reports generated by the aerial surveillance program have led to a 50% increase in the efficiency of port inspections. Aerial inspections have also proven their worth in terms of total costs. Thanks to the high number of air inspections (approximately 1000 per year), the cost per inspection is relatively low at around 150 euros, compared to 400 euros for a port inspection. Ultimately, this has meant an effective cost reduction of 15% per confirmed violation.

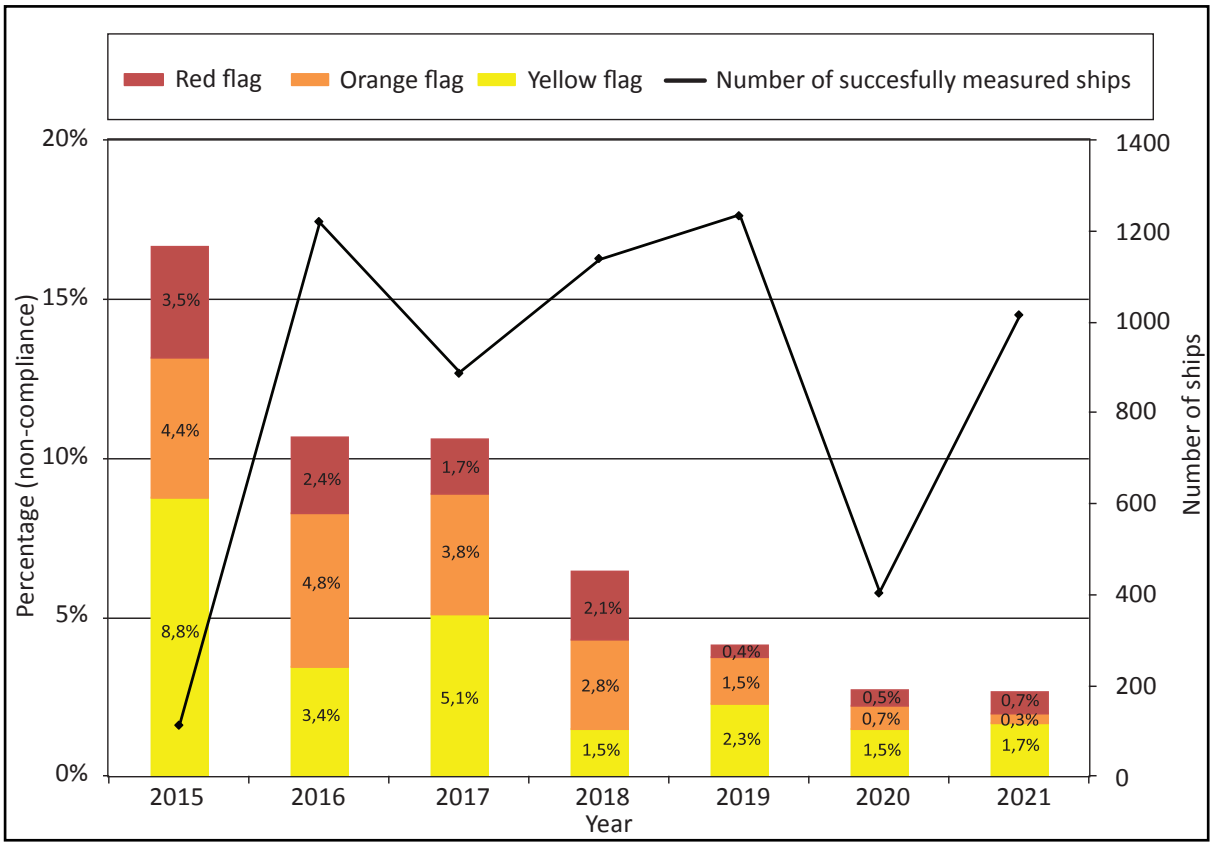

Figure 50. Downward trend in the number of potential fuel sulfur infringements based on the Belgian Coast Guard aircraft's sniffer flights between 2015 and 2021 (yellow, orange and red flags are used to indicate the severity of the infringement).

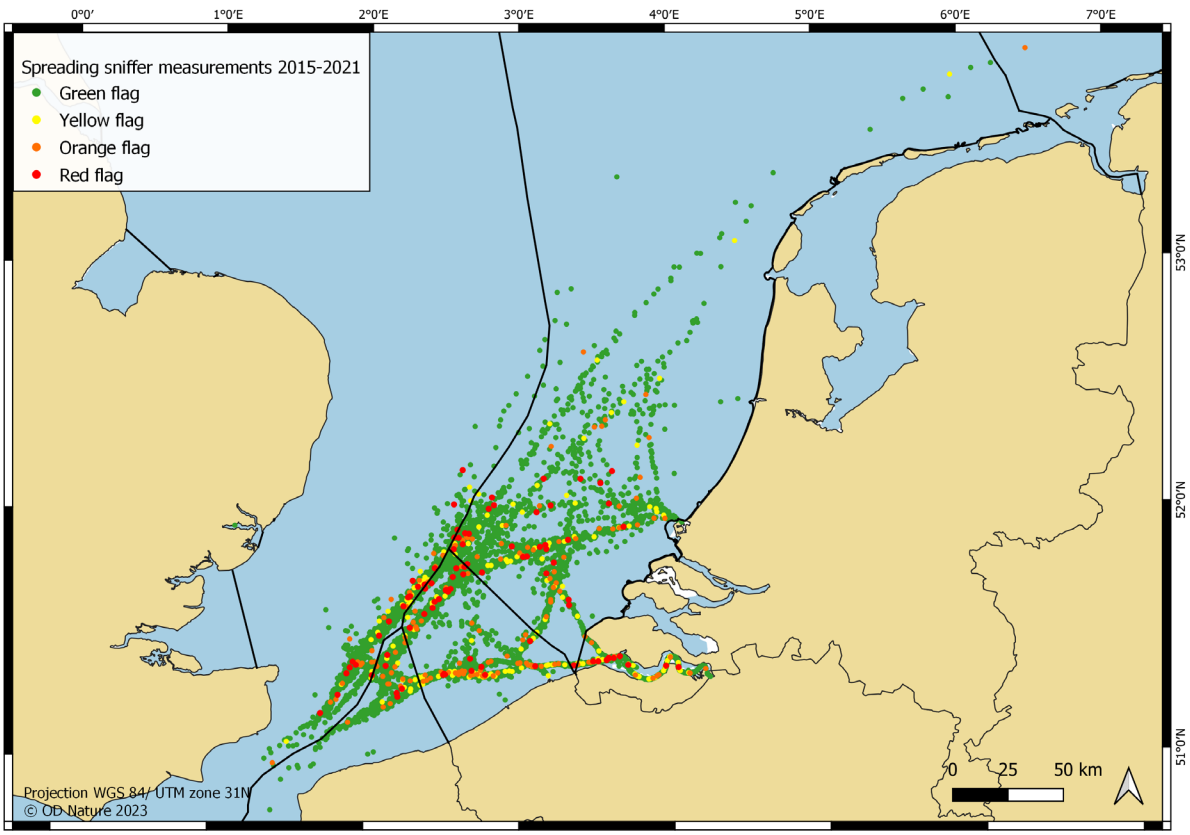

Figure 51. Distribution of the Coast Guard aircraft's sniffer measurements within the southern North Sea, clearly showing shipping routes.

With regard to the issuing of administrative sanctions for these MARPOL infringements, Belgium is at the forefront: thanks to 'sniffer' alerts from the aircraft, 24 vessels were caught in the act in Belgian ports, and 35 were caught in a foreign port. In 10 cases, PSC services proceeded to issue an official statement. The Belgian authorities imposed seven administrative fines, ranging from € 8,000 to € 150,000. In the period from 2015 to 2021, administrative fines worth € 282,800 were issued for sulfur emissions infringements.

4.2.2.2. Nitrogen emission from ships

The NO_x sensor was extensively tested in 2020, and in the same year the nitrogen emissions from 394 ships monitored at sea were successfully checked. The relevant monitoring and reporting procedures were also developed over the course of this start-up phase. This meant that Belgium was the first country to be ready to monitor and enforce NO_x emissions standards from shipping at sea according to the different Tier norms, including the strict Tier III NECA restrictions in the North Sea area that came into force on 1 January 2021.

Out of 1004 ships whose nitrogen emissions were monitored at sea in 2021, 23 were found to have suspect values. NO_x sniffer measurements are important because inspection of NO_x emissions on board of ships is not straightforward. At present, inspection on board can only be based on engine certificates, which are issued by competent agencies and the engine's manufacturer. PSC is currently only able to request access to certification documents to verify compliance with emissions standards. In order to comply with stricter NO_x emission standards (Tier II or III), ships can also make use of emission reduction systems like Selective Catalytic Reduction (SCR) or Exhaust Gas Recirculation (EGR). This presents PSC inspectors with significant additional challenges, as they must try to ascertain during checks in the port whether these systems were functioning properly while the ship was passing through the NECA.

Data from two years of NO_x measurements for individual vessels in the southern North Sea shows that 97% of ships comply with international NO_x regulations (figure 52). More detailed analysis of NO_x measurements indicates that for more recent Tier II vessels, which are subject to stricter emission standards, the average nitrogen value is significantly higher than for older ships (Tier I and Tier 0), especially due to higher NO_x emissions at lower engine power levels. For example, in the period 2020-2021, average NO_x emissions for Tier I ships were 12.6 g NO_x/kWh, compared to 13.5 g NO_x/kWh in Tier II (figure 53). There were also significantly more Tier II vessels with suspicious values that had exceeded a predetermined threshold. Unfortunately, these results suggest that the gradual reduction of nitrogen emissions from more recent seagoing vessels, as envisaged by international regulations, is not (yet) being

Impact of air pollution on people and the environment

Air pollution from ships affects people and the environment in several ways. By burning fossil fuels, primarily cheap heavy fuel oil, shipping is responsible for a significant share of the global emissions of pollutants into the air. In addition to carbon dioxide (CO_2), pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter ($PM_{2.5}$) and soot particles are abundantly present in exhaust fumes. Scientists estimate that air pollution from shipping caused 800,000 premature deaths globally in 2017[94].

During combustion, any sulfur in the ship's fuel is largely oxidized into sulfur oxides SO_x (primarily SO_2), while the residual fraction gives rise to the formation of sulfur particles (a fraction of particulate matter). SO_2 can cause asthma and affect lung function in children, and in adults can lead to cardiovascular and respiratory disorders. It also causes the formation of toxic fog, better known as smog. NO_x in the combustion gases also have a negative impact on public health: the nitrogen dioxide component (NO_2) can increase sensitivity to allergens and cause even more breathing difficulties in people with asthma or other chronic respiratory conditions, while NO_x plays an important role in the formation of particulate matter and the eutrophication of the marine and terrestrial environment. In the lower air layers, they also behave like ozone precursors. Ground ozone formation can lead to significant respiratory problems and is also a greenhouse gas. SO_x and NO_x emissions from ships also contribute significantly to the acidification of the marine environment in busy shipping areas and coastal regions, and lead to the formation of acid rain over land, causing damage to infrastructure and ecosystems[95].

achieved in practice, at least in the southern North Sea area, where the Coast Guard aircraft operates.

It is important to note that Belgium is not the only North Sea country coming to this conclusion: Denmark recently published a study presenting largely the same findings[96]. The Danish study confirms that the average NO_x emissions from Tier II ships are higher than those from Tier I ships in the more northern parts of the North Sea as well.

So while 97% of the vessels checked by the Belgian Coast Guard plane comply with the regulations, it goes without saying that the unexpectedly higher NO_x emissions from more recent ships have adverse effects on public health and the environment around the North Sea. This is a cause for concern, especially since the North Sea was only recently designated as a NECA following a joint application by the North Sea countries to the

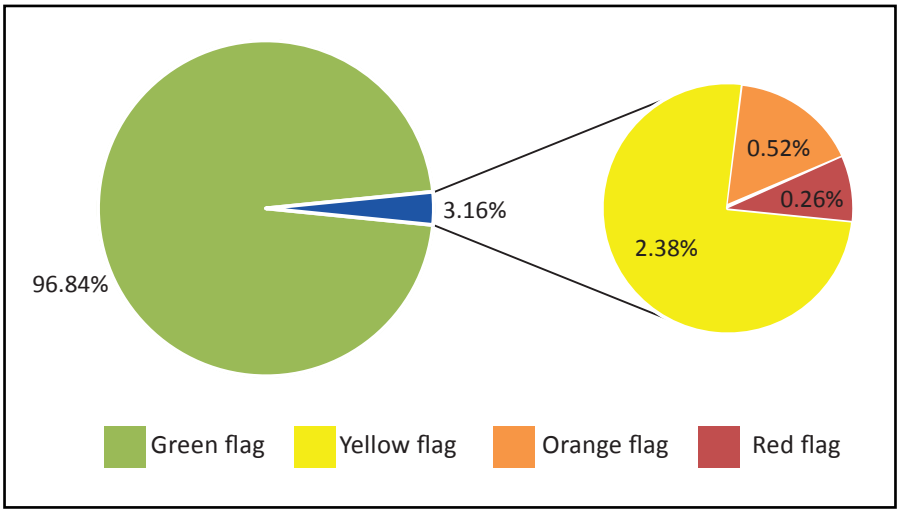

Figure 52. Results of the 2020-2021 sniffer campaign monitoring nitrogen emissions from ships (yellow, orange and red flags are used to indicate the severity of the infringement, the green flag indicates the percentage of ships that were found to comply with regulations).

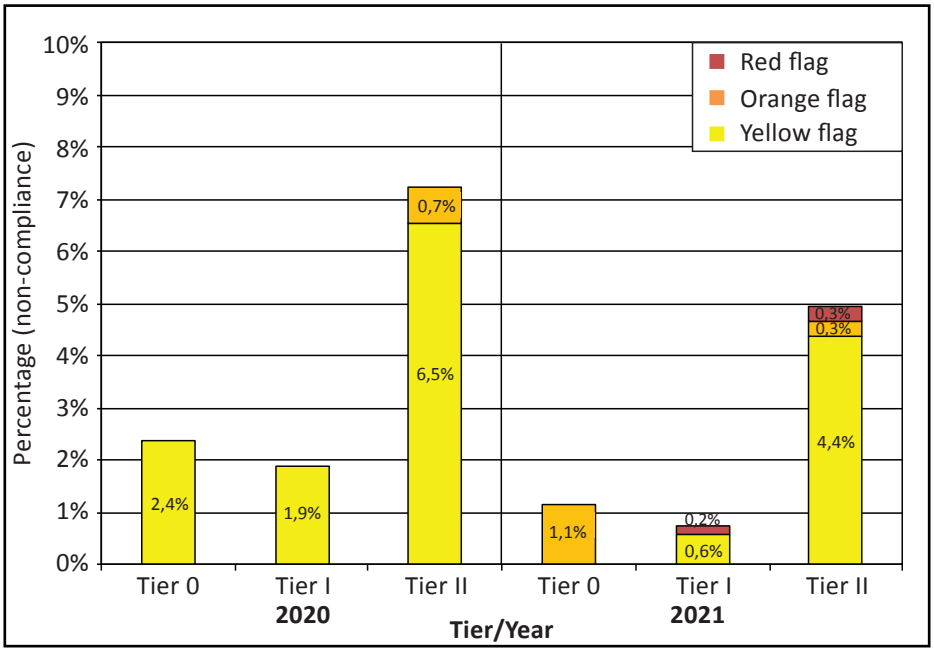

Figure 53. The obtained percentages of vessels with suspect NO_x values in 2020 and 2021 illustrate that limits are being exceeded more frequently by the newer Tier-II ships (yellow, orange and red flags indicate the severity of the infringement).

IMO, specifically because of this marine region's particular vulnerability to the various effects of air pollution from ships. This conclusion also highlights the importance of continuing the air monitoring of ship emissions in future, not just in and around Belgian waters but also in the wider North Sea.

4.2.3. Monitoring of ship emissions to cover the entire North Sea

The pioneering role played by Belgium (together with a small group of other countries like Denmark and Sweden) in the monitoring and enforcement of international regulations on ship emissions - by means of sniffer flights at sea - did not go unnoticed. In 2016, 2018, 2019, 2020 and 2021, Belgium actively worked together with the Netherlands: between 2016 and 2021, a total of about 120 flight hours were carried out for sulfur emission monitoring over Dutch waters, at the request of the Dutch authorities (ILT). Moreover, all North Sea countries are now planning to jointly roll out these monitoring operations under the Bonn Agreement across the whole of the greater North Sea area. On Friday 11 October 2019, at the Ministerial Meeting to celebrate the 50-year anniversary of the Bonn Agreement, the Contracting Parties unanimously decided to extend the work of the Agreement to include the monitoring of ship emissions in this marine region[34]. This amendment to the Agreement was put forward by Belgium, leveraging its pioneering role to convince the other Bonn Agreement countries of the importance of these MARPOL Annex VI surveillance operations at sea. Belgium took the lead, alongside Germany and the European Union, to set up a MARPOL Annex VI Experts Workshop within the Bonn Agreement. This has led to the creation of two working groups, with a view of improving cooperation around the Bonn Agreement MARPOL Annex VI monitoring activities and, where possible, regional alignment and harmonisation of procedures. A first working group led by France and the Netherlands is focused on the strategic and operational aspects, and a second working group led by Belgium and Germany looks closely at technical details. Belgian sniffer operations and the experience gained in follow-up port investigations and prosecution of offenders have also piqued the interest of other marine regions, both in Europe and further afield (China, Canada, Myanmar etc.).

5. ENVIRONMENTAL AND SCIENTIFIC MONITORING

5.1. Initiation of scientific assignments

In the 1990s, when Belgium had not yet declared an EEZ and there was no extensive national legal framework for the protection and conservation of the marine environment (this only came into force in 1999, see chapter 5.2), the surveillance aircraft was already carrying out some scientific missions, for example oceanographic work, research flights and flights in the context of conservation at sea[48,97].

The scientific assignments at that time included:

- The detection of marine fronts (figure 54), as part of MUMM research into eutrophication of the North Sea. Information on fronts contributes to the knowledge and prediction of the spread of nutrients and pollutants released into the open sea from rivers. In 1992, a series of flights was carried out just off the Dutch coast, near the mouth of the Rhine and Meuse, to verify whether a river plume front can be detected through radar imaging. The SLAR proved able to do so. The front lines on radar images corresponded to the foam line and colour discontinuity in a front. This finding led to further satellite-based research in the zone, using a Synthetic Aperture Radar (SAR)[98-100].
- In 1993 and 1994, the University of Liège (Dept. of Physical Geography, Geomorphology and Geology) requested the surveillance aircraft to carry out two test flights as part of a European campaign to develop high-resolution multi-sensors for the study of suspended material, sediment transport, coastal morphology and erosion[101].
- In 1994 and 1995, a number of trial flights were conducted for seabird counts at sea. The shallow sand bank system in Belgian waters is an ideal destination for many wintering seabirds[48]. In 1994, there was also a trial flight related to air monitoring of marine mammals in the Belgian surveillance area. However, not a single sea mammal was observed at the time, indicating that marine mammals were still very rare in and around Belgian waters.
- Observing and documenting the shallow Coastal and Flemish Banks off the Belgian coast, especially along the Belgian West Coast, where some banks (such as Trapegeer and Broers Bank) appear above the surface when water levels are very low (LLWS).
- Documenting and reporting on *ad hoc* observations of notable algal blooms, concentrations of seabirds, both live and dead marine mammals (e.g., four sperm whales beached on the Belgian coast in November 1994).
- In 1998, the surveillance aircraft operated a number of monitoring flights as part of the European conservation project LIFE-NATURE, a project that was run by AMINAL (the former Flemish Department for the Environment, Nature, Land and Water management), MUMM, the NGOs Natuur- en Vogelreservaten vzw and the WWF. This restoration and management project for the West Coast aimed to significantly boost the recovery of the coastal ecosystem's functional cohesion and biodiversity, including around the coastal banks and in shallow waters (up to three nautical miles off the coast, equivalent to the later Natura 2000 area). The

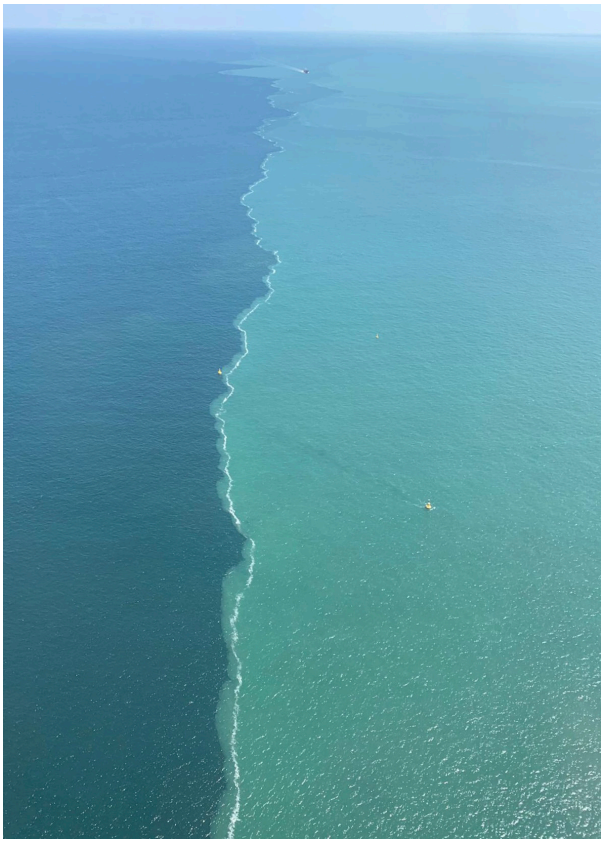

Figure 54. A front at sea.

series of monitoring flights over the western coastal waters between De Panne and Ostend specifically served to assess the impact of summer tourism and recreation in the area.

5.2. 1999 as a tipping point in environmental monitoring

Belgian jurisdiction at sea was extended in 1999, when an EEZ was created adjacent to the territorial sea and a national regulatory framework was developed for the marine environment (with the introduction of the Marine Environment Act[9] and adaptation of the Continental Shelf Act[102]). From then on, Belgium acquired sovereign rights in its marine areas, for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or non-living, of the waters superjacent to the seabed and of the seabed and its subsoil, and with regard to other activities for the economic exploitation and exploration of the zone, such as energy production. Belgium also has jurisdiction in its EEZ with regard to the establishment and use of artificial islands, installations and structures, scientific marine research, the protection and conservation of the marine environment, and other rights enshrined in international law[10]. This much-extended legal framework in the North Sea led to environmental surveillance and scientific monitoring in the context of marine conservation becoming a regular mission for the aircraft, carried out by MUMM operators with full environmental competence at sea.

5.3. Monitoring of authorised activities

Since the extension of the legal framework, various commercial and industrial activities can take place at sea provided that they obtain an environmental permit and respect certain conditions laid down therein. The construction and exploitation of offshore wind farms and aquaculture are two concrete examples of activities requiring an environmental permit. In addition to the environmental permit procedure, there is also a procedure for granting a domain concession for the proposed project area.

MUMM is the service which assesses the impact a potential activity could have on the marine environment, based on an environmental impact report prepared by the applicant, and then advises the federal minister for the North Sea on the acceptability of the project and any conditions that may need to be imposed. For sand and gravel extraction at sea (see chapter 6.4), this judgement is delivered via an Advisory Committee, and the Minister of the North Sea in turn advises the Federal Minister of the Economy. The increase in human activity at sea has brought considerable pressure to bear on the marine environment, and existing activities are in danger of clashing for space. In order to allow these activities take place side by side, with as few adverse effects as possible for the North Sea, a Marine Spatial Plan was drawn up in 2014, to be re-evaluated every six years[103]. The aim is to achieve a sustainable balance between human activities and the natural values of the Belgian marine areas. The current Marine Spatial Plan (for the period 2020-2026) entered into force on 20 March 2020[15,104].

It is clear that this recently extended policy framework of organisation and regulation of human activities at sea and of sustainable management, requires surveillance and monitoring in the field. The Coast Guard aircraft is a major contributor to this. For example, the MUMM uses the aircraft as its 'operational arm', to regularly monitor permitted activities at sea for compliance with the conditions related to e.g., wind farms and aquaculture sites, and to report irregularities, unsafe situations or incidents. In addition, the surveillance aircraft also contributes to scientific monitoring of the marine environment (see chapter 5.4).

5.3.1. Monitoring of wind farms

One of the fastest growing activities in the Belgian marine areas is the production of renewable energy at sea, mainly through the construction and operation of wind farms. The Minister of the North Sea set aside a 238 km² zone for the production of renewable energy – which was further extended in the latest revision of the marine spatial plan. In 2008, C-Power built six wind turbines at sea as part of the first phase of development. Fast forward to 2021, and there are nine wind farms operational at sea (figure 55), representing about 400 wind turbines and a total energy production capacity of around 2,250 MW[105].

During just about every overseas flight, the Coast Guard aircraft flies by these Belgian wind farms (figure 56), both to monitor the permit conditions

and to check maritime safety around the farms. When important observations, irregularities or incidents are found, the operators report this to the Maritime Security Centre who in turn informs the competent Coast Guard partners.

This form of surveillance already begins during the wind farm construction phase. Points of interest include whether a guard ship is present to ensure shipping safety in and around the construction area, whether ships involved in construction

Figure 55. Map of the current and future Belgian wind farms.

Figure 56. Overview of the wind farms from the air.

Figure 57. Use of a bubble curtain during the construction phase of the 'Norther' wind farm in 2018.

are conforming to AIS requirements, whether (construction) waste or (oil) pollution are visible on the water, and whether a bubble curtain is in place in the water column (figure 57). The latter is a curtain of air bubbles placed around a pillar in the seabed, to dampen the noise created during piling and to protect marine organisms, particularly legally protected marine mammals like harbour porpoises[106]. A double bubble curtain is now a standard environmental condition while piling for wind turbines at sea, a condition which is regularly monitored from the air.

While wind farms are being put into operation, the aircraft will monitor other factors, like the 500-metre safety perimeter around the farms (see chapter 6.3.1), the night lighting on the turbines, and any marine pollution or damage to the infrastructure.

The aircraft also collects scientific data used by marine scientists at the RBINS (team SUMO, Suspended Matter and Seabed Monitoring and Modelling), to monitor the impact of wind turbines on the seabed and the water column. If turbidity plumes are visible around turbine towers (figure 58), this observation data is used to verify advanced computer models that can simulate changes in sediment transport within the project area. During the operational phase, seasonal marine mammal monitoring campaigns are carried out across the entire Belgian marine area, as part of wind farm impact monitoring (see chapter 5.4.1).

Figure 58. Observation of turbidity plumes behind windmill pillars.

5.3.2. Monitoring of aquaculture

Aquaculture is another activity at sea requiring a permit. In the early 2000s, a few small pilot projects were set up around mussel farming (specifically *Mytilus edulis*), in three aquaculture zones around Nieuwpoort Bank, Oostdyck and the West Hinder Bank. As part of these projects, mussel cages, buoys and long-lines were used (figures 59, 60). Various difficulties caused each of these projects to be abandoned by 2011-2012, however. For example, the equipment used proved unable to withstand the rough weather conditions at sea. There were no other aquaculture projects in Belgian waters until novel research in 2017-19 (Edulis and Value@Sea[107]) led to a new commercial initiative in 2020. Following positive advice from MUMM, Colruyt Group was granted permission to launch a new economic aquaculture project for the cultivation of mussels, the Westdiep Sea Farm[108]. As part of this initiative, Colruyt will also be testing the commercial viability of oyster and seaweed cultivation. The sea farm is situated 5 km off Nieuwpoort. The first buoys were placed in the water in early 2022, meaning the project is outside the scope of this activity report. During periods of active aquaculture in Belgian waters, the Coast Guard aircraft carries out regular monitor flights

Figure 59. Aquaculture in the Belgian North Sea: Mussel pontoons.

Figure 60. Aquaculture in the Belgian North Sea: Mussel cages

over the areas in question, in order to verify the state of play of activities and structures deployed at sea and communicate this information to competent authorities, to check compliance with any conditions that have been imposed (e.g., the demarcation of the aquaculture zone), to verify the status of the structures at sea (e.g., during or after adverse weather conditions) and in the event of irregularities like drifting buoys or sinking pontoons, to report these to the Coast Guard as soon as possible. During these flights, ships are also monitored for any intrusions (see chapter 6.3.1). If a violation is detected, a report is drawn up and forwarded to the competent authorities.

Although the only aquaculture activity as of 2022 is the "sea farm", additional zones have been designated for future aquaculture in the 2020-2026 Marine Spatial Plan. As soon as these zones are actually brought into use, the aircraft will monitor activities there as well.

5.4. Scientific monitoring assignments

5.4.1. Marine mammals counts

The increasingly prominent human activity at sea has a considerable impact on marine species and habitats. Many land-based activities can also have a negative impact on marine life, such as pollutants entering the marine environment via rivers. This emphasises the need for monitoring programmes, which can use certain species as indicators for the general health of the ecosystem. Sea mammals are warm-blooded animals with long lifespans, sitting at or very near the top of the food chain. Data and trends around their presence, population sizes, distribution and health not only allow us to map populations, but also assess the effects of anthropogenic activity and, where necessary, adapt that activity.

The protection of marine mammals is governed by European, regional and national policies, notably the OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic[109], EU directives including the Habitats Directive[110] and the Marine Strategy Framework Directive[111], and the Agreement on the Conservation of Small Cetaceans of the Baltic, Northeast Atlantic, Irish and North Seas (ASCOBANS)[112]. These agreements resulted in national legislation, centred on the Marine Environment Act of 1999[9]. The Royal Decree of December 21, 2001, on the protection of a number of species was adopted to implement this Act[113]. As a result, all cetaceans, seabirds and some species of fish were better protected. Under the Marine Environment Act, certain activities are subject to environmental permits. The permits for a number of projects, including the construction and operation of offshore wind farms, incorporate a monitoring programme relating to the impact of the permitted activity on the marine environment, including marine mammals.

Harbour porpoises are by far the most common sea mammal in our waters today, but sightings of this cetacean were very rare until the early 1990s. At that point, and for reasons that are still not clear today, a shift occurred in the population within the North Sea, moving from north to south[114]. Monitoring the population of this protected species is a first step in its protection, as required by the European Habitats Directive (92/43/EEC) among others[110]. The objectives of the monitoring include identifying the effects of offshore wind farms being constructed, and determining the period of the year in which additional measures may be useful to avoid by-catches.

Various techniques are used in the monitoring of harbour porpoises: research is carried out into the numbers and causes of death of beached animals, anchored hydrophones are used to determine their presence in a certain area (passive acoustic monitoring), and a few times per year their distribution and numbers are mapped in targeted air surveys by the Coast Guard aircraft.

The strategy used for the air surveys is line transect sampling[115], whereby a number of pre-defined

tracks are followed, and visual observations are recorded, along with their perpendicular distance to the observation platform. The shortest distance at which the aircraft flies past the animals is determined by measuring the perpendicular angle from the track line to the animals using a clinometer. The observations and the flight path are recorded using GPS and the resulting data is then analysed with specific software[116]. The high-wing Coast Guard plane is specially equipped for this type of monitoring, with convex 'bubble windows' which enable operators to look straight down. A test phase was launched in 2008, and monitoring proper started in the spring of 2009, when the aircraft was equipped with a second bubble window.

During the air surveys, an altitude of 600 feet (183 m) and a speed of 100 knots (185 km/h) are maintained. Flights only take place when the conditions for observation are good: swell 0-2 (3) and good visibility (which is why surveys can rarely be performed in the winter months). A survey consists of a series of parallel tracks, about 5 km apart and perpendicular to the coastline (figure 61). Before the wind farm expansion of 2019-2020, an average of 13 tracks were covered for each flight (between 10 and 19), but the increase in the number of wind turbines and the associated safety risks led to the track over the wind farm zone being scrapped. Practical and flight technical reasons, as well as the sometimes high turbidity of coastal waters, have led to the tracks starting 5km off the coast. The westernmost track is partly above French waters. During the flights, high resolution vertical images are captured every four seconds (figure 62) to be used for any further analysis.

In the period 2009-2021, 214 flight hours were spent on marine mammal counts (222 hours if the 2008 test phase is taken into account). The results from 37 air surveys could be used for analysis. A total of 12,809 nautical miles were flown (effective monitoring time) and 3,223 harbour porpoises were observed (between three and 404 animals per survey, on average 87 per survey). Some other species of marine mammals were also regularly

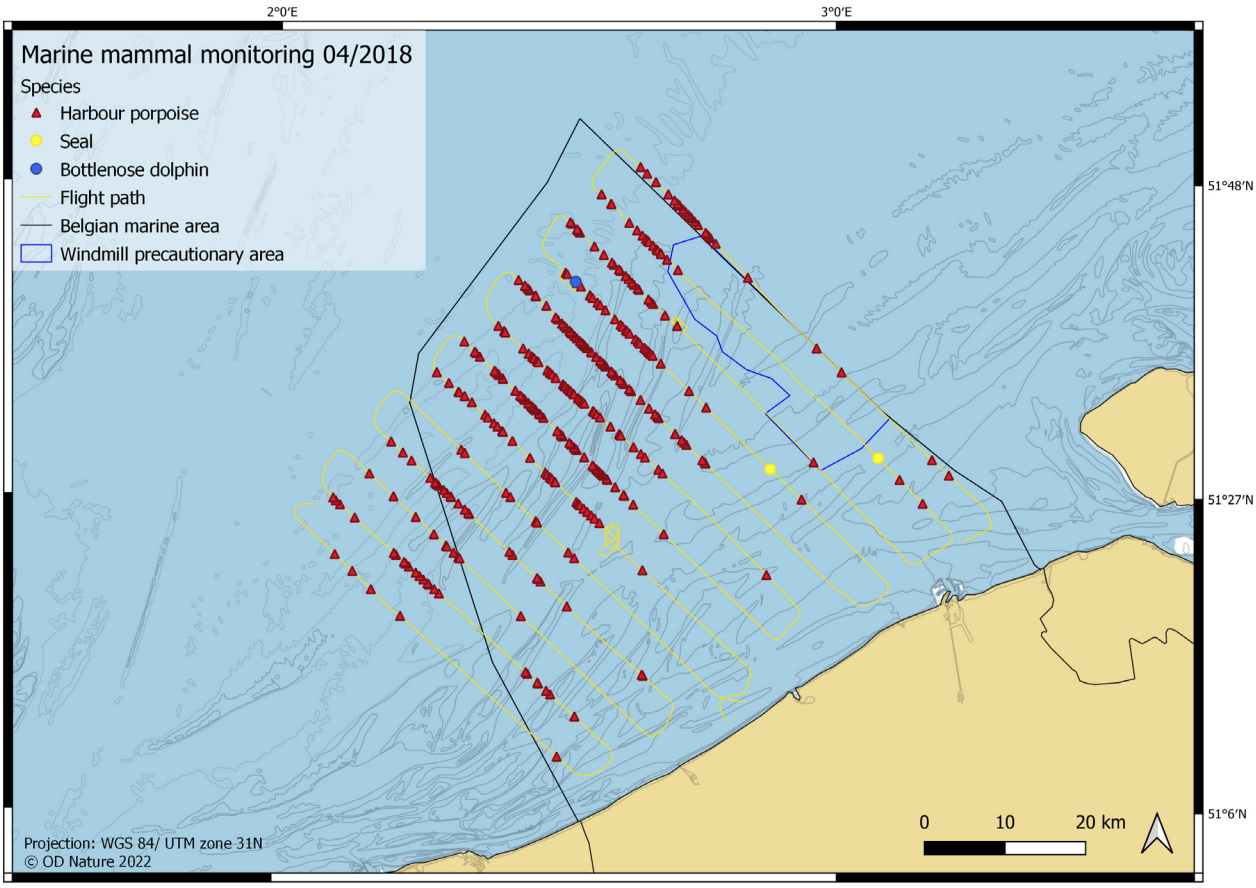

Figure 61. Example of the results of an aerial survey (April 2018): Observations of harbour porpoises (red), seals (yellow), and bottlenose dolphins (blue), along with the route flown (yellow line).

spotted. A total of 100 seals were observed, with a marked rise in sightings from 2017. There were sightings of white-beaked dolphins from 2009 to 2012 (10 observations of a total of 37 animals), after which the species has probably disappeared from our waters. Bottlenose dolphins made a very occasional appearance: one animal in 2018 and in 2020, and two groups of 12 and 13 animals respectively on 16 July 2018. One humpback whale has been sighted (2013), as was a minke whale (2017). Unfortunately, population density can only be analysed for harbour porpoises, as not enough of the other marine mammal species were observed during the surveys.

The average harbour porpoise density in the survey areas varied very strongly between 2009 and 2021: from an estimated 0.06 to 5.4 animals per km², or from a total of 200 to over 18,000 individuals in an area equivalent to, and largely coinciding with, the Belgian sea area (3,453 km²) (figure 63). During this period, the species was commonly found in our waters, especially in spring.

In 2011, it was possible to observe the impact of pile-driving (i.e., inserting foundations into the soil) during the construction of offshore wind farms: three consecutive surveys were carried out, in favourable conditions, just before and after pile-driving took place. The results suggested that harbour porpoises were driven up to 20km away from the piling location[117]. This kind of disturbance was also found in other studies[118,119], and led to compulsory noise mitigation measures for pile-driving, such as the use of bubble curtains (see chapter 5.3.1) and an acoustic deterrent system ('seal scarer') to preventively encourage marine mammals away from the site.

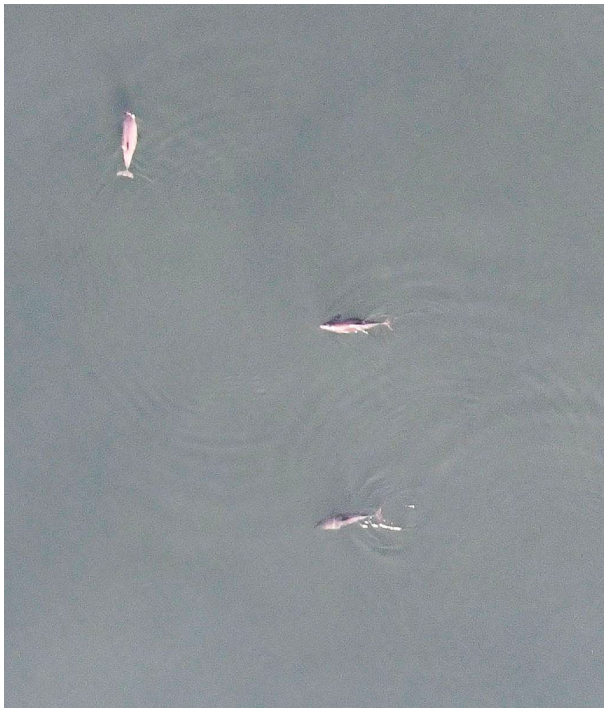

Figure 62. Harbour porpoises are easily visible and recognisable from the air.

The results of the 2009-2021 study suggest that harbour porpoises are spread throughout the surveillance zone in spring, whereas later in the year smaller numbers are concentrated further off shore. These patterns do not appear to be stable, however. Harbour porpoises have been observed swimming very close to operational wind farms. There was usually a lower population density around the West Hinder anchorage area, but a more extensive spatial and temporal analysis would be needed to be able to draw conclusions.

A combination of air surveys, beach monitoring and passive acoustic monitoring reveals a general seasonal pattern where harbour porpoises are commonly present in March and April, but less so from May onwards and into the winter months. However, there are significant variations year to year, probably caused by the limited area of surveillance when compared to the species' mobility: a small shift in the location of suitable prey could cause smaller or much larger numbers to reside in our waters. This weakens any spatio-temporal patterns that may have been observed.

Thanks to an equivalent, standardised methodology being used in neighbouring countries, our data could be leveraged to determine the density and numbers of harbour porpoises in an area significantly greater than Belgian waters[120-122]. This shows that the population density in our waters is relatively high in spring, and that a large area east of England sees a great many harbour porpoises in the summer and autumn months. The results of this research not only allow us to see trends emerging in terms of seasonal density and the numbers of harbour porpoises in the southern and central North Sea, but also to explain their distribution spread according to a number of parameters including prey density, depth and water temperature, and to make predictions.

In addition to monitoring harbour porpoises, the Belgian Coast Guard aircraft also studied the seal population in the Western Scheldt between 2009

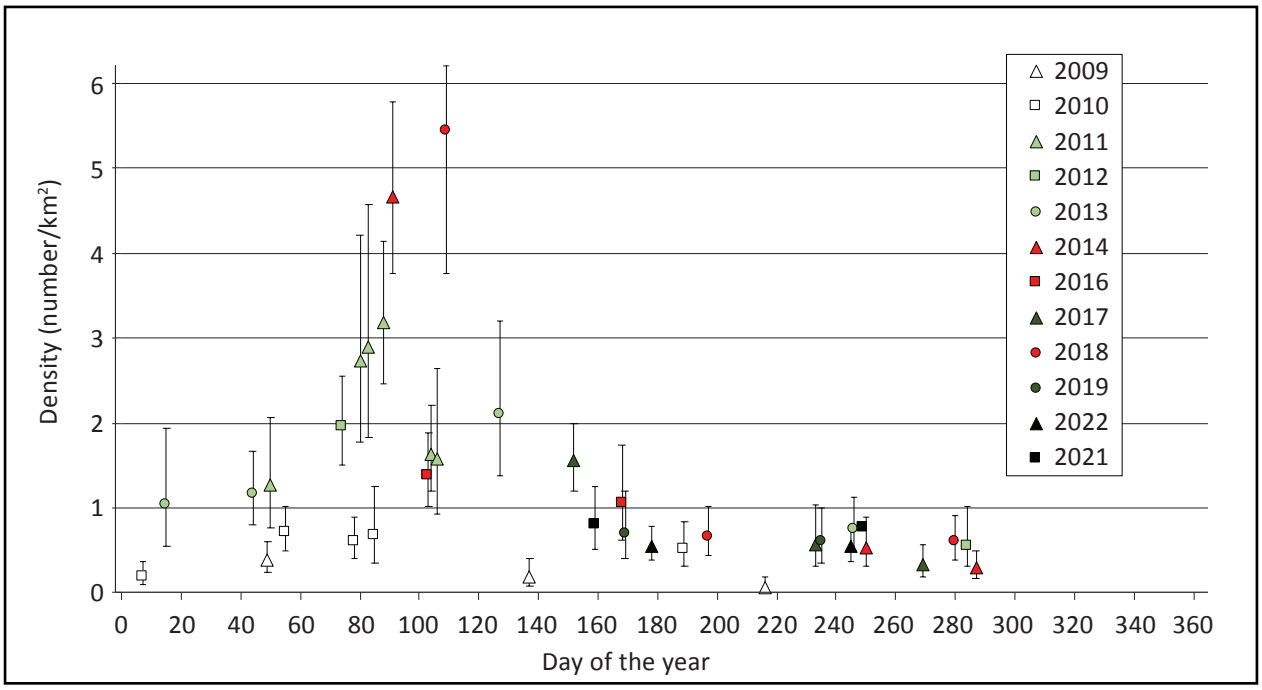

Figure 63. Density of harbour porpoises in the survey area between 2009 and 2021.

and 2012[123-125] (figure 64), during each transit flight from the aircraft's base in Deurne and back again. The small colony of seals established there since the 1990s appeared to have grown, despite the high and still-increasing pressures of shipping in the area. Its regular presence above the area made the Coast Guard aircraft an excellent observation platform for seal counts. The high number of transit flights meant that the variability of seal number could be followed up throughout the year. This monitoring activity was discontinued after 2012 to avoid disturbing bird populations in the Scheldt estuary.

In some countries, work is ongoing to replace visual surveys by digital surveys, which work by creating high-definition images of the water's surface that can be analysed - mostly automatically - for the presence of marine mammals. This technique offers many advantages like reduced survey time (the aircraft can fly at greater speed and altitude) and the avoidance of observer errors, but there are

Figure 64. Seals on a sandbank in the Western Scheldt, easily visible and recognisable from the air.

also downsides. The development of an automatic recognition system is not an easy task, and a lot of time is required afterwards to interpret and verify detections. The digital surveys may provide an additional source of data on floating waste and seabirds, however. Seabirds are currently monitored from ships and, to a limited extent and in a different survey area closer to the coast, from a (different) plane. Hopefully this will change in the next few years, and a Coast Guard aircraft can be used in future for seabird monitoring by means of digital surveys.

Besides carrying out the regular marine mammal counts, the aircraft will be deployed in the event of (sporadic) reports of large marine mammals in the Belgian marine areas, to try and locate them from the air. In particular, dead whales are essentially large floating objects, creating a significant risk for smaller seagoing vessels and pleasure boats (figure 65). For that reason, they need to be located, monitored and, if necessary, towed to a beach. Once they are beached, the RBINS (MUMM) is called in to coordinate scientific research, consisting of an autopsy and finally the disposal and processing of the carcass.

Figure 65. A dead whale floating at the surface can pose a significant risk to (smaller) vessels.

5.4.2. Plankton- and jellyfish blooms

Some species of plankton can occasionally be observed in large quantities in the Belgian surveillance area, when conditions are ideal for their mass reproduction, or when the ecosystem becomes unbalanced, e.g., as a result of an abundance of nutrients ('eutrophication'). When huge quantities of a species of plankton (from micro-organisms to jellyfish) are present, this is called a 'bloom'[126].

5.4.2.1. Plankton blooms

Quite often, third parties (i.e., ships, planes, other coast guard partners) will report a potential pollution incident, but when the Coast Guard plane attends the location it regularly turns out to be discolouration in the water due to soil disturbance (from fishing, sand extraction or dredging) or plankton blooms.

Plankton is a collective name for mainly micro-organisms (both algae and animal species, respectively phytoplankton and zooplankton) which are mostly suspended in the water. This means their (passive) movement largely relies on prevailing currents, unlike nekton, which is able to move against the current by itself[127]. The most common species of blooming plankton in the North Sea are *Phaeocystis*, visible on the sea surface in summer as long bands of white-brown foam or accumulations of foam on the beach (figure 66); sea sparkle or *Noctulica*, visible on the surface as red dots or spots in summer (although green or other colours are possible as well, see figure 67) and diatoms, which are usually not visible from the plane.

Plankton blooms are often harmless, but some rare types of blooms can be harmful or toxic to the marine environment. In some very exceptional circumstances, plankton blooms can even lead to life-threatening situations on shore. When *Phaeocystis* blooms die, for example when the nutrients in the water have been exhausted, the abundant protein in the water is whipped up by the motion of the waves, which is how the characteristic white foam is formed. Obstacles and strong winds can cause extreme accumulations of foam in certain places along the beach, resulting in potentially dangerous and life-threatening situations, which is what happened in the spring of 2020 on the Dutch coast (Scheveningen)[128].

It is important to note that air observation alone is not always enough to say with 100% certainty what type of plankton is involved, except in the case of characteristically abundant *Phaeocystis* foam or clearly recognisable *Noctiluca* blooms. In other cases it can be interesting, or even vital in case of massive blooms, to try and obtain a sample at sea, which can be done by seafaring Coast Guard partners like the Navy, the Maritime Police or the Flemish Service Fleet.

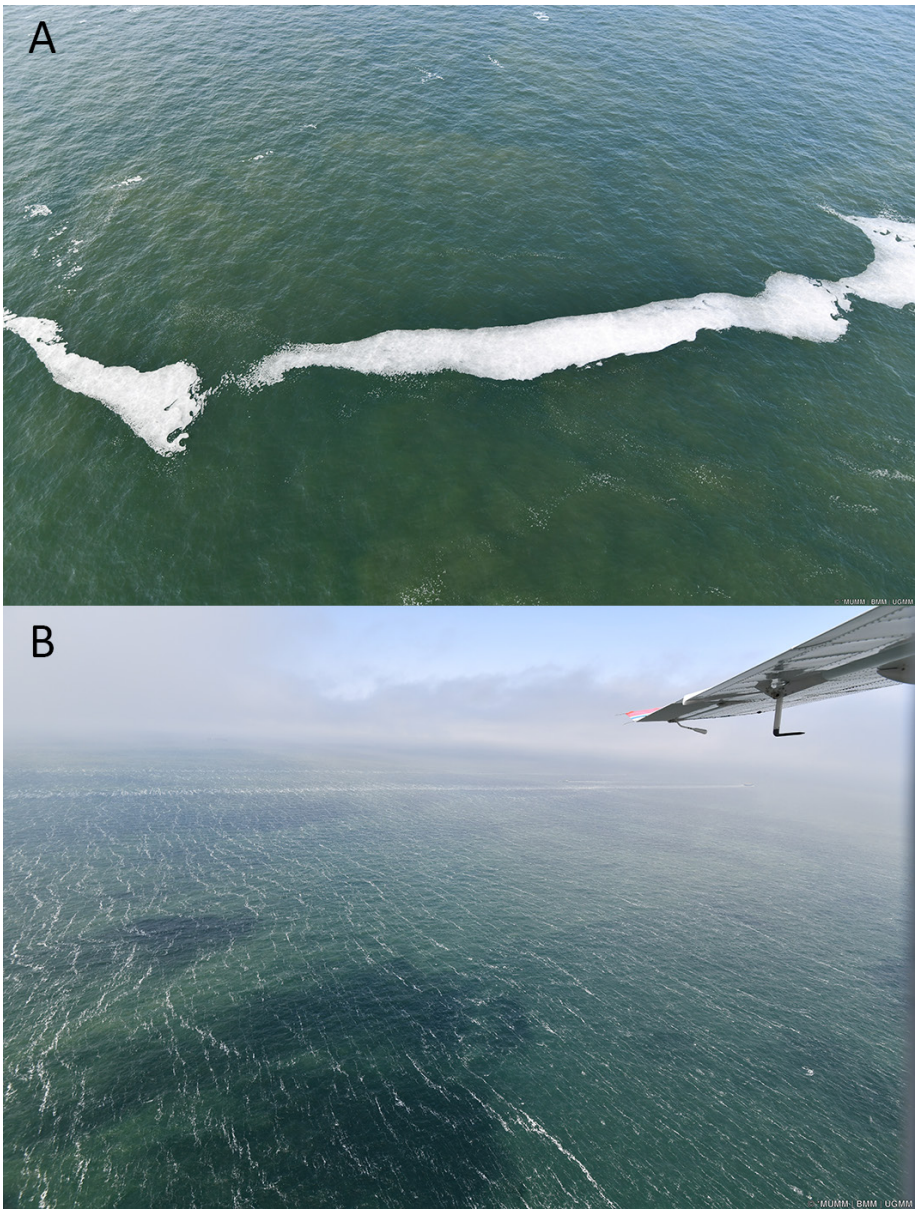

*Figure 66. **A**. Phaeocystis bloom, typified by its white-brown foam. **B**. Phaeocystis bloom can be observed over large areas.*

5.4.2.2. Natural films

In very calm weather conditions, natural films can sometimes be observed on the sea surface. These natural surface films are made up of organic matter (proteins, fatty acids, etc.) and are often found in water with high biological production, places where sediment is resuspended and in coastal areas from terrestrial sources. Their low solubility in water and high intermolecular attraction result in a high surface viscosity and a significant wave damping effect[129]. As a result, these natural films can be detected by SLAR or by satellite sensors in calm weather conditions (0-2 beaufort) and can easily be wrongly detected as an oil or MARPOL Annex II pollution incident. They are visible at the surface as very thin glimmering slicks with an irregular shape, which are usually transparent when viewed vertically from the air.

5.4.2.3. Jellyfish blooms

Jellyfish are classified as plankton, as they cannot swim against the current by themselves. They are the largest zooplankton species. Four types of jellyfish are commonly found in Belgian waters: In spring, there is the moon jellyfish (*Aurelia*

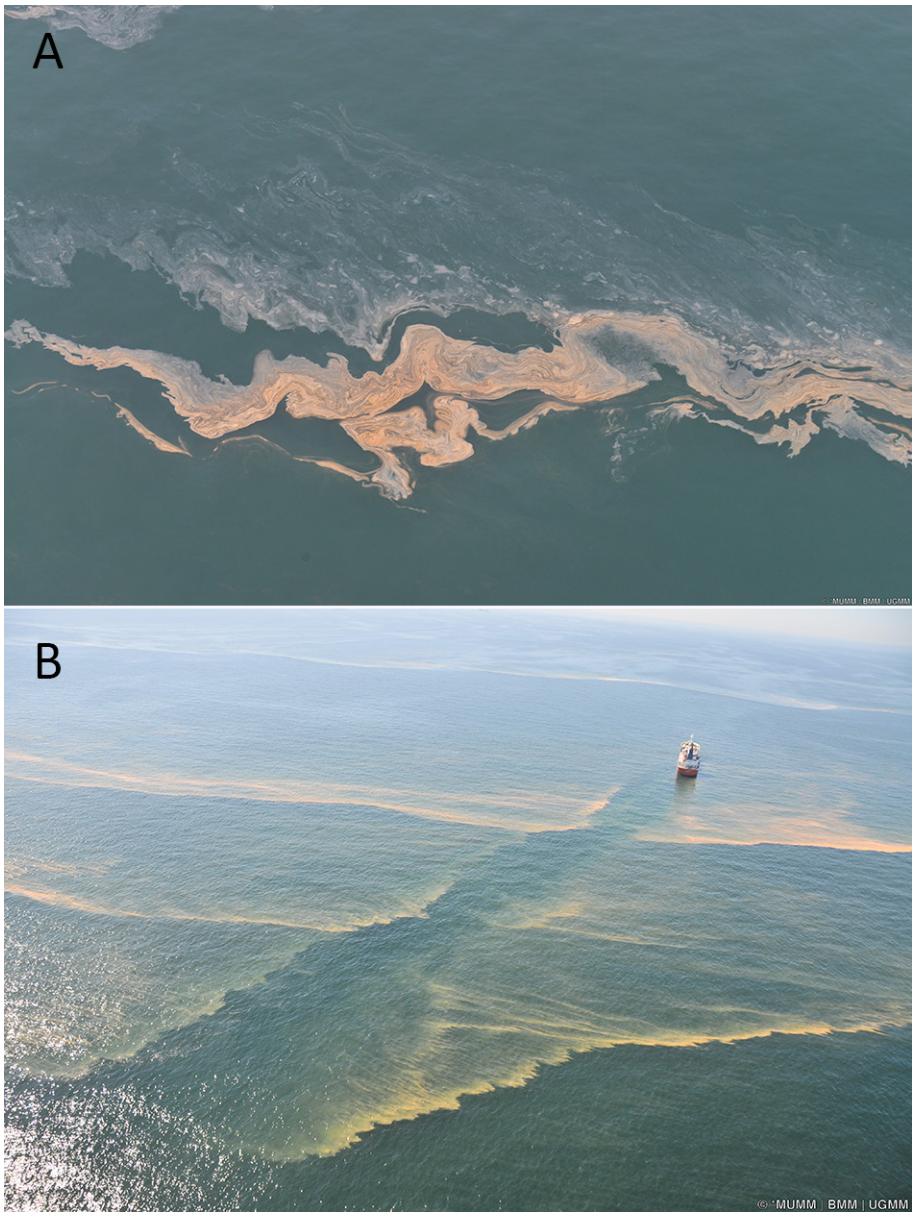

Figure 67. Sea sparkle or Noctulica bloom. ***A****. Detail.* ***B****. Covering a large area.*

aurita), followed by the blue jellyfish (*Cyanea lamarckii*) and the compass jellyfish (*Chrysaora hysoscella*) (figure 68). In late summer and autumn barrel jellyfish, also known as dustbin-lid jellyfish, (*Rhizostoma pulmo*) make their appearance (figure 69).

At certain times of the year, very large numbers of jellyfish can be observed in our waters. In summer, when coastal tourism is at its peak, it is useful for the Coast Guard aircraft to report notable jellyfish blooms, so this can be passed on to the relevant coastal municipalities, who in turn can warn bathers. The problem posed by jellyfish blooms goes further than their painful sting as there is also

Figure 68. Compass jellyfish (Chrysaora hysoscella).

Figure 69. Barrel jellyfish, also known as dustbin-lid jellyfish (Rhizostoma pulmo).

Figure 70. Macroalgae floating at the surface.

a significant ecological impact: mass consumption of fish larvae, competition with fish for plankton and the disruption of the food chain[130]. The project "JellyMOD"[131] was set up within the RBINS to develop biological models, gain insight into the complex biological life cycle of jellyfish, and understand how and why jellyfish blooms are created. For this reason, it is very useful for marine-scientific research if field observations of notable jellyfish blooms are reported.

5.4.2.4. Macro algae

The presence of floating macroalgae (floating packages primarily made up of seaweed fragments) is a fourth natural phenomenon that is often observed at sea (figure 70). Floating macroalgae may have become detached from rocky or sandy coasts or seabeds[132,133], but are also naturally present in the water column[134]. They may be colonised by a wide variety of marine organisms, for various reasons: to find shelter or food, or as a substrate for organisms to cling on to. These floating colonies of macroalgae can have a potentially significant ecological impact, like the spread of associated fauna to new, remote locations.

Floating macroalgae are usually seen in our waters as fragmentary green-brown slicks or clumps of varying sizes, ranging from less than one metre to several metres. Their colour may vary depending on the altitude, the type of seaweed and whether the organic matter is alive or dead. They can be observed all year round, in the biological peak period of spring-summer, or after severe autumn or winter storms.

To keep the North Sea ecosystem in balance, it is important to check parameters that may indicate some disruption, e.g., massive plankton or jellyfish blooms. The observations of the Coast Guard aircraft are also of socio-economic interest (tourism). Over-fishing, eutrophication and acidification of the seas may cause more and more of these blooms to occur, and monitoring will therefore continue to be necessary.

6. BROADER MARITIME SURVEILLANCE IN THE REMIT OF THE COAST GUARD

6.1. Integration of aerial surveillance into the Belgian Coast Guard structure and the evolution towards a multitasking maritime surveillance aircraft

When the 24/7 Coast Guard centre (consisting of the MRCC and the Maritime Security Centre, see box chapter 2.1.3) became fully operational in 2008, MUMM, as representative of the Federal Science Policy Department within the Belgian Coast Guard, developed standard procedures to report around 30 different aerial observations in consultation with the Coast Guard centre and various Coast Guard partners. The observation scenarios ranged from limited natural phenomena to various types of incidents and violations at sea. These air observations are then reported to the various interested and competent services via the Coast Guard centre, so they can be followed up further. This list has since been extended, and currently includes 40 different air observation scenarios. This allowed the aircraft to be fully integrated into the Coast Guard structure and to contribute to various Coast Guard assignments for the benefit of multiple Coast Guard partners.

The air observation scenarios are primarily geared towards the specific tasks and powers at sea assigned to MUMM which also constitute the main missions of the Coast Guard aircraft: marine pollution control, environmental surveillance and marine scientific monitoring. The list of air observation scenarios also contains a multitude of other possible observations and findings that fall outside of MUMM's specific powers but which may be worth making from the air and reporting to the Coast Guard. This list was not drawn up from scratch: it was largely based on prior experience with aerial surveillance of all kinds of activities, phenomena, events or incidents that could occur in the North Sea. MUMM had already been in the habit of documenting notable or unusual events observed from the air, with the aim of increasing our knowledge of the North Sea in its true state. Certain tasks, like monitoring of fishing and sand and gravel extraction, were already being carried out before the official establishment of the Coast Guard. The foundation of the Coast Guard gave these observations and findings an official Coast Guard character and created a thorough procedural framework for them. As a result of these important developments, the surveillance plane increasingly became a multi-tasking maritime surveillance aircraft at the service of the Belgian Coast Guard, to the extent possible; as the plane was mainly equipped for pollution detection at sea, it is sometimes less performant in support of other Coast Guard assignments.

This chapter gives a further overview of the aircraft's various Coast Guard-related secondary missions, like fisheries control, maritime enforcement, monitoring of sand and gravel extraction, participation in coordinated Coast Guard operations ('OPERA') and other *ad hoc* surveillance tasks.

6.2. Fisheries control

One of the surveillance aircraft's most important secondary tasks within the framework of Coast Guard cooperation consists of fisheries control flights on behalf of the Fisheries Authority (*Dienst Zeevisserij*, DZV), belonging to the Flemish Government Department of Agriculture and Fisheries). This bilateral Flemish-federal cooperation has been in place since 1993 and can therefore be considered as one of the successful precursors to the subsequent Flemish-federal Coast Guard cooperation structure.

The Belgian marine areas are home to several commercially important species, including sole, plaice, dab, sea bass, cod, whiting and brown shrimp: all of them marine species that thrive in the shallow sandbank system typical of our waters. A direct consequence of this is highly active fishing in our area (figure 71). Trawling and shrimp fishing are by far the most common activities, but other fishing techniques are also practised in our waters such as otter board trawling, handline fishing, fly shooting and gillnetting[24]. High fishing activity in the Belgian marine areas unfortunately brings with it some risks, including over-fishing, adverse environmental impacts and fierce competition. For this reason fishing is strictly regulated, and with regulation must come monitoring. Moreover,

Figure 71. Dutch fishing vessel (beam trawler) observed in the Belgian part of the North Sea.

fish stocks are part of European common natural resources and fishing is governed by a common policy with rules laid down at an EU level and in force in all Member States, including Belgium. This Common Fisheries Policy has several objectives including the conservation of fish stocks, the protection of the marine environment, ensuring economic viability of the EU fleets and the sustainable exploitation of living aquatic resources[135]. Fisheries control and enforcement are intended to ensure the correct application of fisheries regulations and, where necessary, ensure compliance with EU rules[136]. Fishing control flights over the sea make a significant contribution to this.

Belgian marine fisheries policy is a Flemish responsibility and falls under the Department of Agriculture and Fisheries[137]. The Fisheries Authority (*Dienst Zeevisserij* - DZV) – is part of that department and is tasked with the concrete implementation of the sea fisheries policy, including surveillance at sea, at auctions and from the air or using satellites. DZV also uses the Coast Guard plane and its instruments (positioning and communication equipment, imaging, digital nautical maps, etc.) to carry out regular air monitoring of fishing activities, both during the day and at night.

During these flights, particular attention is paid to compliance with the access restrictions for professional fishing vessels in the shallow coastal waters (3 nautical mile zone) and the territorial sea (12 nautical mile zone). Outside the 12-mile zone, the principle of free access for EU vessels applies. Within the 12-mile zone, fishing is currently permitted for Belgian and Dutch fishing vessels only[138]. French fishermen have a historic right to fish for herring within the Belgian 12-mile zone[139], but at present, no French vessels have an authorisation to actually fish there.

In addition to access rules, vessels fishing in the 12- and 3-mile zones respectively must also comply with a number of technical specifications regarding maximum engine power, fishing gear and minimum mesh size. Within the 3-mile zone, with one exception, only vessels with a tonnage less than 70 GT (gross tonnage) are permitted[140]. Also being monitored is the use of AIS (Automatic Identification System), which was gradually introduced from 2010 based on the vessel's construction date and length (over 15 metres) and has been mandatory for all professional fishermen in Belgian waters since 1 October 2020 (see Chapter 6.3.2)[141]. In the event of an infringement, evidence is collected, any findings are documented and the fisheries inspector on board the aircraft draws up an official report if an unlawful intrusion was observed within the 12- or 3-mile zone. On behalf of DZV, the Coast Guard plane also regularly carries out international fisheries control flights, coordinated by the European Fisheries Control Agency (EFCA). These flights are referred to as

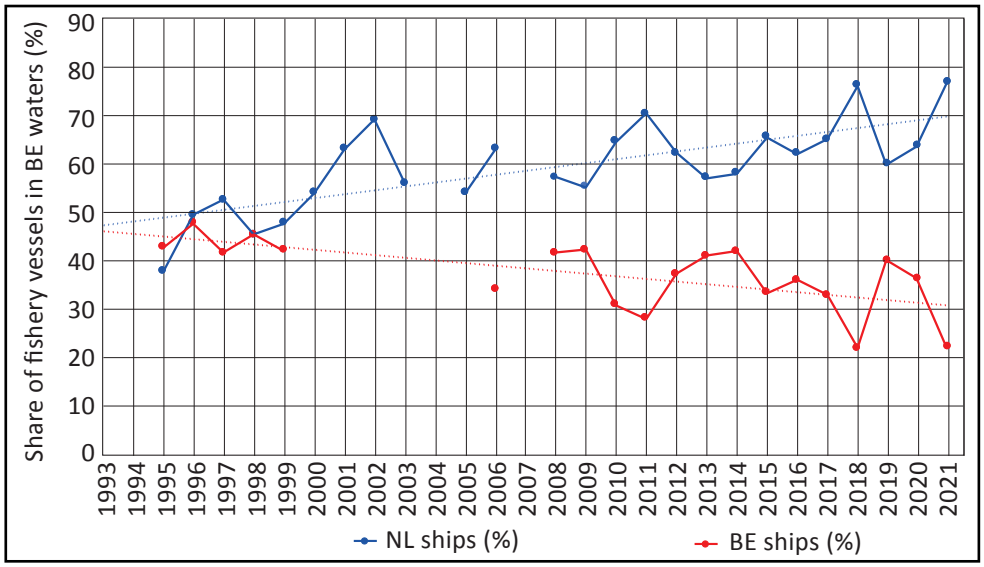

Figure 72. Share of Belgian (BE) and Dutch (NL) fishing vessels (%) in national waters. No data (1993, 1994, 2004 and 2007) or only partial data (2000-2003, 2005) was available for a number of years. These figures exclude international flights for EFCA, except for one flight in 2008 and one in 2009.

Joint Deployment Plan (JDP) flights. This authorises the plane and the Belgian fisheries inspectors to operate above fishing grounds outside of the Belgian marine areas as well.

From 1993 to 2021, 1239 fishing control flights took place (an average of 43 flights per year), amounting to a total of 1185 flights hours (on average 41 flights hours per year) and 7272[c] fishing vessels identified. The proportion of night flights[d] increased gradually, from an average of 21% in the first 15 years (1993-2007), to an average of 39% in the past 14 years (2008-2021). As fishing mostly takes place at night – when fish are at their most active – the goal is for half of the flights each year to take place in the hours of darkness.

Fishing control flights have several aims. On the one hand, they can serve as reconnaissance missions, allowing data collected from the air to be leveraged for checks by patrol vessels on the water and for verification of declared vessel positions in the ship's log and the VMS (Vessel Monitoring System), building up a clear picture of fishing activities in the Belgian sector. On the other hand, the early and late flights and particularly the night flights serve not only as specific surveillance missions but also create an element of surprise and a deterrent effect[142].

The vast majority of fishing activities in our national waters are from Belgian (37%) and Dutch (59%) fishing vessels, compared to a very small share of other nationalities (4%). The data collected by the aircraft indicates that, over the years, the proportion of Dutch vessels fishing in Belgian waters has increased while the share of Belgian vessels (and those of other nationalities) has declined (see figure 72). One possible explanation for the increase in Dutch vessels is the use of electric pulse trawling. This technique is mainly employed by Dutch vessels and makes it much easier to catch demersal species of fish which may constitute potentially unfair competition for traditional trawlers. Following a recent ban on electric pulse fishing[143] in force since 1 July 2021, the expectation is that the proportion of Dutch fishing vessels in our national waters will decline in future. Additionally, the Belgian fishing fleet has shrunk in recent decades while at the same time the Dutch fishing industry bought into a number of foreign fishing fleets. This has led to many British, German, Norwegian and also Belgian fishing vessels operating under Dutch shipping companies[144]. This may also explain the proportion of other nationalities, and the fact that gillnetting has fallen sharply from an economic point of view.

[c] For the years 2001, 2004 and 2007, no data is available for the number of fishing vessels identified. These are therefore missing from this summation.

[d] The understanding of what constitutes a 'night flight' has evolved from 'flights taking place any time between 8pm and 8pm' in the 1990s to the current definition of 'flights carried out after sunset and before sunrise' (i.e., including at twilight).

Usually only a few violations per year are identified as fishing vessels are well aware that any infringement may be spotted from the air. Especially in the spring, when fish migrate to shallower coastal waters, it is notable that vessels go right up to the edge of certain areas but do not cross into them. Data from observations also shows that large beam trawling vessels rarely stray into prohibited areas anymore[142]. Based on available data[e], in the period 1993-2021 a total of 21 official reports were made resulting in fines of up to 9000 euros. One fine was as high as 18,000 euros, because the vessel in question not only intruded into the 3-mile zone but was also found to be committing two more offences at the same time. New fisheries regulations are regularly being introduced such as the ban on electric pulse fishing or compulsory AIS, which means that surveillance will continue to be necessary in the future.

Although fishing control flights focus mainly on professional fishing vessels, the Coast Guard aircraft also monitors recreational shrimp fishing, angling and gillnetting. This mainly entails checks on night fishing (recreational fishing is not permitted between 10pm and 5am), monitoring of specific access rules and use of harmful fishing gear (recreational gillnetting above and below the low-water line is prohibited due to its proven detrimental impact on protected marine mammals)[145]. Just like professional fishermen, recreational anglers can be caught in the act of intrusion or navigational offences (like sailing against the prevailing traffic). These types of infringements and their monitoring are discussed further later on (see chapter 6.3.1).

6.3. Maritime enforcement

The Belgian part of the North Sea is part of a larger maritime area with one of the busiest shipping densities in the world[13,14]. Because of this exceptional traffic density, it is essential that the navigation rules are correctly enforced in order to minimise the risk of collision, especially in a context of ever-increasing numbers of seagoing vessels[146,147]. For this reason, the Coast Guard aircraft has also regularly monitored compliance with navigation rules and AIS use since 2011. All navigational and AIS infringements identified by the Coast Guard aircraft are systematically reported to the Coast Guard centre for follow-up: both to ensure maritime safety and to enable official reporting and additional investigation.

6.3.1. Navigation violations

Modern navigation rules are rooted in the IMO Convention on the International Regulations for Preventing Collisions at Sea (COLREG), which was signed on 20 October 1972 and came into force on 5 July 1977[148]. They were first transposed into Belgian law by the law of 24 November 1975[149].

The ability to remotely monitor compliance with the COLREG Convention is limited due to the very nature of the navigation rules. The target of the COLREG Convention is indeed primarily to avoid collision and has been drawn up for that purpose. The enforcement of many rules is therefore often dependent on the professional judgement of the officer of the watch attending the bridge. For example, the only minimum distance of approach between two ships referred to in the COLREG provisions relates to mine clearance (1000 metres in Rule 27°f). In all other cases, the rule is simply to maintain a safe distance. It is therefore not always possible to check from the aircraft whether a manoeuvre has been carried out correctly. In the same way, it is difficult to verify remotely whether a proper look-out was maintained, whether a vessel proceeded at a safe speed, or whether the risk of collision was correctly determined (COLREG Rules 5, 6 and 7). In all of these cases the general concept of good seamanship, as contained in COLREG Rule 2, is of great importance. This is a good example of the principle of completeness derived from legal theory: a collision can never be attributed to the rules themselves, nor to a lack of rules, but only to those who apply them.

Nevertheless, there are still a number of COLREG rules that can be monitored remotely. This includes the rules for sailing in a traffic separation scheme or TSS (Rule 10), i.e., proceeding in the appropriate traffic lane in the general direction of traffic flow for that lane (R.10°b-i) (figure 73), joining or leaving a TSS at as small an angle to the general direction of traffic flow as practicable (R.10°b-iii), or crossing traffic lanes on a heading as nearly as practicable at right angles (R.10°c)[148].

[e] Unfortunately, concrete data on the number of official violation reports is no longer available for the 13-year period from 1996 to 2008. In reality, the number of official reports for fisheries infringements from aerial surveillance is therefore likely to be significantly higher (possibly double).

Furthermore, within the framework of the Coast Guard, infringements in areas closed to maritime traffic (including safe distances determined by law)[150] are also considered to be navigation violations although, strictly speaking, they fall outside the scope of COLREG. Aerial surveillance is highly suitable for the detection of intrusions, as this form of infringement is called.

Between 2011 and 2021, the number of navigation violations reported by the Coast Guard plane increased from five to 36 per year. There was a total of 148 navigation infringements reported during this period (figure 74).

These infringements can be classified into two main categories (figure 75):

a) presence in areas where shipping is prohibited, such as the zones designated for aquaculture or the calibration of scientific equipment, safety perimeters around the Oostdyck radar tower and the wind farm zone, where shipping is subject to prior authorisation and safe distance applies[104];

b) the second category, sailing against the general direction of the TSS, crossing the TSS at an incorrect angle or anchoring in the middle of the TSS.

The reported number of intrusions (violations relating to entry into prohibited areas) has been relatively constant since 2011 at an average of three reported violations per year. On the other hand, we see a clear upward trend in the annual number of TSS violations (from four violations in 2011 to 33 in 2021). This notable increase may need to be qualified: it is possible that it is an indirect consequence of the evolution of the MUMM aircraft's role since the foundation of the Coast Guard from a primarily environmental mission to a multi-tasking maritime surveillance aircraft serving the entire Coast Guard structure. Nevertheless, the figures clearly indicate that COLREG supervision remains absolutely necessary for reasons of maritime safety.

6.3.2. AIS violations

In addition to these general maritime traffic violations, there are also infringements relating to the compulsory use of AIS on board ships. The Coast Guard aircraft has an AIS receiver on board, making it an effective platform to monitor proper compliance with mandatory AIS usage in and around the Belgian marine areas.

AIS (Automatic Identification System) is a navigational aid that allows vessels to automatically transmit a series of data to other ships and coastal authorities over VHF waves, including the vessel's identification data (name, IMO number, MMSI, call sign), as well as the number of persons on board, the vessel's destination, navigation status, navigational data (e.g., course and speed), etc.[151]. AIS not only facilitates communication between ships but also communication with the various services on shore (VTS, MRCC, etc). It is also a useful tool for preventing collisions when used

Figure 73. A fishing vessel sailing against the flow of traffic in the NHTSS.

in conjunction with other aids on the bridge, like visual look-out and radar[152]. AIS is therefore an important asset to ensure safe navigation, especially in the exceptionally busy Belgian waters which are shared by many different users.

AIS rules have been described in the European Directive 2002/59/EC establishing a Community vessel traffic monitoring and information system[153], hereinafter referred to as the VTMIS Directive, which implemented the general AIS

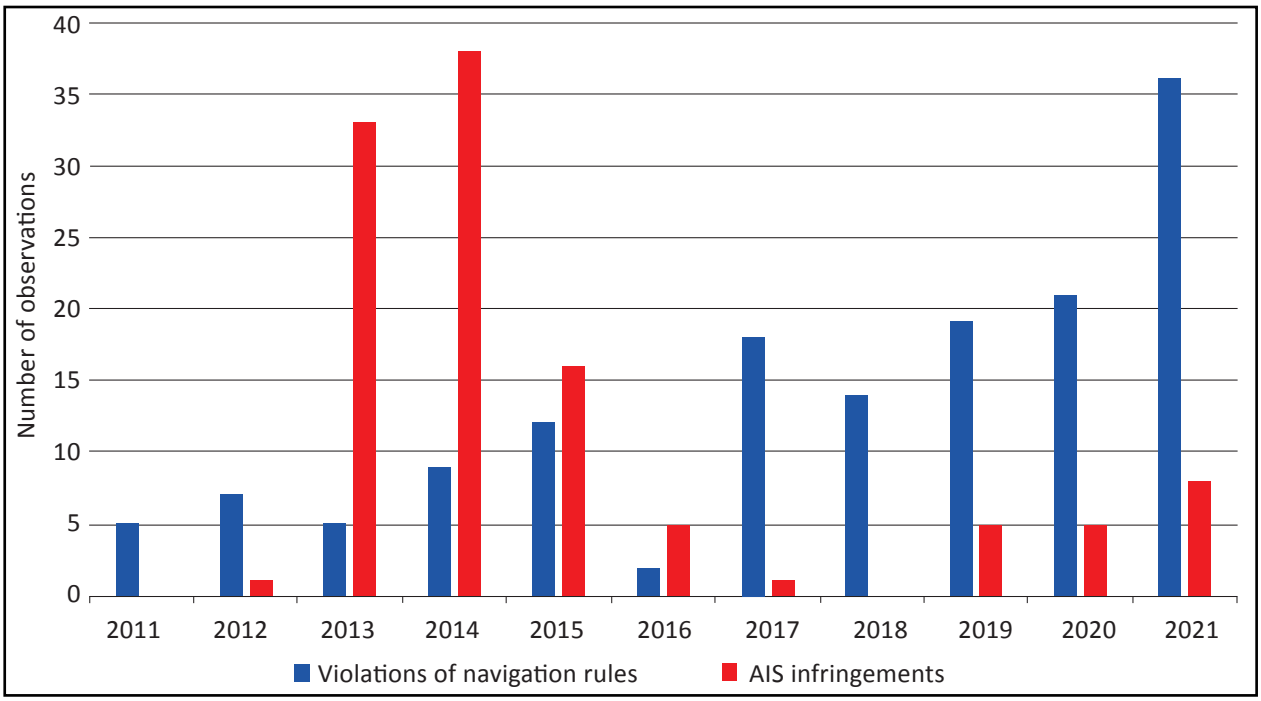

Figure 74. Evolution of the annual number of navigation and AIS infringements between 2011 and 2021.

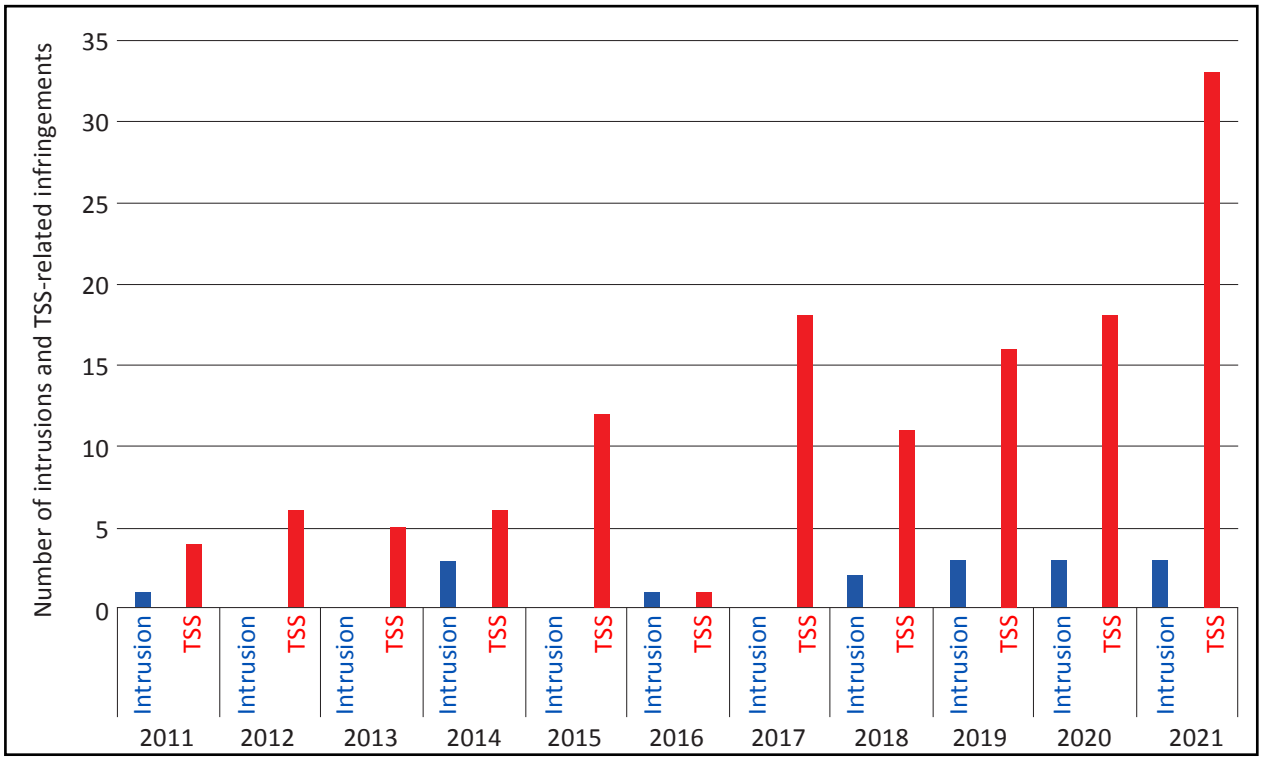

Figure 75. Evolution of the relative number of intrusions and TSS-related infringements (e.g., sailing against the general flow of traffic, crossing the TSS at an incorrect angle or anchoring in the TSS) per year, between 2011 and 2021.

requirement (adopted by the IMO in 2000)[154] at a European level. These rules were subsequently transposed into Belgian law by the Royal Decree of 10 September 2010[155], implementing the VTMIS Directive.

Among other things, the VTMIS Directive sets out that a functioning AIS is mandatory on board any passenger ship and all ships over 300 GT built on or after 1 July 2002. The VTMIS Directive was amended in 2009 to gradually[f] extend the measure to fishing vessels over 15 metres in length[156]. Since 1 October 2020, all professional fishing vessels have been obliged to use AIS, irrespective of their length[141].

This development of the regulation is also reflected in the data collected since 2011. Over the whole period 2011-2021, 94% of the reported AIS infringements originated from fishing vessels, which amounts to 105 fishing vessels out of a total of 112 AIS infringements over the same period.

The peak in the number of observed AIS infringements in 2013-2014 (figure 74) corresponds to the introduction of the AIS requirement for fishing vessels as laid down in the VTMIS Directive, specifically for vessels between 15 and 24 metres in length. The decrease after 2014 also indicates that aerial surveillance, together with the other enforcement measures, is an effective and deterrent measure. In spite of that, there has been a slight increase in the number of AIS infringements in the past few years (2019-2021). This new increase could be related to the implementation of the Royal Decree of 26 June 2020 on the introduction of various safety measures for fishing. This Royal Decree made AIS mandatory on board all fishing vessels of any length from 01/10/2020, which means that this can explain part of the recent increase in violations – mainly those of 2021.[141].

There is no doubt that in order to promote maritime safety the monitoring of AIS infringements must remain a concern for future aerial surveillance missions, particularly in the case of fishing vessels.

[f] Fishing vessels with a total length of more than 24 but less than 45 metres: not later than 31 May 2012; fishing vessels with a total length of more than 18 metres but less than 24 metres: not later than 31 May 2013; fishing vessels with a total length of more than 15 metres but less than 18 metres: not later than 31 may 2014.

6.4. Sand and gravel extraction

The extraction of marine sand and gravel is one of the most important economic activities in the Belgian marine areas. In 1976, the very first year of production, the yield was already at 29,000 m³ of sand (figure 76). Since then, annual extraction volumes have only increased further. In 2014, a record of just under 6 million m³ of sand was extracted, 25% of which was unloaded in Belgian ports, 60% was pumped onto the beach and 15% was taken abroad. A significant proportion of the sea sand extracted in Belgium, on average 75% in the most recent years, is used in the construction sector. Sand is primarily used for concrete, but also for asphalt, masonry, and for drainage, foundations and landscaping. On the other hand, the extracted sand is also used to make our beaches wide and high enough to protect our coast from flooding when storm tides hit. After severe storms, when large quantities of sand have been washed away and sand cliffs appear (figure 77), it is also necessary to perform remedial work (sand suppletion). The gravel in the Belgian part of the North Sea is of low quality, which means that relatively little of it is extracted. Gravel of marine origin is only used for ballast, e.g., for the construction of submarine gas pipelines or quay walls[23].

Sand extraction is only permitted in legally-defined areas, the so-called control areas. In 2021, there are five such control zones as defined in the Marine Spatial Plan: Thorntonbank, the Flemish Banks (Kwintebank, Buiten Ratel and Oostdyck), Sierra Ventana, the Hinder Banks (North Hinder, West Hinder and East Hinder) and Bligh Bank. There is also an exploration zone in the north-western part of the EEZ, around the NHTSS (figure 78). The extraction of sea sand in the Belgian marine areas is strictly controlled by the authorities and is governed by the law of 13 June 1969 on the exploration and exploitation of non-living resources of the territorial sea and the Belgian continental shelf (BCS)[102]. Sand extraction is also subject to additional legislation such as the Marine Environment Act[9], the European Habitats[110] and Bird Directives[157] and the European Marine Strategy Framework Directive[111].

Vessels wishing to extract sand and/or gravel must have a concession permit. In the control zones, concession holders are allowed to extract a total of 15 million m³ between them over a period of five years. Every year, the Federal Minister of

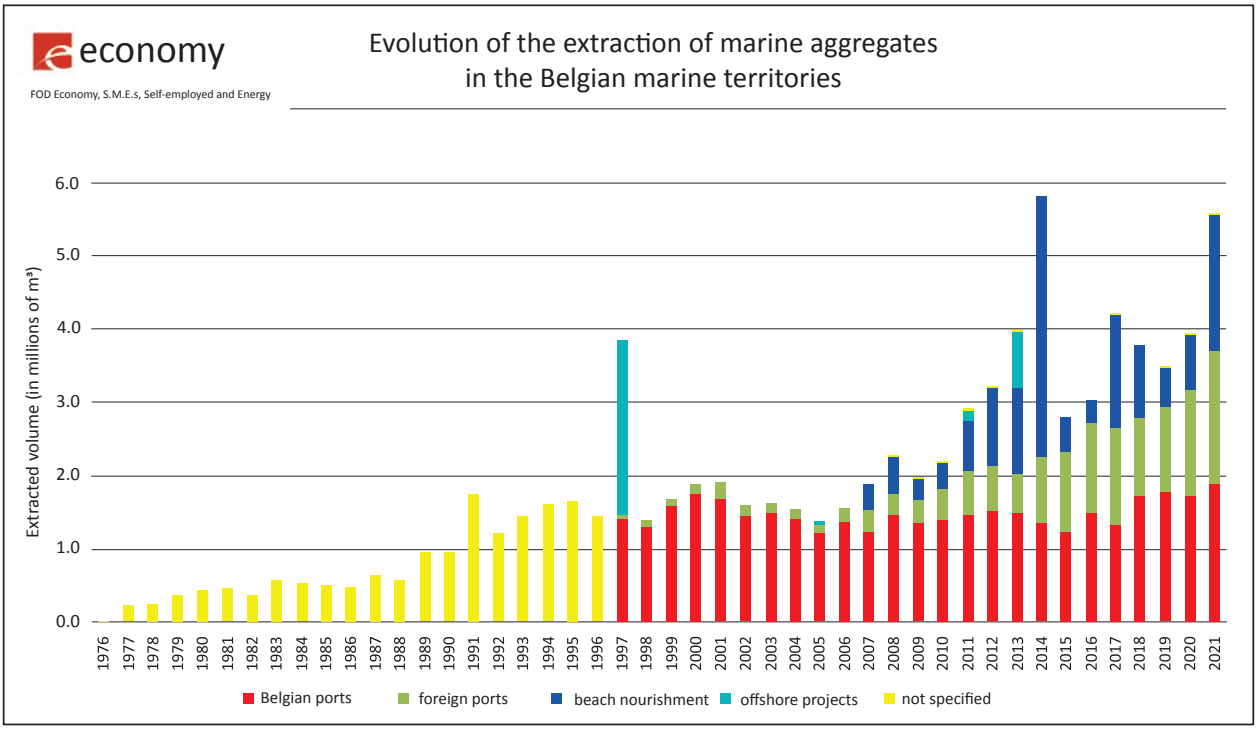

Figure 76. Evolution of sand extraction in the Belgian marine areas from the start in 1976 to 2021.

Economy fixes the maximum annual extraction volume per concessionaire, on the proposal of the Advisory Committee. Any extraction vessel active in Belgium must also have a sealed automatic recording device on board (electronic monitoring system, EMS), known as a "black box". This device records the vessel's identification, the date and time of recordings, the position and speed of the vessel, the status of the pumps and the status of the extraction process. During dredging, these parameters are recorded on average every 30 seconds. On behalf of the Continental Shelf service, the RBINS's Measurement Service Ostend provides the technical management and verification of this automatic recording equipment, and is responsible for processing the data. This allows the conditions laid down in the concession to be monitored[23].

Figure 77. Sand cliffs on the beach after storm Ciara (2020).

The Coast Guard aircraft plays a useful supporting role in this by providing additional reports of sand and gravel extraction activities at sea, which can then be checked against the black box data. Observations of extraction vessels are reported to the Coast Guard centre, including the time, position and activity observed. These kinds of air observations can provide information when technical problems occur with the black box and ensure potential infringements can be identified, for example when a vessel is caught in the act of extraction without a concession, or when extraction occurs outside the control zones or inside sub-areas that have been excluded. The surveillance flights also increase the deterrent effect. In addition, the aircraft also checks whether the sediment overflow from extraction vessels is kept to a minimum (figure 79), which

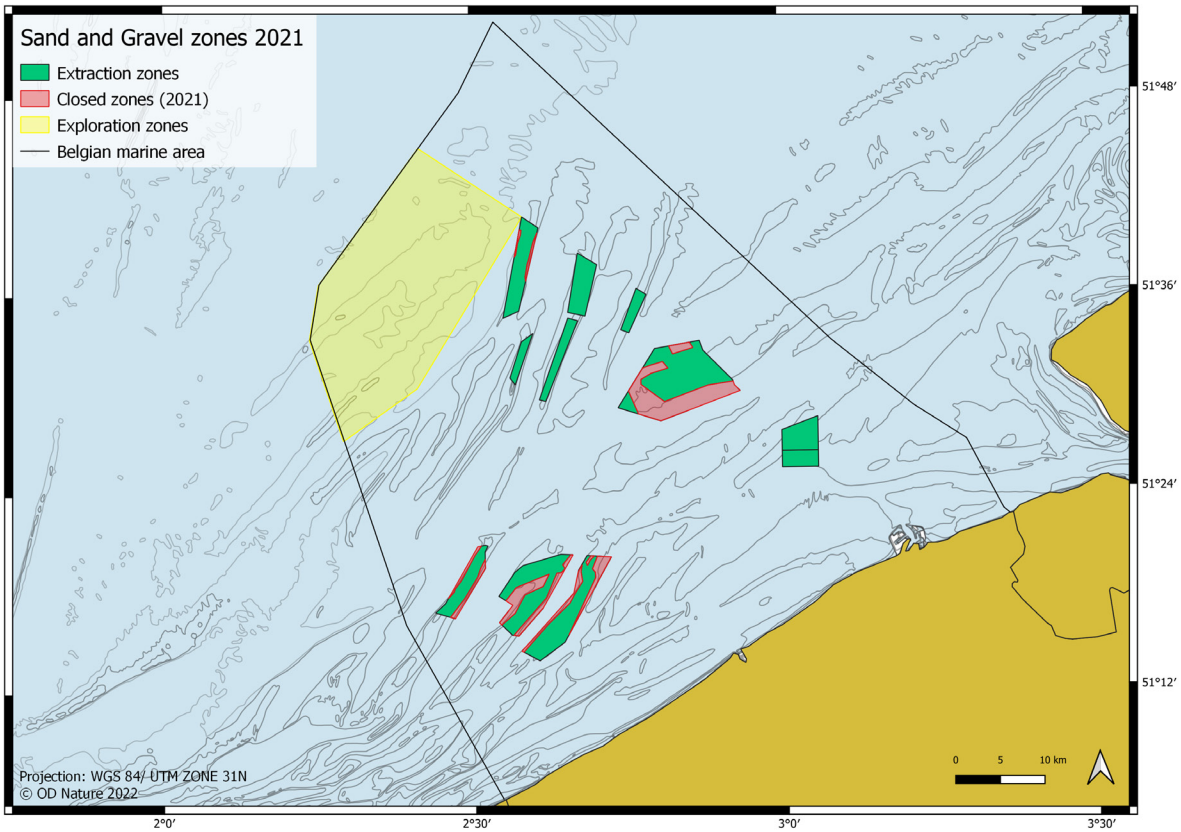

Figure 78. Map of the sand and gravel extraction zones in the Belgian marine areas.

is an environmental requirement attached to the concession permit. Excessive overflow can result in an overly long sediment plume, which may lead to negative environmental impact. Especially in the Habitats Directive area of Hinder Banks, the aim is to reduce the amount of sand in the biodiverse gravel beds[158], while the 'drop' of turbidity plumes from sand extraction activities could cause the opposite to happen, i.e., an increase in sand in the gravel beds.

Figure 79. A sand extracting vessel with sediment plume, as a result of its extraction activities.

Although aerial surveillance of sand and gravel extraction activities on the BCS goes back as far as 1998, monitoring was initially sporadic and observation data was not systematically recorded. This means that only limited data on sand extraction remains available for the period before the foundation of the Coast Guard (13 observations)[97]. Once the Coast Guard structure was in place, there was a more structured approach to monitoring and data was systematically and properly recorded. Since 2009, 146 observations of sand and gravel extraction activities at sea were reported from the Coast Guard aircraft. Based on the available data, at least 159 observations of sand and gravel extraction have been made since 1998, but this figure is likely to be a significant underestimate. The vast majority of the activities observed were entirely in line with regulations. Only one suspected concession infringement was identified and reported, and in only three cases, an excessively long sediment plume was found near or in the wake of an extraction vessel. Although the aircraft primarily has a supportive role in this Coast Guard mission, regular flights over the extraction vessels contribute to the improved monitoring of this economic activity, and help to create a deterrent effect.

6.5. Coordinated Coast Guard operations (OPERA)

As part of the Coast Guard Cooperation Agreement, joint control operations at sea have also been carried out since 2010[12]. Various Coast Guard partners with enforcement powers in the North Sea – the Navy (Defence), the Maritime Police, the Customs Maritime Brigade, DZV , DG Environment and MUMM - agreed to annually schedule a number of joint coordinated operations in the Belgian marine areas, called 'OPERA'. These joint Coast Guard OPERAs can last one day or several days. During an OPERA, personnel from the relevant Coast Guard partners can board a patrol vessel leading the operations. The Coast Guard centre (Maritime Security Centre) and MUMM support the control operations from the shore and from the air respectively. Other aerial surveillance resources are occasionally deployed as well.

The general purpose of OPERAs is to jointly carry out various control activities by inspection teams made up of authorised personnel from the relevant Coast Guard partners. This allows for various control tasks to be combined, including monitoring compliance with MARPOL regulations on board merchant ships, pollution control, checks on fishing activities (both professional and recreational), cross-border traffic, pleasure boats, checks regarding crewing, smuggling, immigration, intrusions etc. Different types of vessels can be boarded and inspected at sea. Any offenders have their details taken and official reports are drawn up. In exceptional cases, vessels can even be brought into a port.

In the period 2009-2021, the Coast Guard aircraft carried out a total of 45 patrol flights to provide air support for 22 different OPERAs. The aircraft fulfils a very varied role in this context, including provision of air support to units on the water, reconnaissance flights and target verification at sea, and real-time reporting of notable observations like concentrations of fishing vessels, suspicious shipping movements, infringements, etc.

OPERAs not only have a major deterrent effect, they also improve operational cooperation at sea between different Coast Guard services, including coordination between units on the water, in the air and on shore. For this reason, OPERAs are now a standard part of annual operational Coast Guard planning.

6.6. Other Coast Guard-related missions

Due to the increase in and diversification of human activities at sea, the establishment of the Coast Guard and the development of a Marine Spatial Plan for the Belgian marine areas, the Coast Guard aircraft's role has evolved in the last 15 years to become a multi-tasking, multi-purpose maritime surveillance platform. This multi-tasking, multi-purpose approach means that – to the extent possible and regardless of the main mission – the plane:

- Is always attentive and observant of the multitude of human activities at sea, the demarcated or protected areas, any sensitive infrastructure, etc.;
- Systematically reports useful observations, suspected infringements or incidents to the Coast Guard;
- Provides air support for specific Coast Guard missions, where possible and if requested by the Coast Guard centre or by one or more Coast Guard Partners;
- Can switch to a different assignment mid-flight, where needed, e.g., in the event of an emergency at sea or an urgent call from the Coast Guard.

Although the Coast Guard aircraft was mainly equipped for pollution control missions and is not sufficiently equipped to carry out all maritime surveillance tasks equally effectively (see chapter 7), the current approach still allows it to make a useful and valued contribution to many other Coast Guard missions.

The following is an indicative list of the aircraft's secondary tasks (since 2008):

- Air support for Search and Rescue (SAR): The aircraft has been called upon four times in second line, to support SAR helicopters from the Koksijde Air Force Base and other (seagoing) SAR units, to look for missing persons at sea;
- Reporting of floating objects: On seven occasions, small or large floating objects were spotted from the aircraft (pallets, an upturned sloop, driftwood, floating pipes etc.). These were all reported to the Coast Guard centre (MRCC) for reasons of maritime safety. In two other cases, the Coast Guard tasked the aircraft with finding floating objects (lost cargo) reported by third parties;

- Surveillance of dredging: The aircraft reported a few (four) suspected infringements of dredging and dumping rules (i.e., spoil from dredging being partially dumped outside the designated sites);
- Customs-related observations: The aircraft occasionally observes potentially suspect manoeuvres at sea, often when visibility is poor, like the presence of angling boats or other small vessels near large merchant ships in the West Hinder Anchorage Area, sports boats heading for coastal ports at full speed, and so on. Such observations are reported to the Coast Guard centre where they can be followed up and further action taken. Customs personnel have joined a number of surveillance flights in the context of specific, pre-planned customs operations at sea;
- Military vessels: The plane also sporadically observes foreign naval vessels in Belgian waters. Usually the ships belong to friendly European NATO countries and are just passing through. Once however, in 2017, an entire Russian fleet was seen in transit (the aircraft had been previously informed of their presence by the Coast Guard);
- Storm damage along the coast: After a few of the heavy winter storms of the past few years, the Coast Guard aircraft documented coastal erosion and/or siltation of port channels along the Belgian coast; as for example after storm Corrie in 2018 or the 2019 and 2020 spring storms;
- Transmigration: The problem of transmigration has recently worsened significantly in the North Sea, with migrants mainly attempting to cross the Dover Strait from Northern France to reach the UK. Since 2021, the Coast Guard aircraft has been regularly confronted with this issue, for example when abandoned small boats are spotted from the air (figure 80). In October 2021, the Coast Guard aircraft was tasked by the Coast Guard centre to locate a small boat with a large number of migrants on board, which was said to have drifted into the Belgian marine areas. The boat had 24 migrants on board and was eventually found near the wind farms in Belgian waters. It was monitored from the air until SAR units arrived on site.

Figure 80. Small and abandoned transmigrants boat observed in the Belgian surveillance area.

7. AERIAL SURVEILLANCE IN FUTURE

7.1. Aerial surveillance over the sea, an inherent Coast Guard function

7.1.1. Findings, added value and (logical) evolution towards expanded maritime surveillance under the Coast Guard

As mentioned earlier, multiple international treaties and national legislation oblige Belgium to protect and preserve the marine environment, to maintain the rule of law in its marine areas, to balance human activities and environmental concerns, and to ensure safety and security at sea. For these reasons, a Coast Guard structure was established. All of these responsibilities demand surveillance at sea, including from the air.

This 30-year activity report describes the various tasks and results, trends and developments of the Belgian aerial surveillance programme over the North Sea since its inception, leading to the conclusion that aerial surveillance is not only useful, but has proved absolutely necessary and efficient. The fight against operational (illegal) and accidental marine pollution – the programme's primary mission – has been particularly successful, both in the Belgian surveillance zone and in the greater North Sea (under the Bonn Agreement), including the fight against air pollution from ships in which Belgium is currently playing an important international pioneering role. Other surveillance tasks over Belgian waters have been added to the aircraft's range of duties over the years in support of the federal North Sea policy and the Coast Guard, such as wider environmental monitoring and surveillance of authorised activities, fisheries control, maritime enforcement including navigational and AIS infringements and intrusions, support for SAR and *ad hoc* support for various Coast Guard operations and interventions. In doing so, aerial surveillance successfully fulfils several operational objectives to this day: monitoring pollution pressures, human activity and protected species, creating a deterrent effect, detecting infringements, catching offenders in the act and flagging suspect ships for port inspections while also supporting emergency interventions at sea and carrying out diversified surveillance on behalf of the Belgian Coast Guard.

The aerial surveillance programme managed by MUMM has evolved over the years in line with various developments at sea and relating to the sea in terms of regulation, cooperation structures and new challenges. As a result, its duties became more diverse over time: from the early days of almost exclusively carrying out pollution control flights under the Bonn Agreement to a broader kind of environmental surveillance and ultimately a much more extensive, multi-tasking approach to maritime surveillance within the Coast Guard structure. It should be noted, however, that the aircraft was initially equipped for environmental surveillance and not for every possible type of maritime surveillance, which limits its capabilities. Yet this evolution actually makes perfect sense. Maritime surveillance, which is understood to include aerial surveillance, is an inherent Coast Guard function and provides substantial support in meeting and fulfilling Belgium's responsibilities and international obligations around marine environmental protection, maritime safety, law enforcement and maritime security. The current surveillance aircraft's contributions to the different tasks entrusted to the Coast Guard are greatly appreciated by many federal and Flemish Coast Guard partners despite the plane's limitations..

7.1.2. Future aerial surveillance needs

Environmental surveillance in a broad sense – encompassing pollution control, wider environmental surveillance and scientific monitoring – will remain an absolute necessity for Belgium in the future. Although our country's coastline is just 65 km long, and its marine areas are only the size of one Belgian province, the Belgian and surrounding waters see some of the busiest shipping traffic in the world. This can be attributed to their location near the Dover Strait (the gateway to northern European waters) and the two largest seaports in Europe: Rotterdam and Antwerp-Bruges[15]. The Belgian marine areas are internationally known to be high-risk for maritime incidents. Environmental and scientific monitoring continue to pose multiple challenges, including the monitoring of protected species, which with the help of digital surveys can hopefully be extended from only monitoring marine mammals to studying

seabirds as well; monitoring new wind farm zones and aquaculture projects; enforcement of future restriction zones in the marine protected areas etc.

The Belgian North Sea is also one of the most 'used' seas in the world, in the broadest sense of the word: shipping, tourism, leisure, fishing, sand extraction, energy production, aquaculture etc. (figure 81). All these activities and users make use of what the sea has to offer and they all require some form of supervision. The unique location of the Belgian maritime area and the multitude of activities taking place there also make these waters very sensitive to phenomena like illegal trade, smuggling and migration. And finally, Brexit has created a new external European border at sea, which must be enforced.

Future aerial surveillance over the sea should therefore not only meet the needs of environmental surveillance but also the wider needs of the Coast Guard. In this way it could be the operational spearhead of a more extensive and efficient cooperation within the Coast Guard and for tangible government intervention in the field.

The term 'Coast Guard', which encompasses aerial surveillance, incorporates many functions related to safety, security and environmental protection – as defined by the European Coast Guard Functions Forum (ECGFF) – all of which are inherently part of a full Coast Guard structure[159,160].

These Coast Guard functions are:

1. Maritime safety
2. Maritime security
3. Maritime custom activities
4. Prevention/suppression of trafficking and smuggling
5. Maritime border control
6. **Maritime monitoring and surveillance**
7. Marine environmental protection and response
8. Maritime Search and Rescue (SAR)
9. Maritime assistance service
10. Maritime accident and disaster response
11. Fisheries control
12. Coast Guard-related activities

With marine spatial planning, the full development of economic activities at sea, the new European external border, a significant risk of disasters, increasing amounts of sensitive and critical infrastructure at sea and so on, the Coast Guard

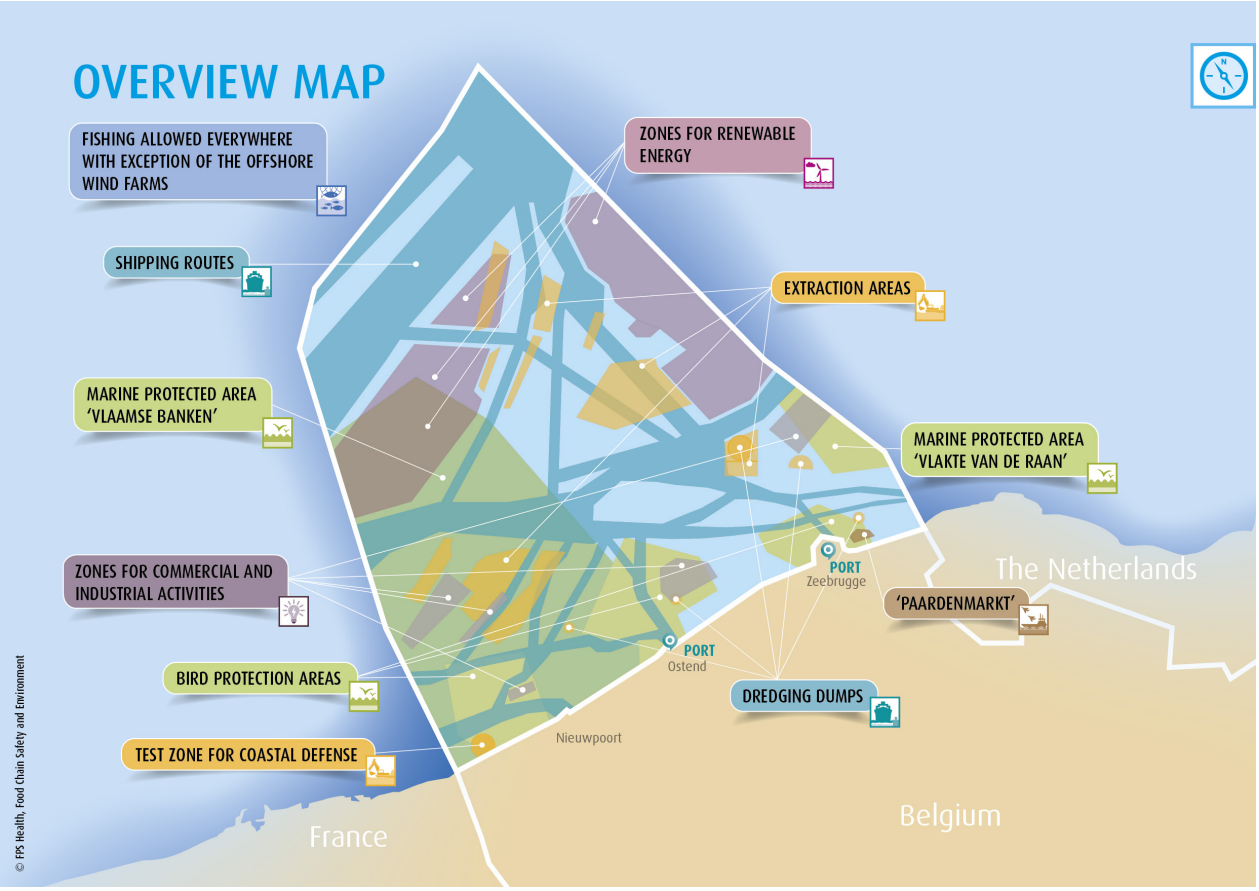

Figure 81. Marine spatial plan 2020-2026.

faces major challenges in the coming decades to ensure that all these sea-based activities can proceed safely, in accordance with regulations and in balance with nature. Multi-purpose aerial surveillance has an important part to play in this because the North Sea is a difficult area to monitor and because maritime surveillance is an inherent Coast Guard function which not only supports other Coast Guard functions but is expected to be carried out by each European coastal State.

The current Coast Guard aircraft supports the functions of maritime environmental protection and response and maritime accident and disaster response, and is also well suited for the functions of marine environmental protection and fisheries control. However, the other Coast Guard functions (maritime safety, security and customs activities, prevention and suppression of trafficking and smuggling, maritime border control and search and rescue) are not currently adequately supported because of the too one-sided equipment on board. For this reason, most other North Sea countries have already switched from aircraft that were primarily suitable for pollution control to more versatile, better equipped maritime surveillance planes operating in a modern Coast Guard context. Belgium could also take that step. A fully-fledged maritime surveillance aircraft could provide significant added value for the Coast Guard as a whole. It could also have a vital supporting role in emergency interventions at sea (in the context of North Sea emergency planning), by providing multidisciplinary aerial surveillance and air support. A robust surveillance aircraft, equipped to modern standards, could even provide (cost) effective added value in the event of emergencies along the coast or on land (like flooding or fires), for example by transmitting images and information about the incident to land-based crisis centres, complementary to other flying resources.

7.2. Towards the aerial surveillance of the future

The current Coast Guard aircraft was built in 1976 (figure 82) and will be half a century old by 2026. When management of the plane was transferred from Defence to the RBINS in 2005-2006, its life was temporarily extended by a thorough refit. That extra lifespan is now, however, coming to an end. The aircraft has always been very well-maintained, but it continuously operates in a salty environment which has caused significant corrosion over time. The plane is becoming old and outdated which apart from corrosion is borne out by more and more unforeseen mechanical problems and breakdowns, increasingly compromising the aircraft's availability. That problem is further exacerbated by many spare parts no longer being available off the shelf. The issue of unreliability will only get worse in future. The instrumentation on board the aircraft is also showing its age: it has largely become obsolete and needs to be replaced. The aircraft will need to be replaced in the medium term (i.e., by 2026) in order to ensure continuity of aerial surveillance over the sea.

This presents a unique opportunity for the Coast Guard to jointly consider what form(s) future aerial surveillance should take, what the current and future aerial surveillance needs are, and how to address them. With that in mind, an inter-departmental consultation was launched with interested partners in 2021, in the form of a Coast Guard Working Group 'Aerial surveillance'. Its goal is to establish a joint strategic vision for the future of aerial surveillance at sea with the priority of developing a technical dossier for a maritime surveillance aircraft.

The 9 federal and Flemish Coast Guard partners in the working group are: Federal Science Policy Department (MUMM-RBINS; president); Defence; FPS Health, Food Chain Safety and Environment (DG Environment); FPS Mobility and Transport (DG Shipping); FPS Finance (Customs & Excises); FPS Interior (Maritime Police, Air Support Directorate; National Crisis Centre); FPS Economy (Continental Shelf Service); the Flemish Maritime and Coastal Services (Shipping Assistance Division); the Flemish Department for Agriculture and Fisheries (Fisheries Authority, DZV). The office of the

Figure 82. The current Coast Guard aircraft.

Governor of West Flanders also participates in the Working Group.

The Coast Guard Aerial surveillance Working Group began its work by carrying out a SWOT analysis, listing the strengths, weaknesses, opportunities and threats related to current and future aerial surveillance at sea and organising them according to priority (ranking) and mutual correlations/connections. The SWOT analysis revealed three clear strategic objectives, forming the starting point for a joint Coast Guard aerial surveillance strategy for the future. These three objectives are:

1. Extension of cooperation on aerial surveillance within the Coast Guard structure

There is an openness and willingness among partners to cooperate more effectively and extend maritime aerial surveillance within the Coast Guard structure involving more Coast Guard partners and more Coast Guard functions. The most suitable foundation for this is the (current) flexible, multi-functional and multi-role approach to assignments.

2. Development of modern maritime air supervision

A manned Coast Guard plane has many strengths: weather resistance, flexibility, high load capacity, the benefit of having eyes at sea, the best possible evidence collection for enforcement, environmental surveillance quality, visibility at sea (deterrent effect) and highly-qualified flying personnel. There is currently no mature alternative which means manned maritime aerial surveillance must be maintained and strengthened. There are, however, some disadvantages and weaknesses too that offer room for improvement: limited flight time (four to five hours) at sea, periods of unavailability due to maintenance, safety risks for flying personnel and mandatory rest periods.

Modern aerial surveillance will have to meet several requirements:

- The known strengths and operability of a manned maritime surveillance aircraft make it a necessity going forward if adapted to the present and future needs of various Coast Guard functions (including instrumentation and operational features).
- Given the recent evolution of unmanned platforms (i.e., drones), the future of modern aerial surveillance above sea will involve an intelligent combination and complementary use of manned and unmanned surveillance (aircraft and drones) based on the various needs and challenges at hand. Despite the use of modern technology, drones are not yet capable of completely replacing manned aerial surveillance, but they do offer some operational benefits: rapid activation, operational continuity, operational safety in hazardous circumstances, invisibility, air support for patrol units, etc. Drones are an entirely separate type of surveillance platform and could be deployed to complement the work of manned aerial surveillance. If working in tandem with a manned plane, drones could significantly increase the surveillance perimeter and improve structural imaging of the sea.
- The extension of Coast Guard cooperation in terms of aerial surveillance also offers the opportunity to expand the skills and qualifications of surveillance personnel by sourcing specialised crew members from various partners and/or by offering the (current/additional) aerial surveillance personnel specialised training.

3. Development of structural aerial surveillance

Future aerial surveillance should be more structural within the Coast Guard structure, for example through live streaming and communications/data links with the Coast Guard centres (Maritime Security Centre and MRCC), coordination of control and planning, better structural imaging at sea, joint prioritisation of the missions and assignments, and the formation of a specific environmental cell at the Maritime Security Centre.

With this strategic vision in mind, multiple initiatives were launched within the Coast Guard in late 2022:

- In the autumn of 2022, the RBINS, with the approval of the Federal Secretary of State for Science Policy, started a consultancy assignment for a feasibility study to replace the Coast Guard aircraft. The purpose of this study is primarily to examine the different options for the replacement of the Coast Guard plane starting from the primary requirements put forward by the Coast Guard Aerial surveillance Working Group. Furthermore, the study will seek to define the monitoring needs and missions of any new aerial surveillance platform, as well as the technical and operational requirements to achieve an optimal configuration (both in terms of the equipment and the aerial surveillance platform itself, and the structural link with the

Coast Guard centres). It will also assess personnel requirements, identify and, where possible, apply sustainable development concepts and analyse the complementarity with drones. Lastly, the feasibility study, which is due to be completed in 2023, will also look at possible funding methods. The (ongoing) study will be followed up by MUMM-RBINS, who commissioned it, and by the Coast Guard Aerial surveillance Working Group which includes operational experts from various interested Coast Guard partners amongst its members.

- As part of that same Coast Guard Working Group, a sub-group was set up to look into drones, chaired by Defence. This sub-group is tasked with developing a complementary drone solution to support the Coast Guard. A first phase is planned for 2023, when drones will be tested at sea to support specific Coast Guard partner operations. It will make use of the medium drones which EMSA (through its RPAS service), on official application, makes available free of charge to European Member States. This will enable the Coast Guard partners to collaborate on drone surveillance missions for the first time and improve their knowledge and capabilities with regard to these new platforms and technologies.

In the medium term, these important initiatives should lead to the planned modernisation of aerial surveillance at sea in support of the Coast Guard and of the North Sea policy, ensuring that aerial surveillance at sea can continue beyond 2026. In this way, aerial surveillance will be appropriately extended to efficiently meet the many current and future surveillance needs, challenges and risks faced by the government at sea (figure 83).

Figure 83. The Belgian part of the North Sea: one of the most heavily used marine areas in the world, including shipping.

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- Figure 14: Ben Ullings
- Figure 28: COWI (www.cowi.dk)
- Figure 76: FPS Economy (Continental Shelf Service)
- Figure 81: FPS Health, Food Chain Safety and Environment
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Annex 1

Technical sheet of the OO-MMM air surveillance platform

1. Airborne platform
Type: Britten Norman Islander
Call sign: OO-MMM
Length: 10.9 m
Wingspan: 14.02 m
Height: 3.77 m
2 Lycoming engines (300 hp)
Mean cruising speed: 120 kts
Autonomy: 5 hrs

2. Radar
Model: Terma SLAR 9000
Range: 20/20 nm (standard opton) to 40/40 nm (74 km)
Resolution on ground: 35-75 m
With pixel per pixel georeferencing of the Flight Management System (FMS)

3. GPS positioning and en Flight Management System
Model GPS: Garmin GTN650 (× 2)
Model FMS: Garmin G600
Data-export latitude, longitude, course, airspeed, groundspeed, windspeed and direction, time, date, altitude (barometric), roll and pitch angle to control-unit
Built in Airband VHF radio-communication
Accuracy: 1 m

4. Control-unit (Mission Management Unit)
Model: Optimare Medusa System
Integration and control of sensors and sensor-images
Equipped with ECDIS and Comar SLR200 AIS receiver
Equipped with UPS (model Mid Continent MD835)

5. Radar altimeter
Model: Bendix King KRA405B
Data-export from barometric altitude to control unit
Accuracy: 1 m

6. VHF/FM Airborne transceiver
Model: Technisonic TFM-138B
Installed in control unit
Sound is recorded on video images

7. Satcom
Model: Garmin GSR 56
Controls integrated in Garmin G600 Flight Management System
Phone calls, text messages and weather information requests

8. Stormscope
Model: Goodrich WX-500

9. Traffic Advisory System
Model: Avidyne TAS600 S

10. Cockpit screen
Model: Avalex AVM 4095
Screen diameter: 8.4 inch
Resolution: 800 × 600
Analog video input: NTSC/PAL
Digital video input: SVGA

11. Sniffer System
Model: IGPS (Identification of Gross Polluting Ships) Sniffer System
Main instruments: SO_2 (Thermo 43i TLE UV Fluorosensor) and CO_2 (LICOR 7200RS NDIR Spectroscopy) high accuracy gas sensors
Software: IGPS Present, Extract, Analysis, TCP-LOG

12. NO_x measurement system

NO_x analyser
Model: Thermo 42i-TL
Power requirements: 110 VAC, 300 Watts
Resolution: 0.4 ppb
Measurement range: 0-1000 ppb
Dimensions: 16.75” × 8.62” × 23”
Weight: 55lbs
Communications: Ethernet and RS232
Tube connectors: 1/4” swagelock

Pump (Factory Suggested Model)
Model: Pu 425 – N026.3-8.90
Power requirements: 110 VAC, 200 Watts
Weight: 9 KG
Dimensions: 11” × 6.0” × 8”
Tubing connectors: 1/4 ‘’ swagelock

Tubing (Suggested connectors + spare parts)
6 × Acro 50 air Filters, 1 + 2 spare filters
4 × SS-400-7-2, connectors to filters
20 × SS-400-NFSET, Female connector for the tubing endings
2 × SS-400-R-6, Optional adapter 1/4 to 3/8”
2 × SS-400-3, T-connector for 1/4” tubbing of the sniffer box (if the sniffer tubing is 1/4”)
PFA-T4-062-100 (PFA tubing)

13. Digital Cameras
Model: Nikon D850+D800
Equipped with GPS connection

14. Video camera
Sony FDR-FX7
Focal distance (35 mm equivalent): 37,4 -748 mm (16/9) 45,7-914 mm (4/3)
Maximum resolution: 1080i
Optical zoom: × 20

15. IR
Model: FLIR A645
Resolution: 650x480 pixels
FOV lens: 45 °

Annex 2 (continued on next page)

Table A2. Detailed overview of the flight hours performed per mission type in the period 1991 to 2021.*

Missions	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
National															
Routine aerial surveillance - Marine pollution	71:20	172:15	170:00	187:35	179:10	208:15	220:05	186:10	180:40	173:25	181:05	191:55	158:35	190:10	35:25
Air pollution	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
On call	0:00	25:10	8:15	13:05	18:35	1:00	5:25	1:15	7:25	6:25	14:55	4:25	32:15	1:20	0:00
Pollution exercises (POLEX)	0:00	0:00	0:00	1:55	0:00	1:40	7:00	3:35	0:00	1:50	1:20	2:15	14:55	0:15	0:00
Fishery control	–	–	48:30	45:00	43:50	44:15	44:35	43:20	39:20	41:30	38:20	39:00	42:40	41:05	41:30
Marine mammal counts	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
International															
Tour d'Horizon	–	10:00	11:45	15:10	17:30	16:35	17:00	11:50	15:10	21:10	11:35	22:10	0:00	23:50	0:00
(Super-)CEPCO	–	–	–	–	–	–	2:10	5:50	0:00	6:00	5:40	0:00	0:00	0:00	0:00
ICAL	5:55	4:00	2:30	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00
Pollution exercises (Subregional POLEX-BONNEX)	–	–	–	–	–	–	–	–	7:40	–	–	–	–	6:55	–
Aip pollution (NL)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Transit	98:35	117:55	119:46	112:55	111:25	110:05	103:45	64:50	65:05	62:10	69:15	77:05	73:05	68:25	49:55
Total	**175:50**	**329:20**	**360:46**	**375:40**	**370:30**	**381:50**	**400:00**	**316:50**	**315:20**	**312:30**	**322:10**	**336:50**	**321:30**	**332:00**	**126:50**
Flight hours national surveillance	71:20	197:25	226:45	245:40	241:35	253:30	270:05	230:45	227:25	221:20	234:20	235:20	233:30	232:35	76:55
Day	71:20	182:31	215:00	196:55	212:26	230:18	244:35	213:25	209:25	211:05	220:01	218:59	224:15	211:23	68:45
Night	0:00	14:54	11:45	48:45	29:09	23:12	25:30	17:20	18:00	10:15	14:19	16:21	9:15	21:12	8:10

** 'Routine aerial surveillance – marine pollution' includes all flight hours during which marine pollution was monitored, in combination with other types of secondary assignments, e.g., monitoring of sand and gravel extraction, aquaculture, wind farms, maritime enforcement and safety at sea, PR related flights and flights as part of simultaneous cooperation with other Coast Guard partners (so-called OPERAs).*

Missions	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
National																
Routine aerial surveillance - Marine pollution	96:09	167:20	186:05	137:13	157:30	115:50	115:52	158:00	171:25	96:53	68:15	64:30	64:20	67:05	56:00	53:40
Air pollution	–	–	–	–	–	–	–	–	–	18:42	110:55	78:55	56:10	61:20	36:00	64:45
On call	1:53	0:00	0:00	0:00	0:00	0:15	7:40	0:35	1:55	53:48	20:35	3:05	2:55	1:10	8:50	2:10
Pollution exercises (POLEX)	0:00	1:20	0:00	0:00	0:00	0:15	0:00	1:15	0:25	1:05	0:15	0:55	1:00	0:00	0:00	2:05
Fishery control	39:05	39:15	39:50	39:40	39:40	39:30	39:45	38:50	40:00	42:25	40:50	40:05	36:50	43:15	27:40	45:15
Marine mammal counts	–	–	7:50	19:21	31:10	40:58	16:25	20:55	15:55	0:00	9:20	15:45	16:00	10:35	8:15	9:25
International																
Tour d'Horizon	14:50	0:00	12:10	18:40	21:10	0:00	18:55	21:30	20:25	0:00	0:00	21:10	22:05	24:25	22:00	19:30
(Super-)CEPCO	0:00	40:07	9:45	5:35	6:40	0:00	10:20	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	18:10
ICAL	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00
Pollution exercises (Subregional POLEX-BONNEX)	0:10	–	0:15	1:00	1:30	1:30	0:15	0:00	1:20	0:00	0:00	0:30	0:00	3:35	0:00	0:00
Aip pollution (NL)	–	–	–	–	–	–	–	–	–	–	25:00	0:00	25:20	35:00	0:00	33:45
Transit	67:49	78:41	83:37	76:01	73:19	75:00	92:21	81:00	66:15	68:25	67:48	65:25	67:30	68:00	69:40	68:30
Total	**219:56**	**326:43**	**339:32**	**297:30**	**330:59**	**273:18**	**301:33**	**322:05**	**317:40**	**281:18**	**342:58**	**290:20**	**292:10**	**314:25**	**228:25**	**317:15**
Flight hours national surveillance	137:07	206:35	225:55	176:53	197:10	155:35	163:17	197:25	213:20	211:48	240:35	186:35	160:15	172:50	128:30	165:50
Day	111:04	180:34	188:49	154:40	166:20	137:55	144:47	160:20	171:25	185:53	222:05	170:15	144:00	151:40	116:05	146:30
Night	26:03	26:01	37:06	22:13	30:50	17:40	18:30	37:05	41:55	25:55	18:30	16:20	16:15	21:10	12:25	19:20

Annex 3

Table A3. Summary of the national surveillance flight hours, the observed number of oil slicks, NLS slicks (Noxious Liquid Substances), and slicks of which the nature could not be determined (unknown – UNK), the average number of slicks per flight hour, the average length (km) for oil and NLS, the total contaminated area (km²) and the total volume (m³) of oil contamination.

		OIL					NLS			UNK	
Year	Flight hours national surveillance	Number of oil slicks	Number per flight hour	Average length (km)	Total surface (km²)	Total volume (m³)	Number of NLS-slicks	Number per flight hour	Average length (km)	Number UNK slicks	Number per flight hour
1991	71.3	17	0.24	3.06	3.37	10.27	2	0.03	16.72	0	0.00
1992	173.6	48	0.28	4.78	39.38	187.09	0	0.00	0.00	4	0.02
1993	224.8	49	0.22	3.12	48.29	57.96	2	0.01	8.40	3	0.01
1994	236.4	65	0.27	3.19	43.65	133.85	1	0.00	6.30	7	0.03
1995	236.5	41	0.17	2.98	15.31	23.29	3	0.01	11.69	2	0.01
1996	251.0	37	0.15	2.99	30.63	124.09	2	0.01	12.25	3	0.01
1997	269.4	51	0.19	4.63	43.89	37.57	9	0.03	2.20	2	0.01
1998	222.7	51	0.23	2.74	42.12	112.18	4	0.02	8.05	1	0.00
1999	221.5	41	0.19	3.83	55.02	84.56	9	0.04	5.41	4	0.02
2000	208.4	26	0.12	1.79	15.76	10.29	2	0.01	7.70	1	0.00
2001	216.1	15	0.07	3.11	21.83	43.92	2	0.01	n.a.	6	0.03
2002	228.8	27	0.12	2.35	24.84	24.84	4	0.02	n.a.	4	0.02
2003	227.3	17	0.07	3.35	24.60	78.32	7	0.03	2.21	0	0.00
2004	230.1	18	0.08	4.82	26.38	41.14	4	0.02	3.70	4	0.02
2005	76.5	3	0.04	2.04	0.22	0.64	2	0.03	0.61	0	0.00
2006	132.0	9	0.07	2.41	5.20	12.89	1	0.01	3.00	1	0.01
2007	199.6	22	0.11	2.24	7.62	3.86	3	0.02	5.33	2	0.01
2008	225.9	16	0.07	9.15	14.96	7.36	8	0.04	5.24	3	0.01
2009	174.6	15	0.09	2.23	13.20	5.82	5	0.03	4.03	2	0.01
2010	197.2	22	0.11	2.43	12.12	2.55	0	0.00	0.00	0	0.00
2011	155.6	10	0.06	9.14	15.58	7.62	9	0.06	13.48	2	0.01
2012	163.3	4	0.02	1.24	1.00	0.08	6	0.04	18.09	0	0.00
2013	197.4	5	0.03	0.99	2.17	0.42	5	0.03	7.50	1	0.01
2014	213.3	3	0.01	0.87	0.17	0.01	13	0.06	3.27	2	0.01
2015	211.8	0	0.00	0.00	0.00	0.00	4	0.02	14.38	0	0.00
2016	240.1	3	0.01	0.09	0.01	0.00	8	0.03	5.34	1	0.00
2017	186.6	2	0.01	6.00	1.35	1.15	6	0.03	6.18	2	0.01
2018	160.3	5	0.03	5.90	2.72	0.94	8	0.05	3.42	0	0.00
2019	172.8	1	0.01	0.05	0.00	0.00	10	0.06	4.21	0	0.00
2020	128.5	2	0.01	0.95	0.08	0.01	8	0.06	6.67	0	0.00
2021	165.8	0	0.00	0.00	0.00	0.00	11	0.07	3.31	2	0.01

Bijlage 4 (continued on next three pages)

Table A4. Overview of national (POLEX), and (sub-)regional (BONNEX) counter-pollution exercises, and Sea Trials in which the Belgian surveillance aircraft participated, in the period 1991-2021.

Year	Date	POLEX	BONNEX CHARLIE	BONNEX DELTA	Sea Trials	CP zone (Org.)	Other CPs	Description
2021	22-24/06	X				BE	–	National POLEX WMP - Spring (Norther & C-Power)
[2020]	*[~~29/09-01/10~~]*		*X (cancel.)*			*FR*	*BE*	*ANED-POLMAR 2020 exercise scheduled by French PREMAR Manche-Mer du Nord in Sept.2020. Was canceled last minute due to COVID crisis.*
2019	16-17/04				X	NL	BE, DE	Dispersant Sea Trials: dispersion tests at sea organised by Rijkswaterstaat (NL) off the coast of Scheveningen, with formation of 3 experimental oil slicks (1 x 1.5 m³, and 2 x 3.5 m³ crude oil). The aim was to improve knowledge on the impact and efficiency of using dispersants to chemically control oil spills at sea. Participating aircraft, including Belgium's OO-MMM, provided mapping and monitoring of dispersed versus naturally weathered oil slicks at sea.
2018	25/04	X				BE	–	National POLEX, as a pre-GUARDEX in the context of the Belgian Coast Guard
2017	26/09	X				BE	–	National POLEX WMP (C-Power)
2017	16-17/05		X			FR	BE, UK	Sub-regional exercise 'ANED POLMAR 2017' organised by the French PREMAR Manche-Mer du Nord off the coast of Boulogne (*Exercice d'assistance à navire en difficulté (ANED) et de lutte contre la pollution en mer (POLMAR)*). For Belgium, the surveillance aircraft took part (OO-MMM), together with an NHV helicopter (commissioned by DG Environment) and a marine Coastal Patrol Vessel (CPV Pollux). Tasks OO-MMM : communication with the French OSC ; detection of simulated oil slicks ; providing aerial support and documentation exercise..
2016	31/08	X				BE	–	National POLEX WMP (C-Power; dispersant spraying exercise)
2015	02/09	X				BE	–	National POLEX with CPV Castor
2015	27/03	X				BE	–	National POLEX and training OSC and CPV Castor
2014	30/09		X			FR	BE, UK	Sub-regional MANCHEX north of Dunkirk, in French EEZ, organised by the French PREMAR Manche-Mer du Nord.
2014	26/05	X	X			BE	–	National POLEX WMP (C-Power; with A963 Stern)
2013	25/06	X				BE	–	National POLEX WMP (Belwind)
2012	28/06		X			BE	NL, EMSA (EU)	Sub-regional control exercise organised by DG Environment off Vlakte van de Raan near the estuary of the Westerschelde, with several Belgian, Dutch and European (EMSA) combat units. Participation of the aircraft OOMMM, alongside an NHV helicopter (commissioned by DG Environment), for aerial monitoring and support to the combat vessels.

Year	Date	POLEX	BONNEX CHARLIE	BONNEX DELTA	Sea Trials	CP zone (Org.)	Other CPs	Description
2011	03/10		X			NL	BE, EMSA (EU)	Sub-regional control exercise in the estuary of the Westerschelde organised by the Dutch Rijkswaterstaat, to mobilise EMSA chartered combat assets and test their deployment in coordination with various Belgian and Dutch combat units. To simulate an oil slick, the harmless product 'Radiagreen' was used. The Belgian aircraft OO-MMM was mainly in charge of guiding the participating oil recovery vessels to the simulated slick.
2011	08/06	X				BE	–	National On-Scene Commander (OSC) coordination exercise in the context of emergency planning at sea.
2011	31/05		X			FR	BE, DE, EMSA (EU)	Sub-regional control exercise 'ORSEC POLMAR Manche 2011' organised by the PREMAR Manche-Mer du Nord off the coast of Dunkirk, with deployment of a total of 7 (French, German, Belgian and EU/EMSA) combat vessels and various flying assets. The mission of the Belgian aircraft OO-MMM consisted in detecting the simulated spots (rice husks) and providing aerial support to the combat vessels.
2010	03/06		X			FR	BE	Sub-regional control exercise 'POLMAR Manche 2010' organised by the PREMAR Manche-Mer du Nord in French waters near the Bay of the Somme, with a total of 8 combat vessels. The mission of the aircraft OO-MMM involved monitoring the simulated oil slicks (rice husks), guiding combat vessels, and training on coordination and communication with the French On-Scene Commander (OSC).
2009	29/09				X	NL		Pollution control exercise organised by NIOZ.
2008	26-27/06		X			BE	NL	Sub-regional control exercise organised by DG Environment (BE), with the participation of 4 Belgian and Dutch combat vessels. The OO-MMM aircraft participated for aerial monitoring and guidance, as well as an NHV helicopter (on behalf of DG Environment).
2007	02/04				X	BE	–	National exercise for testing sampling buoys (as part of the DG Environment "Sampling project").
2006	15/06		X			BE	NL	Sub-regional control exercise organised by DG Environment (BE) in nearby Dutch waters (Vlakte van de Raan, near the Westerschelde estuary). The exercise concerned only deployment of resources, no slick was simulated. 4 Belgian and Dutch combat vessels participated, equipped with means for mechanical recovery and chemical dispersion. The Belgian aircraft OO-MMM trained on communication and guidance.
2004	25-26/05			X	X	FR	BE, UK, SE	Large-scale Sea Trials combined with regional aerial surveillance BONNEX organised by the French Navy, CEDRE, and French Customs in Brittany, in May 2004. The tests at sea involved 3 experimental oil spills (3 x 10 m³ of oil) that were chemically controlled with 2 different dispersants (FINASOL OSR52 and GAMLEN OD 4000) using a Cessna POD spray system from OSRL (UK) and a French Navy ship equipped with a dispersant spray system. The evolution of the slicks was monitored by remote sensing techniques, oil sampling at sea and the deployment of a fluorometer. At the same time, a BONNEX intercalibration exercise took place with the participation of Belgian, Swedish, British and French surveillance aircraft.

Year	Date	POLEX	BONNEX CHARLIE	BONNEX DELTA	Sea Trials	CP zone (Org.)	Other CPs	Description
2004	w.5-9/04	X				BE	–	National POLEX deploying mechanical recovery assets.
2003	15-18/09				X	BE	FR, NO	Third, large-scale NEBAJEX sea trials (full scale monitoring exercise). Due to heavy accidental oil spills from the wreck of the TRICOLOR, the French PREMAR decided to cancel the initially planned exercise 'NEBAJEX-DEPOL 03' in Brittany. The project partners MUMM, CEDRE and SINTEF then decided to organise the full-scale monitoring exercise at the TRICOLOR site in nearby French waters, with the research vessel *Belgica* as the central monitoring platform. All monitoring techniques developed during the project were thus successfully tested in a real incident. The task of the Belgian aircraft involved aerial monitoring of the pollution, and guidance of the various monitoring teams at sea and the anti-pollution vessel present (*Union Beaver*).
2003	03/06	X			X	BE	–	Second series of tests at sea as part of the NEBAJEX project (see below), in which 2 small slicks were simulated with the harmless vegetable oil DIESTER, which were monitored at sea using various techniques. The aircraft trained on aerial monitoring of the experimental slicks, on communication and coordination with the research vessel (*Belgica*) and with monitoring teams aboard smaller boats (zodiac, RHIB) at sea, and on aerial guidance of ships equipped with dispersant spraying systems.
2002	03/09	X			X	BE	–	First tests at sea as part of the European project NEBAJEX (Net Environmental Benefit Analysis Joint Exercise; partners: MUMM, CEDRE (FR), SINTEF (NO)), which aimed to organise a large-scale exercise at sea to carry out effective monitoring of an accidental oil spill in real time using a joint monitoring approach (with the research vessel *BELGICA*; and through oil sampling and analysis at sea, and use of fluorometers), in order to make the best response choice in case of incident. The tests took place during the national POLEX exercise, in which the harmless product 'Finagreen' was discharged into the sea as an oil simulation, to be monitored and combated. The aircraft trained on aerial monitoring procedures and guidance for vessels..
2000	04/10	X				BE	NL	POLEX with the participation of the Belgian and Dutch aircraft. With experimental slicks of the harmless product 'Finagreen' (3 x 200L).
1999	01/06			X		NL	BE, DE, UK	Large-scale, regional pollution control exercise BONNEX DELTA organised by Rijkswaterstaat in the Netherlands off the coast of Den Helder. Several North Sea countries (including Belgium) took part in this exercise with several combat ships, to practice mechanical oil recovery at sea, and with surveillance aircraft. The aim was to test the efficiency of mechanical recovery means on real oil (with discharge of several m^3 of fuel oil and crude oil), with aerial guidance, and to practice multinational coordination.

Year	Date	POLEX	BONNEX CHARLIE	BONNEX DELTA	Sea Trials	CP zone (Org.)	Other CPs	Description
1998	21-22/09		X			BE	FR, NL, UK	Sub-regional control exercise organised by the Belgian Navy in Belgian waters off Zeebrugge, with French, Dutch and Belgian mechanical recovery vessels guided from the air by the Belgian surveillance aircraft.
1997		X				BE	NL	Bilateral POLEX with the participation of Belgian and Dutch units.
1996		X				BE	NL	Bilateral POLEX with the participation of Belgian and Dutch units.
1994	13/09	X				BE	–	National control exercise BOOMEX. The aircraft trained on standard communication procedures with combat units at sea.
1992	1-2/06				X	DE	BE	Intercalibration tests at sea as part of the European project SAMPLEX, organised in the German Bight by MUMM together with several German agencies. SAMPLEX aimed to test and evaluate different oil sampling methods at sea. Several German ships participated, as well as the Belgian research vessel BELGICA, and several air assets (Belgian and German surveillance aircraft and 2 German helicopters). About five small (up to 180L) experimental oil spills were discharged at sea for this purpose. The Belgian aircraft guided the research teams to the experimental slicks, in addition to monitoring and documenting the slicks to verify the colour code (volume estimation methodology of the Bonn Agreement).
1991	18-22/11				X	FR	BE, DK, UK, NL	Intercalibration exercise at sea ('ANTIPOL 1991') to train on aerial surveillance of oil pollution in the sea, organised by the French CEPPOL service in Brittany under the framework of the Bonn Agreement, with several experimental oil discharges (1 x 15 m³ of oil; + smaller experimental discharges up to 80 L/mile from a vessel under way) that were detected, documented and monitored by several surveillance aircraft (from BE, DK, UK, NL and FR).

Annex 5

Table A5. Overview of TdH missions between 1991-2021 with date and flight time, number of pollution detections (number linked to platforms, ships, no known polluter), number of oil detections larger than 1 m³, number of NLS detections (Noxious Liquid Substances) and number of slicks of which the nature could not be determined (unknown – UNK), total number of detections, and total minimum oil volume (m³) according to the old colour code (1991-2002) and the Bonn Agreement Oil Appearance Code (BAOAC).

Year	Date	Flight time (hr:mm)	Aantal detecties							BA Col. Code TOT. VOL (m³)	BAOAC min TOT. VOL (m³)
			OIL				NLS	UNK	TOT.		
			Platform	Ship	No pollutor	> 1 m³					
1991											
1992	28/09-30/09	10:00	0	0	1	1	0	0	1	1.60	1.98
1993	20/01-22/01	11:45	0	0	0	0	0	0	0	0.00	0.00
1994	07/06-10/06	15:10	2	0	1	0	0	0	3	0.26	0.47
1995	11/09-15/09	17:30	6	0	0	1	0	0	6	9.45	10.03
1996	08/07-12/07	16:35	2	0	0	2	0	0	2	4.49	9.81
1997	04/08-08/08	17:00	5	1	2	0	0	0	8	0.20	0.62
1998	20/04-24/04	11:50	3	0	0	1	0	2	5	1.41	3.55
1999	03/10-08/10	15:10	10	0	0	3	0	0	10	5.42	14.88
2000	16/04-21/04	21:10	11	0	1	2	0	0	12	8.13	13.94
2001	28/05-01/06	11:35	21	0	1	3	0	0	22	56.29	74.31
2002	24/06-29/06	22:10	3	0	6	0	0	0	9	0.66	0.68
2003											
2004	30/08-03/09	23:50	12	1	0	0	0	1	14	-	0.68
2005											
2006	16/10-20/10	14:50	3	0	1	0	0	0	4	-	0.03
2007											
2008	21/04-25/04	12:10	10	0	2	2	0	0	12	-	17.02
2009	31/08-04/09	18:40	3	0	1	0	2	0	6	-	0.01
2010	06/09-10/09	21:10	6	0	3	0	0	0	9	-	2.72
2011											
2012	02/07-06/07	18:55	1	0	0	0	0	5	6	-	0.00
2013	23/09-27/09	21:30	8	0	1	0	1	0	10	-	1.51
2014	15/09-19/09	20:25	26	0	2	1	0	0	28	-	5.30
2015											
2016											
2017	31/07-04/08	21:10	22	0	3	1	1	0	26	-	7.06
2018	06/08-10/08	22:05	23	0	1	5	2	0	26	-	11.71
2019	26/08-30/08	24:25	24	0	2	2	1	5	32	-	6.53
2020	14/09-18/09	22:00	22	0	1	2	2	0	25	-	7.55
2021	05/07-09/07	19:30	17	0	1	1	0	2	20	-	3.70

Annex 6

Table A6. Overview of pollution detections associated with offshore oil and gas installations, per coastal state affected (EEZs of UK, Norway, Denmark and the Netherlands) during the Belgian TdH missions from 1991 to 2021, showing A: total number of detections, B: BAOAC min. oil vol. (m^3); C: number of detections linked to platforms.

Year	United Kingdom EEZ			Norway EEZ			Denmark EEZ			Netherlands EEZ		
	A	B	C	A	B	C	A	B	C	A	B	C
1991												
1992	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0
1994	3	0.47	2	0	0	0	0	0	0	0	0	0
1995	6	10.03	6	0	0	0	0	0	0	0	0	0
1996	2	9.81	2	0	0	0	0	0	0	0	0	0
1997	7	0.57	5	0	0	0	0	0	0	1	0.05	0
1998	3	3.55	3	0	0	0	0	0	0	0	0	0
1999	7	14.86	7	3	0.02	3	0	0	0	0	0	0
2000	11	13.92	10	1	0.01	1	0	0	0	0	0	0
2001	15	74.14	14	7	0.18	7	0	0	0	0	0	0
2002	1	0.06	1	0	0	0	4	0.27	2	4	0.36	0
2003												
2004	7	0.25	7	5	0.00	5	1	0.43	0	0	0	0
2005												
2006	0	0	0	4	0.03	3	0	0	0	0	0	0
2007												
2008	8	15.61	7	4	1.41	3	0	0	0	0	0	0
2009	1	0.00	1	1	0.00	1	2	0.01	1	0	0	0
2010	4	1.44	2	5	1.28	4	0	0	0	0	0	0
2011												
2012	1	0.00	1	0	0	0	0	0	0	0	0	0
2013	5	0.42	5	4	1.09	3	0	0	0	0	0	0
2014	18	5.03	16	8	0.26	8	2	0.01	2	0	0	0
2015												
2016												
2017	10	6.36	10	9	0.67	9	6	0.03	3	0	0	0
2018	13	7.55	13	10	4.14	10	0	0	0	1	0.02	0
2019	11	2.55	10	11	1.19	11	4	2.78	2	0	0	0
2020	22	7.48	20	1	0.07	1	0	0	0	0	0	0
2021	13	3.56	13	5	0.14	4	0	0	0	0	0	0

Annex 7

Table A7. Overview of the (Super) CEPCO missions carried out by the Belgian Coast Guard aircraft: year, the organising country, (Super) CEPCO surveillance area, flight hours, number of flights, number of detections of oil, NLS and unknown substances, total number of detections and estimated volume for the total number of oil slicks during the various (Super) CEPCO operations. This is the data of the Belgian Coast Guard aircraft only.

Year	Type	Organising country	Zone	# Flight hours	# Flights	Oil	NLS	UNK	Total	Volume (m^3)
1997	CEPCO	BE	Southern North Sea, with focus on NHTSS – Eurogeul	02:10	2	0	0	0	0	0.00
1998	CEPCO	NL	Dutch waters, above TSS along the Wadden Islands	05:50	2	4	0	0	4	0.94
2000	CEPCO	BE	Southern North Sea (Noordhinder TSS, Sandettie, Strait of Dover)	06:00	2	1	0	0	1	0.02
2001	CEPCO	FR	Southern North Sea, Strait of Dover	05:40	2	2	0	0	2	2.76
2007	Super-CEPCO	BE	Southern North Sea	40:07	16	7	0	1	8	0.06
2008	CEPCO	DK, NO, SE	Northern North Sea, main shipping lanes along the southern coast of Norway and the Skagerrak	09:45	3	0	0	0	0	0.00
2009	CEPCO	NL	Southern North Sea (QZJR)	05:35	2	1	0	0	1	0.04
2010	Super-CEPCO	FR	Southern North Sea, English Channel from België to Ushant TSS	06:40	2	1	0	0	1	2.13
2012	Super-CEPCO	FR	Gulf of Biscay, shipping zone between Brittany (Brest) and Galicia (La Coruña)	10:20	3	0	0	0	0	0.00
2021	Super-CEPCO	DK, NO, SE	Skagerrak	18:10	6	1	1	0	2	0.02

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