NAUTICAL ACTIVITIES: WHAT IMPACT ON THE ENVIRONMENT? A LIFE CYCLE APPROACH FOR "CLEAR BLUE" BOATING

COMMISSIONED BY THE EUROPEAN CONFEDERATION OF NAUTICAL INDUSTRIES - ECNI

JUNE 2009 - SECOND EDITION

european confederation of nautical industries

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EXECUTIVE SUMMARY

In September 2007, the European Confederation of Nautical Industries - ECNI published its first report aiming at identifying and assessing the environmental impact of nautical activities. That first edition took a detailed look at the pollution sources from recreational craft, reviewing in particular the oil and hydrocarbon emissions and their impact on both air and water, the assessment and management of noise, and finally of waste water. The first edition recalled that nearly 80% of the marine pollution is caused by land-based activities and concluded that nautical activities and especially recreational boating were responsible for less than 1% of the overall pollution affecting the marine environment. Nevertheless, the study outlined a number of possible improvements in order to alleviate this minor impact - with professionals in the nautical industry to play a more active role in informing, advising and directing users towards good practices and environmentally friendly products.

By commissioning this second edition, the European Confederation of Nautical Industries - ECNI asked its team of consultants to broaden its scope in order to further examine the environmental impact of nautical activities. This second edition is structured in order to follow the life-cycle approach of a boat, and identify its environmental impact from its conception and manufacturing stage, through its useful life and related operations, and concluding with its disposal at the end of life of the boat. The data which were provided in the first edition were updated for this edition. Finally, the team of consultants applied the same approach as for the first edition, i.e. only existing studies and public data were used in an effort to compile in one study the numerous research efforts carried out so far.

Part One of this study examines the boat design, its manufacturing process and the related environmental impacts. The issue of the boat's end-of-life is presented based on a series of national initiatives taken by the nautical industry in various European countries and Japan, leading the discussion to what is today considered the future for our industry: eco-design of boats. In Part Two of the study, the possible environmental impacts are all linked to the boat's operational life: oil and hydrocarbon emissions, noise, waste water, antifouling paints, garbage, time-expired pyrotechnics, physical damage to the environment and the impact on fish stocks. Additionally, the study examines the environmental impact of marinas and mooring facilities, both at the creation stage of such essential infrastructures, during maintenance operations such as dredging, and operational activities.

For further information and questions about this study, please contact:

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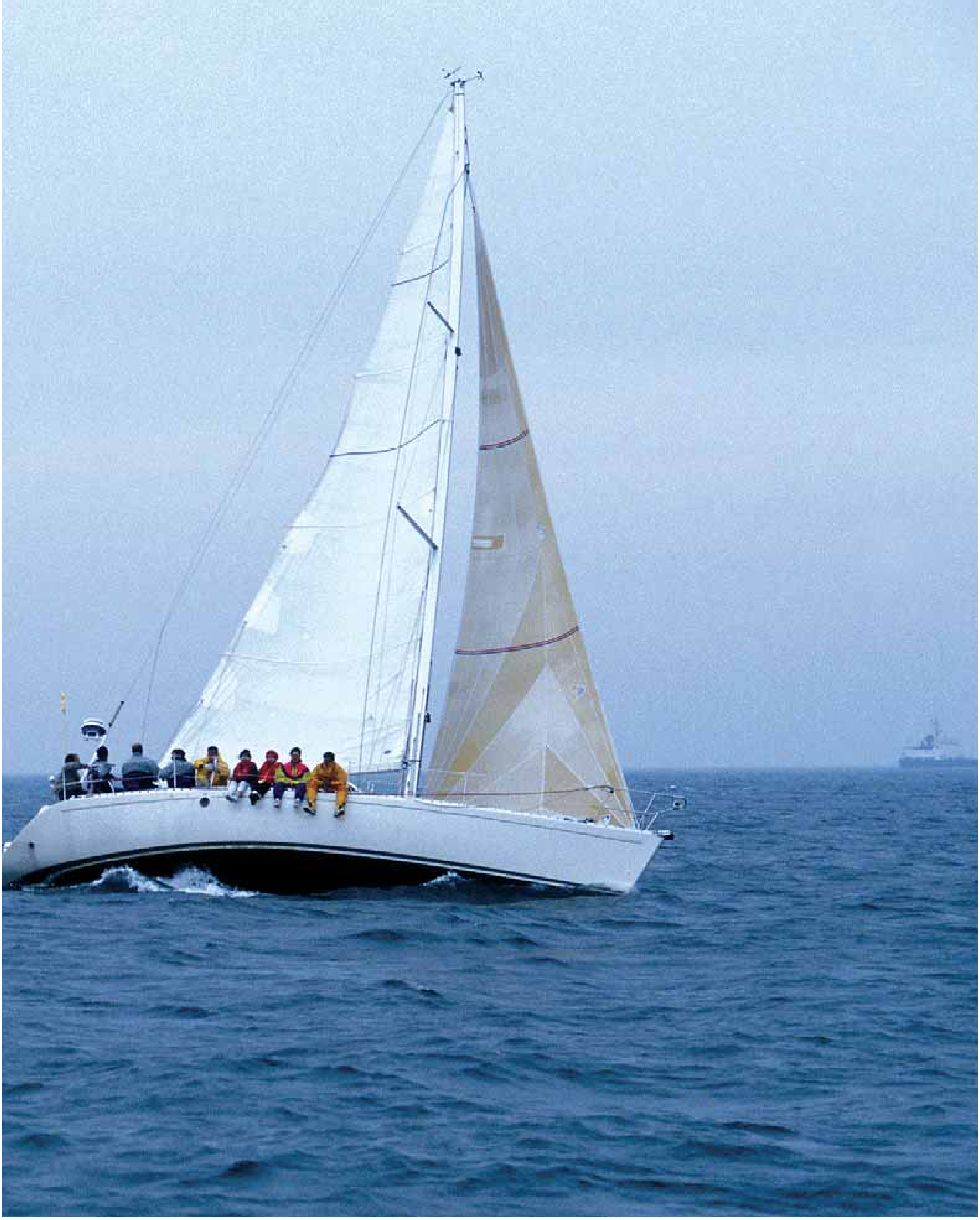


INTRODUCTION TO THE ENVIRONMENTAL IMPACT OF BOATING

One of the most responsible and comprehensive methods for evaluating the environmental impact of an activity or a product is the **life-cycle approach**. In such an approach, the environmental impact of a product is considered from design to disposal, including through life use and associated activities. To support the sustainable development of the sector, the European nautical industry is encouraging an approach which considers both the social and the environmental impacts of nautical activities.

For the present study, the main environmental impact considered is that due to the **operation of recreational craft**. The reason for this focus is that the life of a boat can be more than 30 years, whilst the manufacturing phase of a boat is counted in days. Secondly, boating activities take place directly in the natural environment of the coastal or inland waters. Nautical activities, their direct contact with sensitive ecosystems and the length in time of such contact are the core interests of this study.

A. THE NEED FOR EFFICIENCY IN PROTECTING THE MARINE ENVIRONMENT

The marine or river ecosystem is a fragile environment which is subject to various pressures from human activities. In the near future, **almost 60% of the world's population will live within 60km of the sea**[1]. Thought must therefore be given to finding ways of preserving and protecting the marine and aquatic environment.

A number of **institutions and organisations** have already begun focusing on this issue, whilst a range of international, national, regional and local **regulations and projects** have been adopted to try to deal with environmental issues. International efforts include the eight Regional Seas Programmes carried out under the aegis of the International Maritime Organisation (IMO) and of the United Nations Environment Programme (UNEP). In parallel, the European Union has adopted the directive 2008/56/EC setting out a strategy for the protection of the marine environment. Nationally and locally, EU Member States have adopted their own measures in order to protect the environment. It is vital for the various players involved in maritime and river activities to work together, to avoid efforts being duplicated and to prevent inconsistencies between the different programmes for action. The same applies to efforts to **develop regulation**. Steps need to be taken to ensure that the different pieces of legislation are consistent, and internationally harmonised where appropriate. Regulations also need to be developed by consultation with parties in both private and public sectors, taking into account the specific nature of marine activities.

Looking at the nautical industry, the **International Council of Marine Industry Associations (ICOMIA)** which represents the recreational marine industry worldwide, is championing sustainable boating at an international level. ICOMIA's Environmental Committee promotes a **strategy for the sustainable development of boating**[2] aimed at encouraging its members to take a product life-cycle approach. It reviews the environmental impact of recreational marine products from their design and manufacture through ownership and operation, to eventual disposal. It takes into account the through life carbon and energy tariff of the products, placing particular emphasis on materials selection and through life energy efficiency.

The **European Confederation of Nautical Industries (ECNI)** commissioned a team of European experts to study the environmental impact of nautical activities. The first study was released in September 2007. For the first time, many of the existing, sector-specific studies carried out on the impact of recreational boating, were integrated into a single report. The first edition focused mainly on the environmental impacts linked to the boat's operations. This second edition now aims at addressing the boat during its whole lifetime, from production to disposal, through operations. Special attention is also given to infrastructure ashore.

This study is intended for professionals from the nautical industry, policy-makers and stakeholders who are interested in combining the benefits of a dynamic industry sector with environmental protection. **Several national associations representing the nautical industry** have already adopted voluntary programmes, developing practical measures to prevent pollution and protect the environment. These include the ***"Green Blue"*** awareness campaign for recreational boaters in United Kingdom and the *Programme "Bateau Bleu"* in France[3].

[1] See IMO *Technical Co-operation Brochure*

[2] See ICOMIA Sustainable Boating Strategy

[3] See websites for *Green Blue* on www.thegreenblue.org.uk and *Bateau Bleu* on www.fin.fr

To avoid efforts becoming too fragmented and ensure that the various initiatives undertaken remain broadly consistent, private and public players in the maritime sector need to work in synergy. A number of national associations in the recreational marine industry are committed to national and international dialogue and have developed a range of proactive environmental projects. This approach is to be encouraged.

B. MAJOR SOURCES OF MARINE POLLUTION ARE LAND-BASED & INVISIBLE TO THE PUBLIC

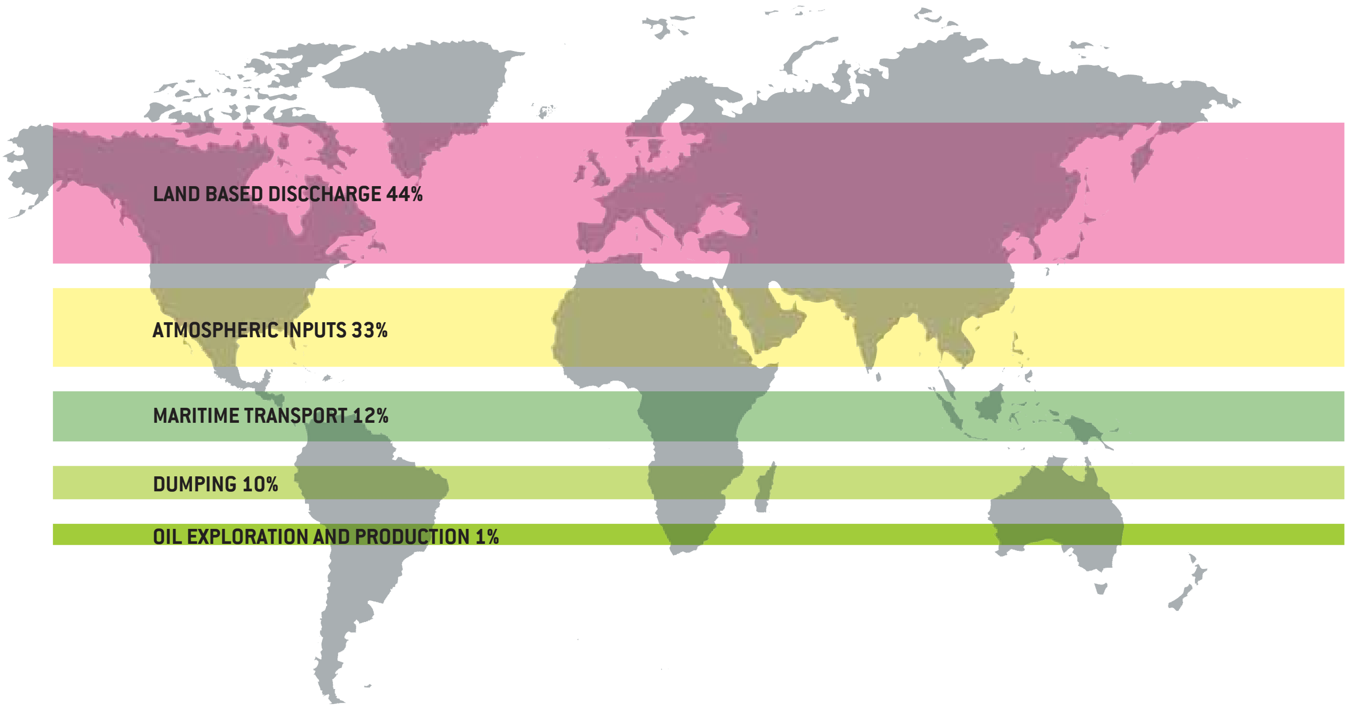
Protecting the marine and river environment is vital for developing and sustaining recreational marine activities in the long term. Human activities in general are exerting pressures on the environment. It is worth noting:

- Marine pollution mainly originates from land-based human activities. Unfortunately, these sources of pollution are mostly unrecognised and invisible to the public.

- Recreational boating must be differentiated from commercial maritime transport because it relies on significantly different technology and operations, and their respective environmental impacts are different. For instance, the air pollution due to sulphur dioxide emissions is an environmental issue which is strictly limited to commercial maritime transport[4]. Recreational boating and maritime transport are regulated by different sets of legislation and control mechanisms. Along the coasts and on inland waterways, mixed activities of leisure and transport are taking place; whilst on lakes, it is almost exclusively nautical activities that are being practised. On the other hand, there are few recreational craft on the high seas where most of the maritime transport activities take place.

- Recreational boating and other water-based activities are sometimes misleadingly regarded as a serious source of pollution, because of their high visibility on lakes and along the coast.

The different sources of marine pollution are:[5]



[4] Engines used by recreational craft do not emit any sulphur dioxide, since the fuel and the technology used are derived from road transport and should be compared with car emissions.
[5] Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) under the responsibility of United Nations Environmental Programme - UNEP

Some 44% of marine pollution (waste water, hydrocarbons, chemicals, industrial waste, etc.) originates directly from land-based sources. Pollutants introduced into the marine environment via the atmosphere represent 33% of all marine pollution. Land-based human activities thus account for some 77% of all marine pollution. Dumping at sea accounts for a further 10% with another 1% coming from off-shore oil exploration and drilling. Only 12% of marine pollution can be attributed to sea-based activities, namely maritime transport, transporting hydrocarbons and hazardous products, port activities, ship/port interface, accidents such as oil spills, degassing, other releases and recreational marine.

Given the sheer amount and diversity of maritime activities, it is not unreasonable to conclude that recreational boating and other water-based leisure activities can only account for a minor proportion of that 12% share of sea-based polluting activities. Based on the various studies available today, it is estimated that recreational marine activities amount at most to a fraction of one percent of the total. Studies on the contribution of recreational marine activities to the overall pollution in maritime cities such as Athens[6] or for US non-attainment areas[7] confirm this estimate of 1% and outline the considerable difference in size and power of commercial seagoing vessels with recreational craft. Considering air pollution, emissions from recreational marine engines only represent 0.56% of total emissions caused by human activities and 1.65% of road transport emissions[8]. It is a matter of regret that the minor role played by recreational marine activities in the pollution of our global marine environment is not always understood by the public.

By commissioning this study by a group of European experts, the European Confederation of Nautical Industries (ECNI) wishes to focus only on recreational marine activities and to study the impact of these activities on the marine and aquatic environment. A better understanding of these complex issues will allow professionals in the nautical industry to adapt their existing and future initiatives, and improve their effectiveness.

Today, 77% of all marine pollution is caused by land-based human activities, but these sources remain largely hidden from view. Taking place near the coast or on lakes, especially during the summer months and in tourist areas, recreational boating and water-sports are sometimes perceived as significant sources of pollution. The reality is that the environmental impact of boating and other recreational marine activities is minor, representing less than 1% of total marine pollution.

C. BOATING: AN ACTIVITY THAT HELPS TO PROMOTE AND PROTECT THE MARINE ENVIRONMENT

Enthusiasts of recreational marine activities normally have a deep affinity with nature; a well-preserved natural environment is key to their continued participation and enjoyment. The nautical industry therefore, by its very essence, has a major role to play in encouraging respect for the environment and in producing clean products and technologies. In addition, water sports and activities are a good opportunity to raise public awareness about ecological issues. Learning to appreciate the marine environment is often best achieved through a recreational pastime. By virtue of the wide range of activities on offer, nautical activities can reach a wide cross section of the population, with no distinction as to age, sex or culture. There are currently 48 million Europeans enjoying recreational activities by the sea, rivers or lakes annually. In the United States, there are 69 million boaters, and in Canada 8 million.

Nautical activities, because of their proximity to nature, are essential in promoting environmental awareness. They are a vehicle for teaching significant numbers of people to discover, appreciate, protect and preserve the flora and fauna of the natural marine habitat.

[6] TNO *Stocktaking Study on the current status and developments of technologies and regulations related to the environmental performance of recreational marine* (Delft, 10 January 2005)
[7] CORINAIR Emission Inventory Guidebook 2006
[8] Op. cit. TNO Report *Stocktaking Study*, pages 17-18

D. BOATING: AN ACTIVITY DEPENDENT ON ENVIRONMENTAL QUALITY

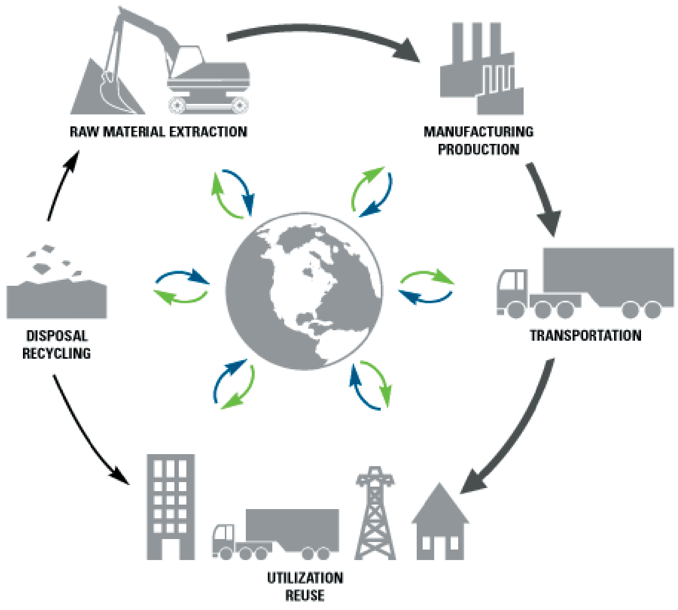
Nautical activities have a key role to play in promoting environmental protection. The nautical sector is also heavily **dependent on environmental quality**, crucial as it is to the **long-term future of recreational marine activities and tourism**. It is clear that any deterioration in the marine ecosystem will have a negative impact on tourism in general, and water-based activities in particular. A study carried out on the Greek island of Rhodes has shown that measures to improve the preservation of the island's marine and coastal environment, boosted its annual income from tourism by around 15 million EUR[9]. Similarly, pollution of rivers and lakes in Europe has reduced and the ecosystems revitalised over the last 30 years. As a result, water-based activities have picked up momentum and developed in these areas, bringing significant health, social and economic benefits.

Nautical activities are heavily dependent on the quality of the environment in general, and the marine and aquatic environment in particular. Recreational marine activities have a low environmental impact and positive social, health and economic benefits. The sustainability and long-term future of these activities can only be guaranteed if appropriate measures are taken to protect and preserve the environment from pollution and unsustainable economic activities.

E. A LIFE CYCLE APPROACH FOR "CLEAR BLUE" BOATING

A life cycle approach to products helps addressing the main environmental challenges that the planet is facing such as the stewardship of natural resources, energy consumption and climate change. The life cycle of a product starts with raw material extraction. It continues with the fabrication of the semi-finished products, finishing and assembling of the final product, its use and maintenance, and concludes with end-of-life operations. This last stage includes recycling of materials and the final disposal of waste.

For easily recyclable products such as those made from aluminium, the life cycle can be considered as "cradle-to-cradle" where recycled material can be substituted for primary material. Only the material that is lost at the different stages of the life cycle needs to be replaced by primary material, as illustrated in the figure below.



As an environmentally and socially responsible sector, professionals in the nautical industry gathered in the European Confederation of Nautical Industries (ECNI) asked for this second study to examine a life cycle assessment of boating activities. This study also includes the voluntary initiatives and projects already undertaken by the sector.

The study addresses all the life phases of a recreational craft, starting from the manufacturing phase, considering raw materials and manufacturing processes, to the end of life (Part One). It then focuses on the operation and use phase of the boat, including the marina and port infrastructures needed (Part Two).

[9] Communication from the European Commission to the Council and the European Parliament, concerning the thematic strategy on the protection and conservation of the marine environment -COM (2005) 504 & 505 final (24 October 2005)

PART ONE: BOAT DESIGN, MANUFACTURING AND THE RELATED ENVIRONMENTAL IMPACT

Boat building involves a diverse mixture of materials and methods, aimed at producing durable, resistant and largely autonomous craft. Methods from the aeronautical industry are sometimes used to achieve the best performance for a given weight. Materials are to a large extent fibre or glass reinforced plastic (FRP or GRP) composites manufactured with a matrix resin and for some the use of structural foam. The vast majority of craft is still made of glass fibre and polyester resin.

CHAPTER 1:
A COMPARISON OF THE MATERIALS USED IN INDUSTRIAL BOATBUILDING

The main phases in manufacturing a boat are the production of the hull and deck, the interior furnishing, the rigging and sails for a sailing boat, the installation of the engine and propulsion system plus the technical and electronic equipment of the boat. The study will concentrate on the manufacture of the hull, structures and the deck, which is the most demanding phase in terms of resources and energy.

There are no figures for the proportion of the different materials used for hull, structures and deck manufacturing in Europe. Nevertheless, it is safe to assume that composite materials represent the vast majority of boats built in Europe. Wood, aluminium and steel are also used as construction materials, but are a small minority of current boat production volumes. Metals and wood are to be found in much lower quantities in the interior furnishing, the boat equipment and its rigging. As an illustration, the French nautical industry produces about 95% of boats in FRP, about 3% in aluminium, some 2% in wood (plywood and moulded wood), and 1% at most in steel.

ALUMINIUM BOATS:

Despite the fact that bauxite (aluminium ore) is found in abundance, it is nonetheless a non-renewable resource. Aluminium is nearly non existent in its native form and involves an energy-costly process of transformation of its bauxite ore to produce the metal itself. The production of 1 ton of aluminium requires from 4 to 5 tons of bauxite and large amounts of water. Between 13,000 and 17,000 kWh of energy is required for the electrolytic manufacturing process, which also generates carbon dioxide emissions (CO_2). However, once produced, the metal is easily recyclable, with the recycling process using 95 % less energy than the production process.

An aluminium boat hull at the end of life can, to a very large extent (nearly 95%), be brought back into the production chain by recycling. In addition, its lightness, its ease of repair and its high elongation at break makes it a safe material for boats which are to be used in more extreme conditions.

STEEL BOATS:

Despite its non-renewable character, iron ore is also abundant on Earth. Its conversion to steel involves a well understood process and, furthermore, steel is almost totally recyclable. Its main value derives from its fundamental mechanical properties: tensile strength, hardness and elasticity. Steel's main disadvantage is its poor resistance to corrosion and its density. A steel hull built to the same set of rules will weigh more that its aluminium counterpart, using more energy to drive the boat through the water. Corrosion issues can be addressed by the use of anti-corrosion coatings. These coatings (mainly paint) increase the environmental impact of a steel boat during its life time. Stainless steel could be a solution, but its price and deformation during welding make it normally used only for fittings.

WOODEN BOATS:

In general terms wood is a renewable resource and the living trees from which it is produced are a carbon sink and a source of oxygen. It is worth noting however that most of the wood used in boatbuilding is imported from Africa, South East Asia and America and the carbon cost of its transport negates some of its initial positive impact as an oxygen source and carbon sink. Locally grown wood would be preferable although boat building requires specialist woods which are not always found in Europe. Regrettably, some forests are exploited in a non-sustainable manner. To reduce the prevalence of this practice labelled wood[10] should be used where possible.

There are two types of construction for wooden boats: the classic way using massive wood and the modern one which is more common today using extensively glues and epoxy resins. Plywood is the most common wood construction method used today. The construction of wooden boats requires trained personnel and high quality bonding techniques, with efficient surface protection provided by the use of synthetic substances and paints. There are natural surface sealing products available on the market, but these can require more frequent maintenance intervals.

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[10] Forests managed in a sustainable manner are using the following certifications (non exhaustive): FSC - Forest Stewardship Council or PEFC - Pan-European Forest Certification

Wooden boat hulls in a series production are generally built on a male mould using plywood panels for hard chine hulls, or thin strips of wood bonded together to form a multi-layer monocoque for round bilge types. A wooden hull may be lighter than its metal or monolithic composite counterparts. However, plywood and cold moulded wooden boats require the extensive use of resins, glues and surface sealers, making their recycling virtually impossible, unlike traditionally planked ones. For this reason, modern wooden boats have a relatively high environmental cost at the end of life.

COMPOSITE BOATS:

Boats built from sandwich or monolithic composites account for the vast majority of recreational craft produced today. The principal advantages are its low manufacturing cost, rather light construction weight, relatively low maintenance in both cost and time, and the relative ease of modification. However, the use of composites depends on the availability of oil, and the production of resin and fibre reinforcement involves high energy use and consequential atmospheric emissions. These drawbacks are to some extent balanced by considerable efforts by the manufacturers to reduce emissions during final product manufacture. New processing techniques, voluntary initiatives to address the boat's end-of-life disposal and research and development into recyclable composites and bio-composites are all helping to keep emissions to a minimum.

Considering the different construction materials used in boatbuilding, the following comparisons can be made between traditional materials and composites for a catamaran production and life time[11]:

Comparison for the production of a catamaran:

Body Production with Material input (T/body)	Composite Version	Steel Version	Aluminium Version
Abiotic Raw Materials	22,6	39,4	68,6
Water	641	337	2194
Air	9,9	14,1	22,2

Comparison for the life time of a catamaran:

Usage Phase Material input (T/25 years)	Composite Version	Steel Version	Aluminium Version
Abiotic Raw Materials	9 997	20 981	20 981
Water	58 082	121 900	121 900
Air	27 851	58 453	58 453

It is worth noting that the lower weight of the composite structure together with a smaller engine results in a 52% reduction in fuel consumption in this study.

THERMOPLASTIC RESIN BOATS:

Since a few years, a large number of small boats (tenders, kayaks, small sailing dinghies, etc.), tanks or fitting parts are made of thermoplastic resins. Parts for fittings are moulded by injection of thermoplastic resin (PE or others) pure or reinforced with glass or carbon spheres or fibers. Larger parts are either made by rotational moulding or by extrusion blow-moulding. These resins have a high impact resistance and are recyclable. But the resins alone, i.e. non reinforced, are not very resistant in flexion and the pieces produced are heavier than the ones in composite materials. It results in limiting the size of the parts produced.

Recently, composite materials using glass or carbon fabric and thermoplastic resin started being used in the boatbuilding industry. These composite materials are light (PE resin is lighter than polyester) and have an incredible impact resistance. Their production is nowadays limited to expensive parts where the impact resistance is essential. But this process certainly has a future.

All construction materials have their environmental advantages and disadvantages. A balance needs to be struck between the two. Contrary to common belief, wood is not necessarily the most environmentally friendly material for boatbuilding due to the large amount of surface coatings and glues required for its construction and maintenance. Steel and aluminium have high material production costs and through life maintenance. Propulsion energy consumed during the boat's life time also needs to be considered. Composite constructions have numerous advantages but currently they still lack good recycling capacities.

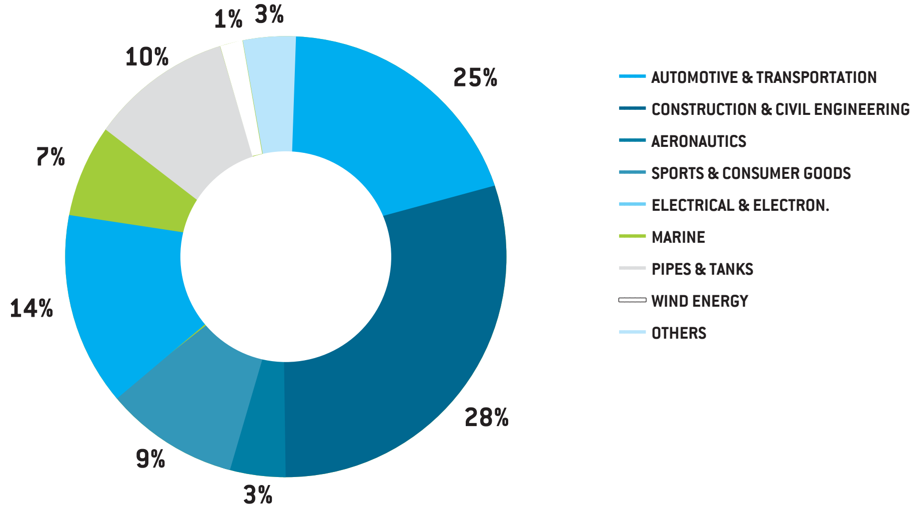
[11] Hartmut Stiller for Wuppertal Institute für Klima, Energie: *Material Intensity of Advanced Composite Materials* (February 1999)

CHAPTER 2:
THE GREENING OF COMPOSITES & OTHER MANUFACTURING PROCESSES

This chapter focuses on composites and the efforts made to reduce the environmental impact of the materials used and the manufacturing processes involved in the boatbuilding industry.

A. THE COMPOSITE USE IN THE NAUTICAL SECTOR IS SMALL & CONCENTRATED

Despite the fact that most recreational craft are built from composite materials, the nautical sector remains a relatively small consumer of composites. The two main users are the automotive and the wider transport sector, plus the construction and civil engineering sectors. The marine sector only represents **7% of total composites consumption.**



Worldwide composites consumption in 2005 by volume[12]

Marine applications of composites are concentrated in the recreational marine industry i.e. boatbuilding of both motor and sailing boats. Commercial shipping rarely uses composites although it is found in the military sector for applications where a low magnetic signature is required. Motor and sailing boats built specifically for racing represent a market niche consuming between 1-2% of the materials used in the volume market. These specialist applications tend to lead the market in terms of technological breakthroughs however. Good examples of this can be found in the high performance sailing racing boats, such as the Open 60s and multi hulls built in carbon fibre sandwich for races under extreme conditions such as the *Volvo Ocean Race* or the *Route du Rhum*. Racing designers strive to eliminate any surplus weight by using advanced building methods and exotic materials. These boats have to survive some of the toughest conditions experienced by non commercial vessels and are excellent proving grounds for new technologies which may ultimately find their way into a broad range of nautical products.

In terms of geography, North America is the main market for marine composites. It represented 56% of the total sales of composites for marine use in 2005, with two dominant companies in boatbuilding[13]. Asia and the Pacific area represent 28% of total sales, while Europe ranked third with 16%[14]. Some 6,000 yards are registered worldwide in the boatbuilding industry, but most of them are small companies[15]. The use of composite materials for boat production tends to be concentrated in a handful of large companies. In fact, 55% of the global marine composites market is made up of only 15 players of which just 5 main companies[16] represent nearly 30% of the activity[17].

[12] JEC Group: *Composite Materials in Marine* (2006)
[13] The two companies are Brunswick and Genmar based in the USA.
[14] Op. Cit. JEC Group study
[15] The nautical industry in Europe is composed at 98% by small and mid-sized companies
[16] Brunswick and Genmar in USA; Groupe Bénéteau, Azimut-Benetti and Ferretti in Europe.
[17] Op. Cit. JEC Group study

This concentration of activity can help to simplify the implementation of improved environmental and social standards in composite boat production. Indeed, the actions of just a few companies can significantly modify the environmental impact of the nautical industry in that area. Furthermore, these larger players usually have more human and material resources available for the integration of sustainable development practices in their production processes. The following closed mould processes do not emit any volatile organic compounds (VOC) into the atmosphere:
- Injection by resin transfer moulding (RTM) is usually used for smaller parts, giving a clean surface aspect on both sides;
- Infusion where the resin is vacuumed through is more and more common for small series, giving a clean surface aspect only on one side, but several elements used in the process (vacuum bag, peel ply, etc.) are consumable materials generating waste;
- Injection by both vacuum and low pressure resin transfer moulding (RTM Eco) which was developed in France is economically competitive. It gives a clean surface aspect on both sides of the part, uses light moulds but requires demouldable surfaces.

These processes are constantly evolving and more and more used by boatbuilders.

B. ADDRESSING THE ENVIRONMENTAL CHALLENGES OF COMPOSITES MANUFACTURING

The two main environmental challenges to be addressed in the use of composites for boat manufacturing are the atmospheric emissions during production and the ability to recycle composites at the end of boat life.
In order to deal with these challenges, three main types of regulation apply to the composite sector in industrialised countries:
- Regulations limiting the emissions of volatile organic compounds (VOC), notably styrene, in North America, Europe and Japan;
- Recycling requirements addressing the product's end-of-life treatment in Europe and Japan;
- General regulations limiting the emission of carbon dioxide (CO_2) in Europe and Japan.

Amongst other, environmental policies aim at limiting the emission of carbon dioxide, which is not toxic by itself, because of its role in the greenhouse effect leading to climate warming and the acidification of fresh and sea water. Volatile organic compounds (VOC) are also playing a role in the greenhouse effect and are harmful for the ozone layer. To date, the nautical sector is not subject to a mandatory recycling regime for composites in any country; nor are there regulations that limit the emission of carbon dioxide during the manufacturing process for the sector. This is due to the minimal environmental impact that the industry makes which does not justify sector specific measures. Nevertheless, the nautical industry is promoting sustainable development and environmental protection measures of its own and has initiated several voluntary projects to improve the life cycle impact of its products.

1. A POSITIVE BALANCE FOR CARBON DIOXIDE EMISSIONS

Emissions to air from manufacturing in the nautical sector are of two main types: carbon dioxide emissions (CO_2) which are rather low, and volatile organic compounds (VOC). The main VOC released during the composites manufacturing process is styrene which is the polymerising agent used to cure the resin. Styrene is considered to be only weakly toxic in humans, and was used for more than 40 years in boatbuilding without major problem. It is classified as an irritant by the European Union[18 19 20].

Carbon dioxide emissions are not a result of specific processes during boat manufacturing, but rather the result of general industrial activities, such as the manufacture and transportation of raw materials and products. However, it has been commented that the use of composites materials by the nautical industry has a rather environmentally positive balance in term of carbon dioxide emissions (CO_2)[21]. As mentioned previously, composite boats are generally lighter than their steel counterparts meaning that less fossil fuel is necessary for their land transportation, and for propulsion when in the water. Furthermore, production of the composites raw materials generates much less CO_2 than steel and aluminium extraction and transformation. As regards wood, if managed in a sustainable manner, it can be a carbon sink but unsustainable forestry practices can aggravate carbon dioxide emissions.

The carbon dioxide (CO_2) emissions associated with the manufacture and use of composite boats has a rather positive balance when comparing the small fraction of CO_2 related to raw material production with the lighter weight of their structures.

[18] Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006

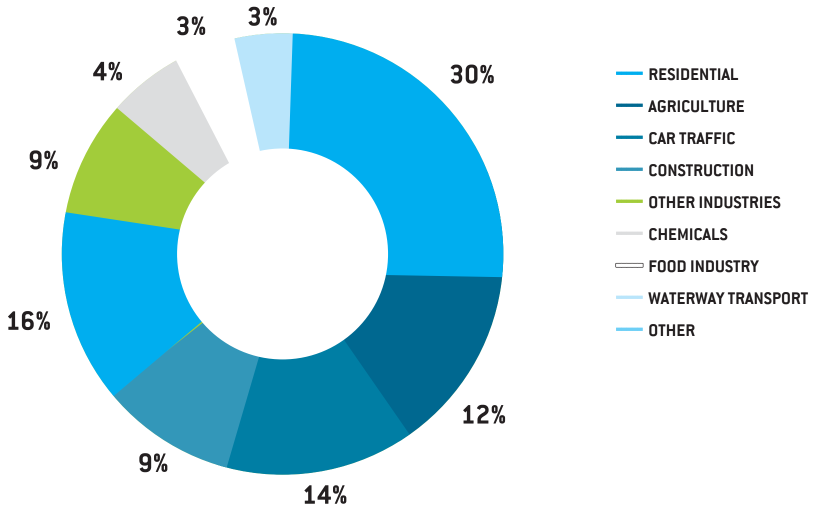
[19] The International Agency for Research on Cancer (IARC) classified styrene as a possibly carcinogenic (2B) substance based on a study carried out in the 1970s. However, recent studies carried out in 1990s did not find a correlation between styrene and cancer / lymphoma (Cf. INERIS toxicological sheet on styrene *-DRC-01-27803-00DF384.doc, Version N°2.1- June 2008)*.

[20] The Environmental Protection Agency (EPA) in the United States did not evaluate this substance for potential human carcinogenicity.

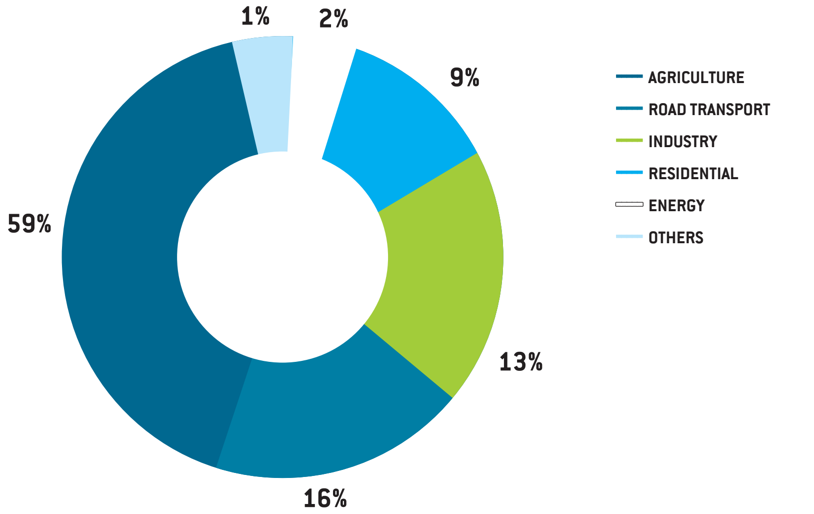
[21] Ben Drogt, Innovation Manager - DSM Composites Resins: *The Impact of Composites on CO2 emissions* (forum proceedings) from the conference "Environment & recycling: the composites contribution" (April 2008)

2. VOC EMISSIONS AND COMPOSITES: AN EU REGULATED PROCESS

A volatile organic compound (VOC) can be defined as any volatile substance containing at least one carbon atom. VOC are composed by hydrocarbons and their derivatives. They are said to be "volatile" when vapour is emitted at ambient temperature. Butane, propane, ethanol, acetone and solvents in paints or inks are all considered to be VOC. Methane is a VOC which occurs naturally in the ambient air and for this reason, it is treated separately from the other "non methane VOC" (NMVOC). The VOC content of paints and varnishes gives rise to significant emissions of VOC into the air, which contribute to the local and transboundary formation of photochemical oxidants in the boundary layer of troposphere.



Example of main VOC emissions sources in a local urban environment in Europe[22]



Example of main VOC emissions sources in a local non urban environment in Europe[23]

The recreational marine sector is generally considered to be a minor source of VOC emissions included in the 12% to 13% of VOC emissions generated by the industry as a whole. Most VOC emissions generated by the nautical sector are due to the solvents found in varnishes, paints and gel coats used during the manufacturing process. Solvents are found in the lamination process, with mainly acetone used for cleaning moulds and tools (rollers, brushes, etc). Such emissions can be dramatically reduced with inexpensive measures (adapted tooling such as acetone fountains and acetone recycling machines) and good practice (covering pots, rag boxes, careful use). The substitution of acetone with water-based products is also progressing and becoming widely used. For many years now, most boatbuilders in France for instance use polyester resins with low emission / low content of styrene in their open mould process, guided by the intention of reducing VOC equivalent emission. This was an important and effective step in the emission reduction process.

[22] Paris Chamber of Commerce / Chambre de commerce de Paris (France) on http://www.environnement.ccip.fr/air/reduction/cov.htm
[23] ATMO Poitou-Charentes - Air quality monitoring / La surveillance de la qualité de l'air en Poitou-Charentes (France) on http://www.atmo-poitou-charentes.org/Quelles-sont-les-sources-d.html

3. THE IMPACT OF EU LEGISLATION IN GREENING THE BOAT MANUFACTURING PROCESS

With the objective of limiting pollution from industrial activities, the European Union, North America and Japan imposed legal limits on the emissions of VOC into the atmosphere as well as provisions aiming to limit the pollution from large industrial plants. The EU directive 2001/81/EC on national emission ceilings sets emission thresholds for certain atmospheric pollutants (incl. VOC) and serves as a basis for regulating air pollution. These thresholds are implemented by the Members States through national plans and legislation applying to all human activities.

Large companies in the boatbuilding sector in Europe may be subject for their main installations to the requirements of the EU directive 2008/1/EC[24] concerning integrated pollution prevention and control (often referred to as the IPPC directive). This directive sets out a set of common rules for permitting and controlling industrial installations. In essence, the IPPC directive is about minimising emissions of greenhouse gases and acidifying substances, waste water emissions and waste from various industrial sources throughout the European Union. Large industrial installations can also be subject to waste permits under the EU directive 2006/12/EC on waste.

The EU directive 1999/13/EC as amended by the Directive 2004/42/EC imposes specific limits for the emissions of volatile organic compounds (VOC) linked to the use of organic solvents in the course of an industrial activity. This directive applies to nautical installations generating over 5 tons of VOC per year in the activities of wood and plastic lamination (hull and structures building), or 15 tons of VOC per year in the coating of wooden surfaces (interior furniture), or 100 tons of VOC per year in the manufacture of coating preparations, varnishes, and adhesives[25].

The directive defines an organic solvent as any VOC used without undergoing a chemical change. The part of styrene used in unsaturated polyester resins is not considered as a VOC since it is involved in the polymerisation reaction and stays in the material. Some countries such as France and Germany consider the part of styrene emitted in the atmosphere (i.e. not involved in the chemical reaction) as a VOC and therefore subject to the emission limits established by the EU directive 1999/13/EC.

The nautical sector is composed of few large players and a large number of small boat yards. For most of these companies, their levels of VOC emissions are far under the thresholds set by the VOC directive 1999/13/EC. Nevertheless, there is a clear trend today among small and medium-sized boatyards investing in modern emission-free technologies, since these technologies improve the company productivity and the working conditions for its employees, contributing to the attractiveness of the sector which is seen as a clean industry. The combination of available emission-free technologies and the use of low emission products allow the nautical industry to fully comply with the current EU legislation limiting air pollution. However, the nautical sector remains dependent on raw material producers for the environmental qualities of the composites, resins, fibres, paints and varnishes made available on the market for a boatbuilding application.

C. BOATBUILDING IN CLOSED MOULD: EVOLVING TOWARDS EMISSION-FREE PROCESSES

Prior to addressing the building methods with closed moulds, one needs to recall that composite boatbuilding started in the 1960s with the manual contact moulding in open moulds. This open mould method is the historical and traditional way of composite boatbuilding. It is still used for the vast majority of produced parts throughout the world. Numerous companies have invested or are carrying out investments in emission-free technologies. Besides the emission reduction, these technologies bring an improved quality of the laminated material and also an important reduction of the hull's weight due to the lower content of resin in the laminate, often associated with a sandwich structure. This weight reduction will also lower the fuel consumption and the environmental impact of the boat during and at the end of its life. In the year 2000, only 5% of boat decks were manufactured using close mould processes. Five years later, the proportion had risen dramatically and is estimated between 20 and 50%1 according to sources. This same trend is beginning to be seen in hull construction. Together with the rationalisation of processes involving less manufacturing waste, this phenomenon generated a decrease in composites volume used per boat2. Whilst this technological evolution is strong in the USA and Europe, countries where there is less legislative or economic pressure are still using open manual mould manufacturing methods.

[24] This EU directive modifies and codifies the EU directive 1996/61/EC
[25] Installations that fall under the scope of the directive have to comply with emission limit values in waste gases, fugitive emission values and total emission limit values, either using a monitoring system measuring emissions in the installation or using an emission reduction scheme described in the directive. The EU directive sets maximum emission limit values and it allows Member States to impose nationally or locally stricter values to the industrial actors. Considering the composition of the nautical sector where a few large players dominate the market, such regulations appear to be well implemented in their installations.
[26] Op. Cit. JEC Group study
[27] Op. Cit. JEC Group study

THE MOULDING PROCESS TYPOLOGY FOR NAUTICAL APPLICATIONS:

Apart from the filtration and closed cabin systems for manual contact moulding, the principal emission reduced processes developed and used by the marine sector are the following:

- The resin infusion process where the resin is vacuumed in
The resin is vacuumed in after applying the gel coat and installing the dry glass reinforcement and the core material for a sandwich construction in the mould. They are then covered by a series of reinforcement layers or fabrics, then with a peel ply, a flow medium, than the plastic vacuum bag. The vacuum will then pull the resin through the fiber reinforcement. Low viscosity resins need to be used and the polymerised resin has a theoretical slightly lower tensile strength than conventional hand lay-up resins, which is largely compensated by higher reticulation rate due to one shot process. Styrene emissions are nearly nil due to the closed mould nature of the process and the fact that most of the styrene remains chemically bound into the finished product. Given the high fiber ratio, the material is of high performance but thinner than the one obtained with manual contact moulding. The infusion process produces high performance and light laminated materials, with highly reduced emissions. On the negative side, there is a large amount of consumable waste material at the end of the moulding process (consisting principally of the polythene bagging material, flow mesh, bleeder layer and peel ply). This process is more expensive than the manual contact moulding. Finally, it is still necessary at the moment to laminate manually or by projection some additional layers.

- The RTM process where the resin is injected in the mould
In the Resin Transfer Moulding (RTM) process, the resin is forced into a closed mould containing the dry glass reinforcement. This process gives a clean surface on both sides of the produced part and allows a high production rhythm. The two moulds need to be highly structured and they are expensive. The RTM process is profitable for producing small parts.

- The RTM Eco process where the resin is both drawn into and injected at low pressure
First developed in France for boatbuilding, the RTM Eco process is largely used for increasingly larger deck parts (over 50 sq.m., i.e. decks for boats with a 15m length). It is weight effective and tremendously cost effective. It uses two lightly built moulds and adds void and low pressure injection. It allows moulding the deck and the inside liner in one shot, using lightly built moulds. The advantages of the RTM Eco process are its competitive cost, the clean surface on both sides of the part, no consumables and nearly no emissions. On the negative side, it requires two moulds (though lighter), it is slightly heavier compared to infusion, and at the moment the sole use is for decks as the part shall be demouldable.

- The manual contact moulding remains largely necessary
Even when closed moulds are used to produce the main parts, the contact moulding is still largely used to join parts or partitioning, etc. In the traditional manual contact moulding, reinforcing fibres and other structural materials are placed into a mould, to be impregnated with accelerated and catalysed resins. The resin is applied manually using rollers, brushes and pistols. Simultaneous projection moulding is also considered as a manual process. The resin, the accelerator, the catalyser and the glass fibre are projected simultaneously into the mould through special nozzles and the resulting composite has a random array of glass fibres. The advantages of the manual contact moulding are its low cost and the simple tooling and technique required. Unlike closed mould lamination, this process emits styrene and solvents in the air, though the emissions have been reduced by the use of new low emission resins. The composite material obtained is relatively resin rich and heavy with mild mechanical properties. Also, the work with sticky material is not pleasant and little status-enhancing.

- Void gluing
During the last ten years, the gluing of sandwich cores became more common, especially in the building of multihull craft. Mastering the void technology helped numerous boatbuilders in moving from the gluing of foam in open mould construction to the production in closed mould.

In highly regulated areas such as Europe, the recreational marine sector is benefitting from concentration of activity and further industrialization. A practical result of this trend is the growing use of emission reduced moulding processes in the building of composite hulls, decks and components for large series production.

D. THE RAW MATERIALS USED IN COMPOSITES FOR BOAT MANUFACTURING

The marine sector only represents 7% of the world consumption of composites and so, given its minority position, is not well placed to influence raw material producers in the "greening" of their products. A similar situation prevails

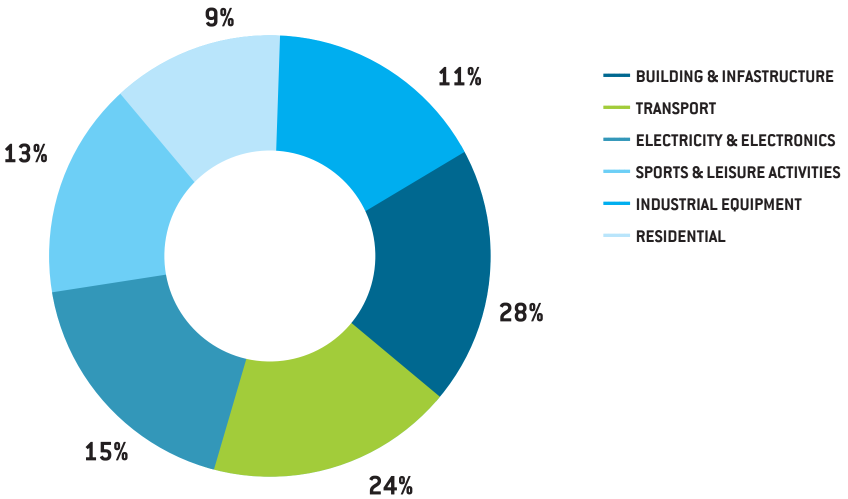
[28] Dr. Eng. Elodie Bugnicourt & Dr. Darcy Culkin: *Unsatureted polyester resins based on bio-renewable resources* (forum proceedings) from the conference "Environment & recycling: the composites contribution" (April 2008)

with regard to paints, varnishes and coatings. Despite this, raw material producers and other suppliers are developing new products which are environmentally-friendly, and are investing in research and development for low-emission and bio-based products.

THE "GREENING" OF COMPOSITE RAW MATERIALS

In boat construction, the resins used in fibre reinforced plastic (FRP) structures are mainly thermosetting (polyester, epoxy, vinylester, etc.). Thermoplastic resins (polyamide, polypropylene, PET, PBT, etc.) only start being used for boatbuilding or fittings. Recently, the composition of resins has evolved in two ways: low emission and low styrene content resins are now available on the market. More recently, bio-based resins have started to appear but their use is still very limited in the nautical sector. In addition to their environmental advantages at the end of life, bio-based resins reduce the dependency on oil resources. For instance, propylene glycol, which is derived from bio-glycerine, a by-product from bio-diesel production, can be used as standard raw material in polyester resins. Vegetable oils from soya beans, castor trees or linseed can also constitute a base material for polyester. Many resin producers have launched R&D programmes to obtain 100% bio-based resins and a similar trend is currently evident in the development of bio-based adhesives. The environmental benefits of bio-based resins and adhesives lie in the elimination of toxins in general, the focus on human health and environment, the reduction of hazardous and toxic materials and waste, the reduction of polluting air emissions and their recycling capacities[28].

As regards fibres, glass fibres represent 89% of the worldwide volume of fibres used in composites whilst only 10% are natural fibres. Carbon represents just 0.6% of the world composite production. Glass fibres are used as a reinforcing agent for many polymer products, resulting in the material commonly known as fibreglass. For a given unit strength, fibreglass is 30% lighter than steel. Its properties include among others chemical resistance, shocks resistance, and electrical insulation.



Uses of glass fibre by sector[29]

Glass fibre producers have significantly improved their manufacturing process in order to reduce air emissions and energy consumption, whilst improving the durability and the corrosion resistance of their materials. For example, boron free glass fibre has a considerably reduced environmental footprint compared to traditional glass fibre.

Natural fibres are also beginning to enter the composite market but their use in structural elements is limited due to their relatively poor physical properties. Currently they are used predominately for filling functions but numerous R&D studies for the use of natural fibres are under way and should allow greater industrial applications in the mid-term future.

THE "GREENING" OF PAINTS & OTHERS COATINGS

The EU directive 2004/42/EC aims to reduce air pollution by limiting the total content of volatile organic compounds (VOC) in certain paints and varnishes, and finishing products. This directive applies more specifically to products applied on buildings and vehicles but it does influence the compositions of the whole paint and varnish sector. It entered into force on 1st January 2007, with more restrictive limits to be adopted from 1st January 2010. In this area, the green evolution is driven by more restrictive legislation.

Greening of products and processes used for manufacture are key elements when the end of life is considered. These can play a key role in the recycling qualities of recreational craft.

[29] Article by F. Barthélémy, BRGM: *La fibre de verre : Un point sur le renforcement des nouveaux matériaux*, in the French review ECOMINE (January 2004)

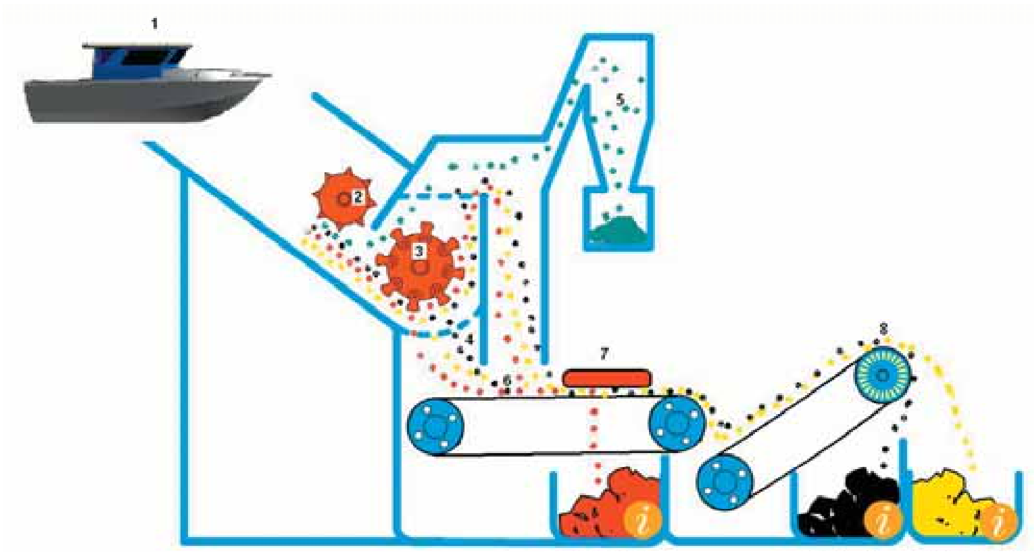
CHAPTER 3:
END-OF-LIFE BOATS: AN ENVIRONMENTALLY RESPONSIBLE APPROACH TO DISPOSAL[30]

A recreational boat can be expected to have a lifetime of over 30 years provided that it is well maintained. The robustness of its hull and deck construction permits multiple upgrades through life, increasing significantly its useful life and maintaining its sea going capabilities. With the boom of the nautical sector having started in the 1960-70s, the nautical industry nevertheless expects that a number of boats will come to the end of their useful life in the coming years. Even if these "dead" boats are not polluting in the sense that they are not releasing any harmful substances into the land or water, there is a risk that they will occupy valuable space in marinas and boatyards, or will be abandoned and dumped illegally, not to mention the derelict look it gives to the surroundings. Facing the reality of such risks, the recreational marine industry has recently launched several studies and pilot projects in Europe.

Currently, there is no regulatory regime on boat disposal, involving the responsibility of the boatbuilders, in any country in the world. Nonetheless, the nautical industry and boatbuilders in European countries and Japan carried out several pilot projects to tackle this issue. Recent studies undertaken in France[31], Finland[32], Japan[33] and an earlier study in Norway all established that it is feasible to scrap recreational craft at the end of their life. Metals and some other materials can be recovered and recycled using conventional routes, while composites can be reduced to fragments. Unfortunately this composite residue is frequently contaminated with paint, oil or embedded materials such as balsa core making any kind of re-use rather difficult. Recycling or disposal of the composite material appears problematic but extensive studies have already been undertaken into this subject, notably by the automotive and building industries, and disposal routes exist[34].

All of the studies to date, including the Japanese national programme, agree on the basic processes. Boats need to be located, identified and transported to a dedicated disposal site. Major items such as engines, interiors and metals are removed for recycling using established routes and the FRP hull is then broken up. The first study carried out in France recommended that boats need to be dismantled initially by hand and then crushed; while the Japanese programme used a combination of hand dismantling and then crushing and sorting. In Finland, the boat in its entirety is crushed and materials sorted.

The diagram below describes the process in place in Finland[35] :



[30] European Confederation of Nautical Industries - ECNI: *A brief report on the current state of the art in end of life boat disposal* compiled by Triskel Consultants Ltd (October 2007)
[31] Fédération des Industries Nautiques - FIN: *La filière BPHU* (France, January 2006)
[32] Finnish Marine Industries Federation - Finnboat: *Boat recycling in Finland, English summary* (Finland, November 2006)
[33] Japanese Boating Industry Association study - JBIA: www.marine-jbia.or.jp/english/index.html
[34] European Confederation of Nautical Industries - ECNI: *Study on Current state of the art in end of life boat disposal* (June 2007)
[35] Diagrams and some photographs are reproduced with the kind permission of the Finnish company Kuusakoski. Copyright acknowledged.

1. Boats are fed into the shredder
2. Feeding roller
3. Hammer crushes the boats
4. The filter separates small parts for further processing
5. Dust is sucked away
6. Transportation by conveyer belt
7. Magnetic separator separates the ferrous metals
8. Eddy current separator separates the nonmagnetic metals from plastics

DISPOSAL ROUTES FOR COMPOSITES

The Japanese national scheme is orientated entirely towards the use of the FRP scrap in the cement manufacture. The Finnish study ends with the reduction of the FRP to chips with no indication as to the preferred added value disposal route. The French study explores two principal disposal routes: incineration with domestic waste; and use in cement production. There is an extensive body of academic material relating to the disposal and recycling of composites, much of which was commissioned by the automotive and building industries and which is ultimately motivated by legislation[36].

There are a number of well known methods for reducing waste in general. In decreasing order of desirability, these can be ranked as follows:

- Produce less waste material at source, both manufacturing waste and by using less material in the product itself;
- Reuse a product at the end of life;
- Recycle the material;
- Incinerate;
  - With material and energy recovery
  - With energy recovery
  - Without energy recovery
- Disposal in landfill.

All of the routes are available for end of life boat disposal and most were researched extensively.

Produce less waste material at source:
In the manufacturing process, this relates primarily to improved and well controlled manufacturing in which waste streams are tightly controlled. This requires the application of modern production technologies and a well-trained workforce, two key elements that will bring more safety at work, lighter products and lower consumption of raw materials for production. Moreover, modern technology such as RTM allows for consistent quality over series and reduces waste. In the product itself, improved design and structural analysis allow for the elimination of excess material in the structure.

Reuse a product at the end of life:
As mentioned earlier, boaters nowadays do regularly upgrade their boats through refits of new equipment and interiors, which improve navigation pleasure and safety. Given the long lifetime of boats (over 30 years), there is scope for further work which could include the production of more modular designs which are more amenable to mid life upgrade and refit.

Recycle the material:
Following the whole boat disposal methods researched by the French FIN and Finnish Finnboat federations[37], recycling of all but the composite materials has already been dealt with. Recycling - in the sense of making further economic use of the composite material - is more problematic but two principal routes exist: mechanical recycling and use in new thermoset / thermoplastics.

[36] Bos G.: *EU waste legislation and the composites industry*, IFP SICOMP (Sweden, May 2002)
Hartt GN, Carey DP: *Economics of recycling thermosets*, SAE technical paper 920802 (1992)
Pickering SJ.: *Recycling technologies for thermoset composite materials - current status*, Elsevier Composites: part A 37 (2006)
Network Group for Composites in Construction - NGCC: *Composites recycling* on http://www.ngcc.org.uk
[37] Fédération des Industries Nautiques - FIN: *ELB Network, preliminary study summary* (January 2006)
Op. Cit. Finnboat: *Boat recycling in Finland*

Looking at mechanical recycling first, by means of mechanical crushing and/or pounding, the composite can be reduced to a mixture of polymer, fibre and filler in either powder or granular form. A number of commercial companies[38] were involved in attempting to recycle the material resulting from crushing clean composite waste but with limited success. They focussed primarily on the reuse of the materials in bulk or sheet moulding compounds where it can be used as a substitute for calcium carbonate filler. Only limited quantities, typically around 10%, can be incorporated before the mechanical properties of the resultant materials are compromised. Alternative applications explored have been using the recycled material in new thermoset moulding compounds and in new thermoplastics. Other work explored using the porous nature of the recycled material to act as a resin flow path during vacuum impregnation of new products and as a noise insulator. The UK's Building Research Establishment - BRE has investigated using recyclate to produce plastic board where the material is used as an alternative to wood chips and further work has been carried out to investigate its use as reinforcement in asphalt. All of these methods are difficult to employ when the composite is contaminated with other materials, as will be the case with crushed boats.

Incinerate:
Where the composite material is contaminated with other materials, such as sandwich fillers (balsa and other plastics) or metal fixings, thermal processing is more effective.

- With energy and material recovery:
Thermoset composites have a high calorific value and can be burnt to release energy. Trials have shown that mixing up to 10% composite waste with municipal solid waste for incineration is a practical solution. If more than this amount is required to be incinerated then the high calorific value of the material plus the nature of the gases released means that the incinerator has to be dedicated to composites. This leaves a much larger amount of 'normal' household waste that cannot be incinerated as the incinerator is busy with the FRP load. This extra 'normal' waste then ends up in landfill instead of the FRP, resulting in no net gain. This is the conundrum faced by the French study.

- Use in cement manufacture:
A more promising route is the burning of scrap composite materials in cement kilns where the glass reinforcement and mineral fillers can all be incorporated successfully into the cement. The effect of these materials on the properties of the resultant cement has been investigated and up to 10% of composite waste can be used with no detrimental impact. The Japanese national scheme follows this route. This concept was taken further by the European Composites Recycling Services Company[39] which has set up a working system for the recycling of composite parts in cement manufacturing.

- Fluidised beds:
Fluidised bed thermal processes have been used to recover the fibre content from scrap composite materials, including contaminated materials. The fibres are recovered as filaments of 6 to 10mm in length. These have a reduced strength but can be reused. Any metals which have not been destroyed can be recovered from the bed of the incinerator.

- Pyrolysis:
Pyrolysis results in recovery of the organic materials which constitute the resin, as well as recovering the fibre content[40].

Disposal in landfill:
This option should only be taken when the above mentioned are not feasible.

The disposal of boats at the end of their useful life has been extensively researched. Although there is no perfect environmental solution today, significant progress has been made in developing and adapting commercial processes for recycling non composite components. As regards the composites, solutions do exist for their recycling either as a filler material or in cement manufacture but current volumes from the marine industry are too low to warrant the investments that would be needed. This results in the composite waste being sent to landfill. As the numbers of boats coming to the end of their useful life increases and recycling technology improves, it is expected that more environmentally and economically acceptable solutions will be found.

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[38] For instance, ERCOM Fibertec GmbH in Germany and Phoenix Fiberglass in Canada
[39] For more information, please visit the company website on www.ecrc-greenlabel.org
[40] Both the University of Leeds (UK) and the School of Engineering in Bilbao (Spain) are active in this field of research.


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CHAPTER 4:
ECO-DESIGN OF BOATS: INITIATIVES FOR A TOTALLY INTEGRATED APPROACH

Eco-design, also referred to as "sustainable design", "green design" or "design for the environment", is the art of designing physical products to comply with the principles of economic, social, and ecological sustainability. Eco-design considers environmental aspects at all stages of the product development process, striving for products which make the lowest possible environmental impact throughout the **product life cycle**. This is a global and integrated approach of all of the greening efforts that we have been describing previously in this study.

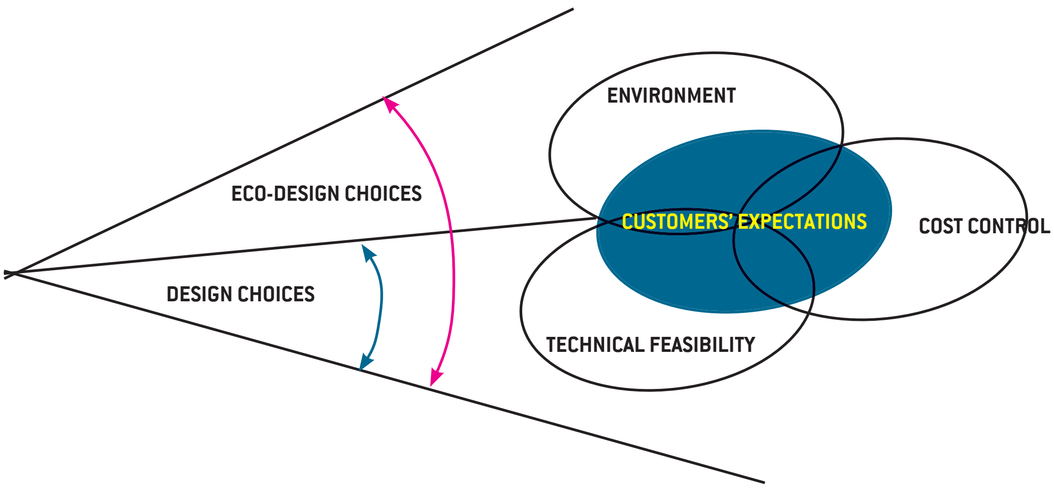
This approach, where the manufacturer takes responsibility for a product's lifetime impact and not just the impact of the manufacturing phase, is known as **extended producer responsibility (EPR)**. The first EPR strategy was designed in 1999 under the OECD, to promote the integration of environmental costs associated with products throughout their life cycles into the market price of the products[41].

The European Union adopted several directives which contribute at setting regulatory regimes on eco-design, such as:

- EU **waste framework directive** 2006/12/EC,
- EU directive 2005/32/EC on the **eco-design of energy-using products,**
- EU directive 2008/33/EC amending Directive 2000/53/EC on **end-of-life vehicles**,
- EU directive 2002/95/EC on the **restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS)** and directive 2008/34/EC amending Directive 2002/96/EC on **waste electrical and electronic equipment (WEEE).**

While eco-design in some areas was implemented through mandatory EU legislation, the nautical sector initiated **eco-design projects and approaches on a voluntary basis**. This proactive approach demonstrates the desire of the recreational marine sector to be ecologically and socially responsible, promoting competitive and sustainable development of its activities.

The success of adopting a voluntary approach on eco-design, which has also been adopted by some other industry sectors, is dependent on demonstrating combined environmental, economical and social benefits. The following improvements are expected from eco-design: better management of production costs in general; better management of raw materials and energy; better safety in raw materials supply; innovation in processes and products; environmental communication and image of the product; management of waste and product at end of life; compliance with future and existing environmental regulations.



Example of multiple factors considered in eco-design

[41] OECD : *Extended Producer Responsibility: A Guidance Manual for Governments* (2001)

Initiatives involving eco-design are already taking place in the recreational marine sector. A good example is the **Open Bic**, a new generation of sailing dinghies, which won the **2007 Bateau bleu R&D Award on eco-conception**. More than 20 projects on eco-designed boats and boat equipment were submitted to the annual Award of the French Federation for Nautical Industries. During the conception phase, the construction of the Open Bic hull uses a unique low-energy process (short 15-minute cycles and low electricity consumption, less than 80 kWh). It is also a resource saving process, through the reduction and the recycling of waste (scrap-work ratio <2.5/1,000 systematically recycled) and an emission free process (closed circuit, no gas emission, no solvent). At the end of life the Open Bic is a potentially recyclable boat (polyethylene, wood and polyethylene foam).

The most efficient tools for eco-design of products are IT based and adaptable for a whole sector. Such tools allow each designer to consider multi-environmental impacts, such as CO_2 emissions, global warming and human toxicity for each phase of the product's life. Initiated in France, the **Cap-Vert project**[42] is an eco-design IT tool dedicated to the recreational marine sector and boat builders in particular. The first module is being designed to address issues around hull construction, but over time all aspects of the boat, including equipment, will be included.

A sector-based eco-design tool could serve to integrate the disparate efforts of the recreational marine sector, and could become a significant resource in the drive for a "clear blue" nautical sector. This would allow the next generation of boats to be designed in a more environmentally friendly fashion. Notwithstanding improved manufacturing practices, the longest phase of a boat's life is in the water where it is in direct contact with natural ecosystems. The second part of this study will explore how the user's choices and practices can largely minimise the boat's environmental impact.

[42] This French project is run by the University of Brittany, EVEA and Ephese.

PART TWO:

THE ENVIRONMENTAL IMPACT OF BOAT'S OPERATIONS

Before considering the different possible impacts of nautical activities and practices on the marine environment, it is worth considering the current and future state of protection of the marine environment within the European Union (Chapter 1). A series of environmental impacts linked to the use and operations of recreational craft and private water craft will then be reviewed (Chapter 2). Finally, the coastal infrastructures built for recreational marine activity (marinas, harbours, boat storage and access to the water) will be reviewed (Chapter 3).

CHAPTER 1:
AN OVERVIEW OF EUROPEAN EFFORTS TO "BLUE" THE MARINE ENVIRONMENT

A. EU FRAMEWORK DIRECTIVES ON THE MARINE ENVIRONMENT AND WATER

In 2008, the EU adopted the directive 2008/56/EC establishing a framework for Community action in the field of marine environmental policy. The Marine Strategy Framework Directive requires Member States to take the necessary measures to achieve or maintain good environmental status in the marine environment by the year 2020 at the latest. For this purpose, the directive identifies 4 marine regions (Baltic Sea, North-East Atlantic Ocean, Mediterranean Sea and Black Sea) for which Member States have to develop a marine strategy.

A marine strategy is based on:
- An initial assessment of the current environmental status and the environmental impact of human activities, together with the determination of what a good environmental status for the waters concerned would be, to be completed by 2012;
- The establishment and implementation of a monitoring programme for ongoing assessment and regular updating of targets, by 2014;
- The development and entry into force of a programme of measures designed to achieve or maintain good environmental status by 2016 at latest.

This new legislation should bring significant improvement for the protection of the marine environment in Europe, although it will not produce its effects before some years. Looking at fresh water, the EU Water Framework Directive 2000/60/EC defines the European strategy on water quality and aims at maintaining a good environmental state of both inland and marine waters.

B. THE EXTENSION OF THE NATURA 2000 NETWORK TO SEA

In the nearer future, the EU will extend the network of protected areas under the Natura 2000 framework to sea and marine areas, which should considerably improve the marine environment protection in the short term. In May 2007, the European Commission launched a set of guidelines for the establishment of the Natura 2000 network in the marine environment and the application of the Habitats and Birds Directives at sea. The extension of the Natura 2000 network to the marine environment will be the main focus of the European Commission's work in the coming years, since the terrestrial component is now well-established.

Natura 2000 is an ecological network of protected areas in the territory of the European Union. In May 1992, governments of the European Union adopted legislation designed to protect the most seriously threatened habitats and species across Europe. This legislation is called the Habitats Directive[43] and complements the Birds Directive[44] adopted in 1979. These two Directives are the basis for the creation of the Natura 2000 network. The Birds and Habitats Directives respectively require the establishment of Special Protection Areas (SPAs) for birds and Special Areas of Conservation (SACs) to be designated for other species, and for habitats. Together, SPAs and SACs make up the Natura 2000 network of protected areas. The Natura 2000 network contributes to the "Emerald network" of Areas of Special Conservation Interest (ASCIs) set up under the Bern Convention on the conservation of European wildlife and natural habitats[45].

The marine component of the Natura 2000 network will be an integral component of the overall Natura 2000 ecological network in Europe. As for the terrestrial environment, the marine network will aim to protect sites of European conservation importance for natural habitat types and the habitats for the species listed in the Habitats Directive, in order to ensure that these features can be maintained or, where appropriate, restored at a favourable conservation status in their natural range.

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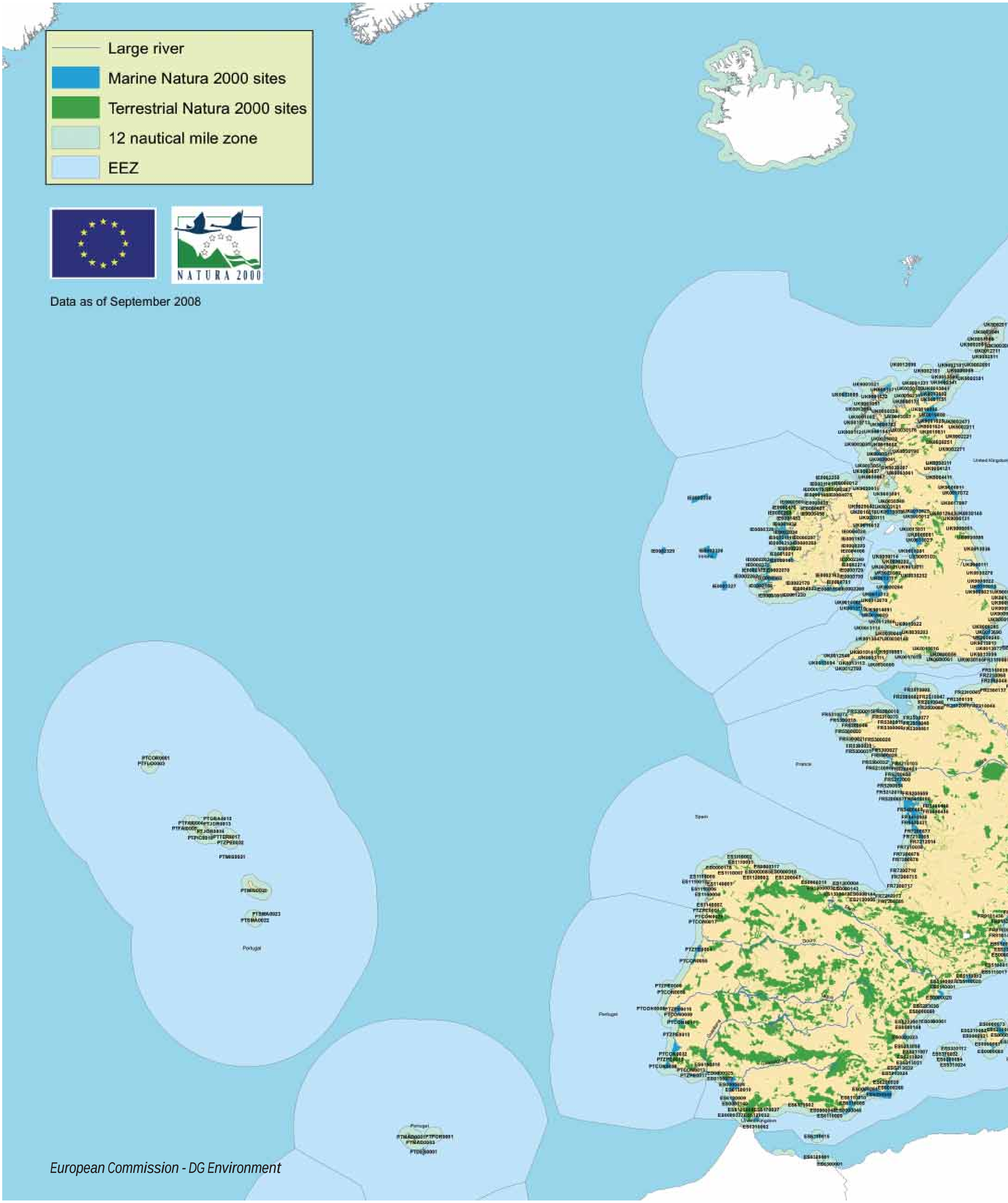
[43] EU Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora
[44] EU Council Directive 79/409/EEC on the conservation of wild birds
[45] Council of Europe - Bern (Switzerland), 19 September 1979

The Natura 2000 at sea network is likely to cover large portions of the European coastline, as the map illustrates. If Natura 2000 principles do not involve the prohibition of sea based activities, it requires management plans of human sea-based activities, which encompasses nautical activities. These plans would thus address the different impacts of nautical activities, such as noise and wave generation, mooring and landing of people, discharges at sea, with the objective of lowering them to a level which is not putting at stake the local marine environment.

The Natura 2000 network at sea, which is part of the EU marine strategy directive's activities, is therefore expected to become the most important regulatory system regarding the environmental impact of nautical activities. This development should be welcomed because, contrary to some national regulations which sometimes lack a scientific basis, Natura 2000 will address the environmental sensitivity of the marine environment and should propose adequate and proportionate measures to limit the sources of pollution and environmental deterioration.


Large river
Marine Natura 2000 sites
Terrestrial Natura 2000 sites
12 nautical mile zone
EEZ
NATURA 2000
Data as of September 2008
European Commission - DG Environment

CHAPTER 2:
CONSIDERING THE POSSIBLE ENVIRONMENTAL IMPACTS OF BOATING ACTIVITY

A typology of the possible environmental impacts
What sort of phenomena needs to be taken into account when studying the impact recreational boating and other water-based leisure activities might have? In order to assess the environmental impact of these activities, a series of phenomena linked to nautical activities should be considered:

- **Hydrocarbons releases and other oil residues** from recreational craft and private water craft engines;
- **Noise disturbances** from recreational engines;
- **Black water or sewage** to be collected on board and at port when necessary;
- **Grey water** from all onboard aqueous washings and operations;
- **Antifouling paints** during their use on hull boats for boat maintenance;
- **Garbage and other waste** generated onboard and to be disposed at the port;
- **Physical damage to the environment** such as bad anchorage or wave generation;
- **Depletion in fish stocks** from recreational fishing and angling;
- **Introduction of non-indigenous species** through long voyages.

The review of the various environmental impacts will show that the industry can efficiently limit some of them through technological improvements. Others are closely linked to the user's behaviour and will have to be addressed through measures and actions aimed at better informing the public. In such areas, recreational boaters and nautical activities' enthusiasts have a key personal role to play in minimising the environmental impact of their activities. However, it is the nautical industry's responsibility to provide them with environmental-friendly technologies and products. The industry is also responsible for raising awareness, regularly informing and contributing to the users' education for sustainable practice in boating and water sports. Further research and development is required in certain areas in order to provide the users with products and technologies which respect the environment.

The marine environment is sensitive to external influences and represents a multifaceted compound of air, water, fauna and flora which is vital for human welfare, health and climate. Several international organisations are acting to protect the quality of air and water. This table presents the complex network of interrelated international responsibilities and identifies the position of nautical activities among them.

Regulatory or supervisory organisation	Scope	Focus on:	Application to recreational craft:
International Maritime Organisation (IMO)[46]	Seagoing ships in national and international waters	Waste management & discharges, sulphur dioxide (SO_2) emissions, antifouling paint, nitrogen oxide (NO_x) emissions, transfer of organisms in ballast water, etc.	Depending on size and engine power, recreational craft may fall under IMO jurisdiction for certain aspects
European Union US Environmental Protection Agency	Commercial inland waterways and recreational craft	Engine exhaust and noise emissions (EU/US EPA) Waste reception facilities in ports (EU)	
Regionally: US CARB[47] Lake Constance in Europe as well as other lakes	Recreational boating and commercial transport	Europe: engine exhaust emissions and noise	Emphasis on recreational boating which is the most common activity and size of boat park

A. OIL & HYDROCARBON EMISSIONS

It is interesting to compare releases of oil and hydrocarbons from recreational boating with other sources of marine pollution, in order to ascertain the true proportion of these types of emissions. An analysis reveals that marine engines only account for a tiny proportion of overall hydrocarbon pollution.

1. GENERAL OVERVIEW OF SOURCES OF MARINE POLLUTION BY HYDROCARBONS

Pollution of the marine environment by oil and other hydrocarbons originates mainly from land-based sources. A report released in 1993[48] showed that **63% of marine hydrocarbons pollution comes from land-based activities, including via the atmosphere**.

The principal sources of oil pollution from land are:
- Vehicle motor oil
- Oily water runoff from roads
- Waste treatment sites
- Releases to the atmosphere

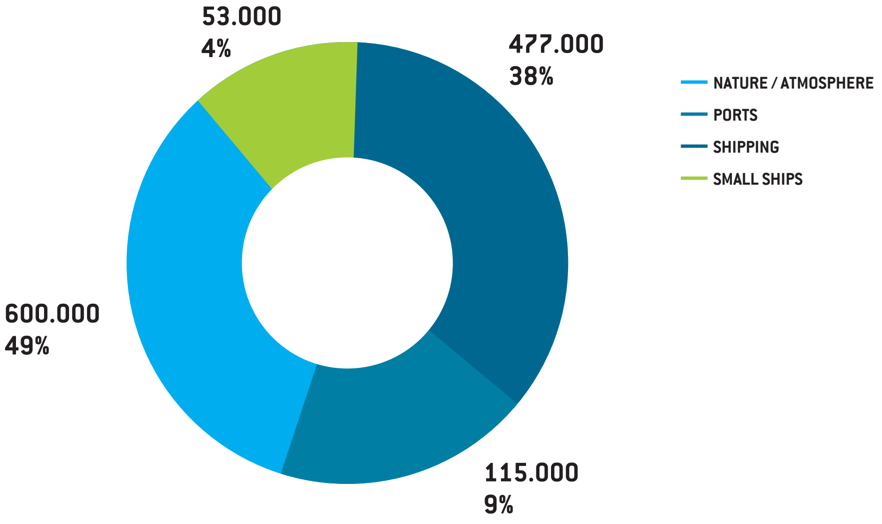
For example, in the course of a single year, runoff water alone from a city of five million inhabitants releases into the marine environment a quantity of oil equivalent to a large tanker's oil spill. Atmospheric emissions are another major route for oil input into the oceans.

Taken together, all maritime activities - including the transportation of hydrocarbons, oil spills and off-shore oil platforms - accounted for **26% of marine hydrocarbon pollution**. It is worth noting as well that 11% of oil releases in marine environment are related to **natural seismic phenomena**. In conclusion, like the other types of marine pollution, oil pollution mainly originates from land-based sources.

2. SOURCES OF MARITIME POLLUTION BY OIL AND HYDROCARBONS

After having considered all sources of oil marine pollution, a recent study by UNEP GESAMP for the International Maritime Organization (IMO) compared the sea-based sources of oil marine pollution, which represent 26% of total oil pollution.

[46] A major sector of IMO activities is the International Convention for the Prevention of Pollution from Ships (commonly referred to as MARPOL 73/78) adopted in 1973, and modified by the Protocol of 1978 relating thereto
[47] CARB - California Air Resources Board in the USA



"Maritime" sources of marine pollution by hydrocarbons in metric tonnes per year[49] (2004)

The biggest source of marine pollution by hydrocarbons is coming from **natural releases (49%)**. As explained previously, the phenomenon is partly observed in areas of high seismic activity, such as the Gulf of Mexico, the Mediterranean Sea and the coast of Alaska.

Maritime transport, including the transportation of hydrocarbons, port activities and off-shore operations account for **47% of pollution by hydrocarbons**. **"Small craft"[50]** under 24 metres of length, are responsible for **4% of sea-based oil pollution**. However, within the small craft category, it is difficult to distinguish recreational craft from small fishing boats or commercial vessels (used for the transport of goods and passengers).

Almost 65% of marine pollution by oil and other hydrocarbons comes from land-based and natural sources. Among the remaining quarter coming from maritime sources, almost 50% of the hydrocarbons releases are due to natural phenomena (seismic activity). Oil pollution caused by "small craft" as defined by IMO accounts for approximately 2% of total oil pollution, including land-based sources. The proportion of oil pollution caused by recreational craft should therefore be significantly lower than 2%.

3. POSSIBLE ENVIRONMENTAL IMPACT OF RECREATIONAL MARINE ENGINES[51]

There are various possible sources of marine hydrocarbon pollution associated with nautical activities and which need to be analyzed in view of their relevance to the practice of recreational boating. Those sources need to be considered and minimized, both by improving the boat and engine design, and improving the boat owner's and user's education:

- Use of marine engines (e.g. unnecessary idling, or running at full throttle)
- Fuelling (e.g. spilling of fuel)
- Poor operation and maintenance of marine engines (e.g. not following manufacturer's maintenance schedules)
- Legal oil discharges
- Engine oil
- Oily water discharge
- Tank washing

[48] UNEP GESAMP: Report *Oil pollution of the sea* (1993) - http://www.offshore-environment.com/oilpollution.html
[49] UNEP GESAMP: *Report and Studies n°75 - Estimates of Oil Entering the Marine Environment from Sea-based Activities*, IMO Marine Environment Protection Committee - 55th session (9th - 13th October 2006)
[50] In IMO-terms, *small craft* are vessels less than 24 metres in length, with less than 130kW engine power and less than 150 gross tons

Fuelling:
Oil and hydrocarbons may be unnecessarily and unintentionally discharged when boats are fuelled. The problem can be tackled by improving awareness and behaviour among recreational boaters, and by installing systems to prevent fuel flowing back through air vents. Systems of this kind are already available on the market, and others are in the development stage. They can prevent this type of pollution, and therefore their use should be widely promoted to recreational boaters, but also in other professions using small craft. For instance, fuelling stations could play an advisory role to users and raise their awareness about this issue.

Poorly operated or maintained marine engines:
This is another issue on which recreational boaters should be given more information and education, as there is a range of ways to properly maintain and operate a recreational marine engine. A regularly maintained and well operated engine will consume and pollute less. This is the reason why some supervisory bodies responsible for inland lake navigation ask for a regular service inspection of the boat and engine (e.g. every three years) to maintain the navigation licence of the boat[52].

Legal oil discharges:
Legal discharges of hydrocarbons at sea are permitted in small concentrations under international law. For example, oil discharges are allowed for vessels of under 400 gross tons, when the discharges' concentration is under **100 parts per million**, provided the vessel is sailing more than **12 miles off shore**[53]. It is estimated that **188,000 metric tonnes** of **hydrocarbons are discharged legally** by merchant shipping each year, more than **3.5 times the total amount of pollution generated by all "small craft"**[54].

Engine oils:
There are now a number of biodegradable synthetic engine oils available on the market. Furthermore, in decision 2005/360/EC, the European Commission recommended the adoption of an environmental label setting down ecological criteria and associated requirements for assessing and checking lubricants. These measures are due to be transposed into national laws in EU Member States by 2009.

Oily water discharge from recreational craft:
Oily water comes from two primary sources:
- Bilge water and
- Engine exhaust cooling water.

Bilge water is a chemically complex mixture of solvents, surface-active agents (surfactants, i.e. soap) and metal salts such as greases and lubricants. Some of these are bio-accumulative persistent organic pollutants (POPs). Others such as aromatic hydrocarbons (BTEX[55]) and oil, copper, iron, mercury, zinc and nickel, organic metal salts, detergents and solvents are aquatic toxins. **Engine exhaust cooling water** includes typical constituents of diesel engine exhaust such as various hydrocarbon combustion byproducts, measured as volatile and semi-volatile organic compounds (VOC). The primary pollutants expected to be present in the discharge, i.e. cooling water, include polycyclic aromatic hydrocarbons (PAHs), toluene, and possibly metals. Both these streams contain dispersed and dissolved hydrocarbons. Although this sounds awful, the actual impact is very low as the volumes involved are tiny. Only in areas of high boating activity is this likely to be an issue.

Despite the unpleasant nature of the chemicals contained within these waste water streams, oily water discharge can be addressed. Good practices from boat users in engine maintenance operations and bilge water cleaning, by using proper absorbents or a separation bilge pump absorbent and disposing the residues in the appropriate port reception facilities can totally neutralise this impact. Existing legislation and monitoring relates only to the dispersed fraction. New technology is likely to be developed over the next few years to strip the oil out of both bilge and engine cooling water but in the meantime the best method for tackling the problem is sensible operation of craft.

[51] Op. Cit. UNEP GESAMP Report and Studies n°75 - page 101
[52] This is the case for recreational navigation on Lake Constance in Europe
[53] MARPOL Convention 73/78 - Annex I, Rules 9 & 10
[54] Op. Cit. UNEP GESAMP Report and Studies n°75 - page 26
[55] BTEX : benzene, toluene, ethylbenzene and xylenes

4. RECREATIONAL MARINE ENGINE EMISSIONS

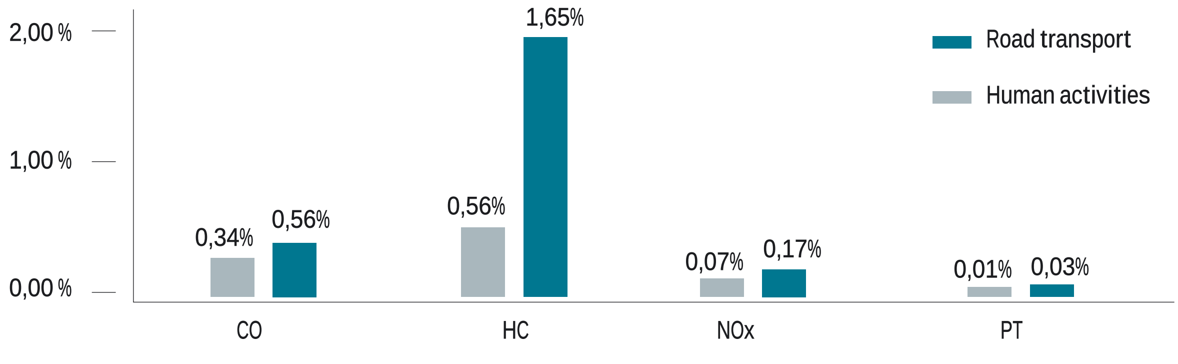
There are three main categories of marine engines to be considered in Europe:

Vessel operation	Engine & fuel type	Pollutants to be controlled	Regulatory agencies	Measures to be taken
Seagoing commercial	Diesel engine(CI) High sulphur and high viscosity	Sulphur oxides (SO_x) Nitrogen oxides (NO_x)	IMO European Union	Regional control of bunker fuel, NO_x-reduction by engine design, operational restrictions in sensitive areas
Inland waterway commercial	Diesel (CI) Non-road low sulphur quality	Predominantly nitrogen oxides (NO_x)	European Union	Engine design and operation, adopt future on-road fuel quality
Coastal and inland waterway recreational boating	**Diesel and petrol** **Fuels are typically road fuels or close equivalents**	**Hydrocarbons, particulates and NO_x**	**EU Recreational Craft Directive as amended**	**Engine design, operational restrictions in sensitive areas**

The predominant emissions from recreational marine engines are nitrogen oxides (NO_x) and hydrocarbons (HC), with small but measurable quantities of particulates (PT). The permissible levels of these pollutants are strictly controlled by the EU recreational craft directive[56] in Europe and both the emission rules adopted by both the Environmental Protection Agency (EPA) and the California Air Resources Board (CARB) in the United States. EU restrictions on emissions from outboard engines, which became fully effective in January 2007, are the strictest in the world. However, further legislation to reduce emission levels and driven by the political will to tackle climate change issues will be proposed in 2010 by the European Commission, and in 2008 by the US EPA. In both regions, the intention is to introduce best available technology at a fair price to the consumer. With the recreational marine industry being a truly international and global business, it was key that measures taken in Europe find a corresponding action in other regions of the world.

4.A) AIR QUALITY AND RECREATIONAL CRAFT MARINE ENGINES

In Europe, when the **EU Directive 2003/44/EC** amending emission levels of **EU Directive 94/25/EC** was adopted, the contribution to air pollution from recreational marine engines already accounted for a very small proportion of the total emissions from human activity and road transport.



Proportion of air emissions from recreational craft marine engines compared with all emissions from human activities (anthropogenic origin) and from European road transport (1995)[57]

Under the environmental regulatory standard, pollutants to be limited and controlled from engine exhaust are:
- CO = carbon monoxide
- HC = hydrocarbons, sometime more exactly called VOC - volatile organic compounds

[56] EU directive 2003/44/EC amending directive 94/25/EC
[57] TNO: *Stocktaking study on the current status and developments of technologies and regulations related to the environmental performance of recreational marine engines* (Delft, 10 January 2005), pages 17-18

- NO_x = nitrogen oxides
- PT (or PM) = particulate matter

Sulphur emissions are low and limited by the low sulphur content in fuel used by recreational marine engines. Proportionately the most significant emissions from recreational marine engines are hydrocarbons (HC) and these **represent 0.56% of total emissions caused by the human activities and 1.65% of road transport emissions**.

The implementation of the revised emission limits in Europe is already having a **significant long term positive impact** on emissions to air from recreational marine engines. Once the current stock of engines is replaced by engines complying with the regulation in force (what takes between 10 and 15 years), the following changes in emissions are anticipated[58]:

- NOx	+20% (because of engine optimization toward a minimum of the total NO_x plus HC)
- Particulates	No change (since it is not regulated by the directive)
- CO	- 30%
- HC	-77%

These regulations came into force fully on 1st January 2007[59] and emission reduction will be a long term process based on the replacement of existing engines by newer and cleaner ones. It is anticipated that the relative contribution of recreational marine engines to atmospheric pollution will remain the same during this period[60]. Since 2007, the new EU emission limits have brought a significant change in the market for marine petrol engines. All carburetted 2 stroke engines were withdrawn from sale and those 2 stroke engines which do remain on the market are all direct injection. Hydrocarbon emissions from 4 stroke engines were reduced substantially but there is a direct trade off with NOx emissions which have risen slightly as a result. Overall the combined burden of NOx and HC will reduce by over 60%.

In 2008, the European Commission published the conclusions of a complementary study[61] to investigate the most stringent but feasible scenario to limit recreational craft exhaust emission to a further Stage 2. An amending proposal to the recreational directive is expected to be adopted by the European Commission by the end of 2010, leading to more stringent emission limits. In 2008, the US EPA published new regulations for marine diesel engines[62] and for petrol engines used on boats and personal watercraft[63]. From a technical point of view, these new regulations will require in many cases the installation of exhaust gas after treatment systems.

Emissions of pollutants into air from recreational marine engines are minor in Europe, compared to other sources of air pollution. Recreational craft emissions represent 0.56% of total emissions due to human activities and 1.65% of road transport emissions. The emission levels are further reduced by continuous technological improvements and new legal restrictions. The emission reductions in force since January 2007 (also referred to as Stage 1) will result in a 60% reduction in hydrocarbon (HC) plus nitrogen oxides (NO_x) emissions from boats in Europe compared to the non-regulated boats operating in the EU (e.g. small fishing and commercial vessels). With the proposal for further reductions to be presented by the European Commission in 2010 (so-called Stage 2 emission level), the reduction of recreational marine engine emissions will be dramatically reduced. This will represent a further reduction of the local environmental impact of nautical activities in areas where a high boat population is concentrated. The Stage 2 emission level will represent an additional reduction by 25% compared to Stage 1 for the most relevant pollutants (HC+NO_x and PT).[64]

[58] European Confederation of Nautical Industries - ECNI: *First interim report, Study on the feasibility nad impact of possible scenarios for further emission reduction measures for recreational craft engines in the context of Directive 94/25/EC, as amended by Directive 2003/44/EC* (European Commission under contract ETD/SI2.424729, 3 July 2006), page 144
[59] Introduced by EU directive 2003/44/EC amending directive 94/25/EC
[60] IFEU Institute Heidelberg on the TREMOD-Model : U. Lambrecht et al. - *Development of a calculation model for air pollutant emissions and fuel consumption of combustion engines in mobile equipment and machinery*, www.ifeu.org
[61] Arcadis - S. Bogaert, L. De Smet, S. Vermoote, A. VanHyfte: *Complementary Impact Assessment Study on possible Emission Reduction Measures for Recreational Marine Craft engines* (Gent, July 2008)
[62] US EPA *Final Rule: Control of Emissions of Air Pollution from Locomotives and Marine Compression-Ignition Engines Less Than 30 Liters per Cylinder* (published 6 May 2008)
[63] US EPA *Final Rule: Control of Emissions from Nonroad Spark-Ignition Engines and Equipment* (published 8 October 2008)
[64] All EU and US regulations apply to new engines. Therefore, measures reducing emission levels only take their full effect once the existing boat engine park is renewed, by 2030 at latest.

4.B) WATER QUALITY AND RECREATIONAL CRAFT ENGINES

Within the framework of a study[65] initiated by the German Environmental Protection Agency (UBA - Umweltbundesamt), various tests were carried out locally to study the impact of 2-stroke and 4-stroke **recreational craft engines on water quality**. In this study, the main substances taken into account were benzene, toluene, ethylbenzene, xylene and naphthalene, which are regulated under EU water quality legislation. There are two sets of EU regulations which are relevant: the exhaust gas emissions from boat engines[66] and water quality regulations[67]. For the purpose of the study, a research model was carried out on a small lake, in which the water is renewed relatively infrequently[68].

The results obtained showed that even prior to the application of **Directive 2003/44/EC on recreational craft**, the content of pollutants in water was about a factor of 10 lower than the limits on drinking water quality standards after the operation of recreational craft engines. Moreover, the limits continued to be met even under the circumstance of intense activity on the lake. The experimental findings of the UBA Study were carefully compared with several relevant international measuring campaigns, even on natural waters, and are fully consistent with the results from a TNO Study. It is most important to underline that hydrocarbons released into water are released to the ambient air over night and do not remain in the water[69]. It should also be mentioned that all studies took into consideration a number of different types of hydrocarbon, with special attention given to benzene as the substance with the highest impact for human health.

In conclusion, the UBA Study says "(E) it can be stated that the exhaust gas emission of the recreational craft drives looked at can be reduced substantially through improved technology. This reduction would primarily benefit an improvement in air quality, as the assessment of pollutant discharge into the water has shown that the current situation is already to be classed as tending towards uncritical."

Characteristics of lake water vary greatly and it is important to take into consideration possible pollution resulting from past and current activities (e.g. agriculture, industrial activities), related rivers or surrounding land. A new study on artificial, man-made landscapes and waters[70] considered the influence of recreational motor boating on a new recreational area developed nearby the city of Leipzig (Germany) by flooding the open pit lignite mines. Detailed scientific limnologic analyses support the future touristic and recreational use of such lakes in an environmentally-friendly manner. However, several conditions need to be observed to preserve the flora and fauna: diesel engines are the preferred propulsion mean for boats, 2-stroke engines should only be with direct injection, and the total population of motor boats should preferably be limited to an average of one boat per two hectares. The monitoring of water quality would guarantee that motorboating activities do not harm the environment.

The various research and studies carried so far show that under EU regulations, there is no risk of water pollution, especially of drinking water, or threats from recreational marine engines to the flora and fauna, even where the boating activity is intense. This is convincingly confirmed by the example that the water supply system of Lake Constance which provides drinking water to 4 million people comes directly from the lake without chemical processing[71].

[65] RWTUV (renamed into TUV NORD) / Fahrzeug GmbH - M. Horn, H. Steven, U. Haberkorn, L.E. Schulte: *Pollutant and noise emission for motorboats - basis for updating the EU Directive 94/25/EC for limiting the emissions of motorboats* (Essen, July 2005)

[66] As specified by EU Directive 2003/44/EC

[67] As regulated by EU Directives 76/464/EEC and 98/83/EC, the latter specifically reducing the limit for benzene

[68] A "small lake" is a lake of about 1 to 7 square kilometres of surface and 1.5 to 2.3 metres in depth. It is worthwhile to note that the UBA Study did run the calculations for very extreme conditions, i.e. for a 0.5 square kilometre surface with 75 boats for 2 hours a day.

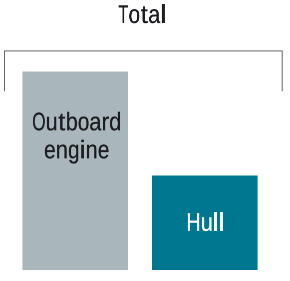
[69] It is worthwhile referring also to a measurement campaign on a river in Japan. A significant conclusion reads "(...) concentration of benzene gets temporarily higher than other compounds, but it lowered as the PWCs (personal water craft) ceased running in the area, and on the following day, the concentration has been reduced to the level observed prior to the PWC operation".

[70] K.P. Lange: *Concept of the sustainable use of lakes from former open pit mining in the region of Leipzig - Use of motorboats* (Conference in Leipzig, 10 October 2008)

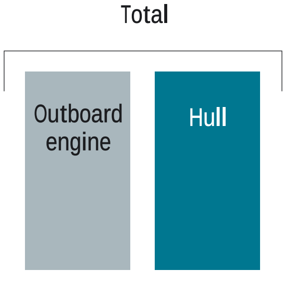
[71] Bodensee-Wasserversorgung (BWV) on www.zvbwv.de

B. ASSESSMENT & NOISE MANAGEMENT FROM RECREATIONAL CRAFT

Detailed studies carried out during the R&D *SoundBoat* project[72] demonstrated that approximately 50% of the external noise from a power boat is as a result of hull noise rather than mechanical or exhaust noise from the engine. Reducing the noise generated by the engine would only partially reduce the overall noise level produced by the recreational craft, since the "hull effect" could only be reduced through innovative design and materials. Today, boatbuilders and engine manufacturers are investing in R&D projects on noise reduction. New products clearly reflect this trend.



Origin of noise generated for 6 kW



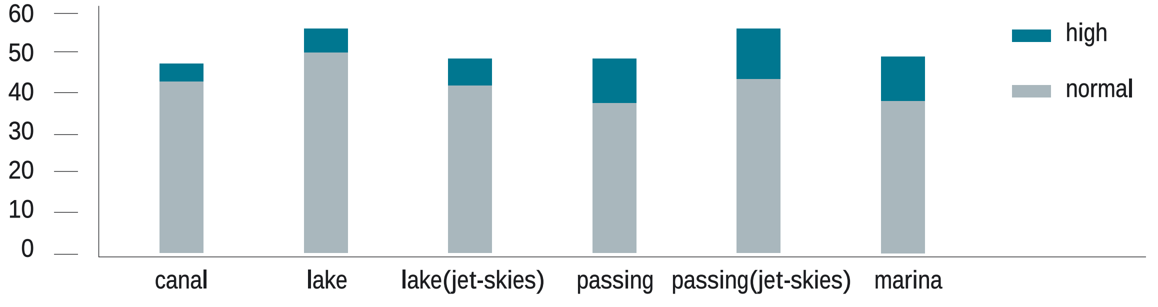
Origin of noise generated for 60 kW

It is also important to distinguish between sounds emitted above the surface of the water, and underwater sounds produced by hull, propellers and exhausts. To date very little work has been carried out on underwater noise, the focus having been on noise which is likely to cause a human nuisance. **EU Directive 2002/49/EC** relating to the assessment and management of the impact of noise on the environment and on humans introduced the **Lden** (Level day-evening-night) as the unit of noise measurement.

TNO Automotive in their study[73] summarized the findings resulting from a comprehensive number of tests and measurements. It established that the current noise levels generated by recreational craft are acceptable near **residential and leisure zones**. Generally speaking, they are well below the maximum limits permitted under the EU Directive 2002/49/EC. On the other hand, the same study showed that the noise levels generated by recreational craft and other motorized watercraft are, in most cases, too high for **natural parks and protected areas**. Again, regulations should be developed according to the local circumstances in order to properly protect animal life in these sensitive areas.

Zone	Lden limit in dB
Residential zone	55
Leisure zone	40-60
Natural park or protected zone	30-40

Noise levels generated by recreational craft and other motorized watercraft during normal activity and high season[74]



[72] Project of the European Commission's 6th Framework Programme - Contract G3ST-CT-2002-50364
[73] Op. Cit. TNO *Stocktaking Study* (2005)
[74] Op. Cit. TNO Report - *Stocktaking study* (2005)

It appears that in most cases, the noise levels generated by **jet skis and other high-speed craft** are no higher than those produced by the passage of other recreational craft. It is **the way such watercraft are used and their user's behaviour** which can be a nuisance, e.g. accelerating, running in tight circles and jumping close to sensitive areas such as beaches.

However, the progress made in this area by marine engine manufacturers should be acknowledged. In the United States, the noise levels produced by motorised watercraft have been reduced by **70% since 1998**[75]. In Europe **they have been limited since 1994** by **Directive 94/25/EC as amended by Directive 2003/44/EC**. A point to note is that all personal watercraft manufactured today in Europe strictly comply with the EU noise limit legislation but the compliance testing method cannot take into account the multiple ways in which they are used in practice. This means that in use, as explained previously, personal watercraft may sometimes exceed the EU noise limits.

The impact of noise on the ecosystem and in particular on animal life (fish, marine mammals, birds) is not well known and there are few statistics available on the subject[76]. In the United States, research is currently led by an agency of the National Oceanic and Atmospheric Administration. Protection of fauna from noise disturbances could be achieved by limiting access and speed within specific areas which were identified as environmentally sensitive. **Speed limits** can help in reducing wash which is liable to damage fragile banks and shorelines, particularly on inland waterways, although the new generation boats specifically designed for wake boarding create very high wash at low speed. Speed limits can be effective at reducing noise levels near sensitive zones, but they also increase the time it takes for motorized craft to pass by. **It is therefore important to strike the right balance between sound levels and the time taken for craft to pass by**, depending on the nature and degree of sensitivity of the zones concerned: beaches, canals located near housing, protected natural areas.

On board noise

Commercial and recreational motor boats continue to deliver better performance and higher levels of comfort and convenience. Generally this means using bigger diesel engines as the prime movers and fitting larger diesel generators to power auxiliary equipment. In parallel with this need for greater power, there is a clear understanding that such developments must not mean more environmental noise, whether that is occupational noise levels on board, nuisance noise above the water or unacceptable environmental disturbance below the water.

Looking at safety at work, many larger craft have employed crew. Maximum noise exposure levels in the work place are governed by EU directive 2003/10/EC. The directive's entry into force was 15 February 2006, with an additional period of 5 years provided for the application to the personnel on board sea going vessels. The directive will therefore fully apply to crews as from 15 February 2011.

The directive requires that, taking into account technical progress and the measures available to control the risk at source, the risks arising from exposure to noise shall be eliminated at their source or reduced to a minimum. For older vessels, management of access to noisy spaces and the use of ear protection are likely to be the favoured response. But the nautical industry has to tackle the noise problem at source for new built craft.

It has been shown that recreational craft do not generate noise levels likely to be a nuisance in residential or leisure zones. However, it is more likely to be the case when operating in natural parks or environmentally sensitive areas. Legislation has driven noise levels down by 70% and technological advances are likely to reduce mechanical noise still further. Hull noise is more difficult to control and this would need to be taken into account if further reductions were contemplated. In most case, it is the utilisation of the craft which affects the noise level. As a general rule, it is thus vital for users to be informed - notably via pictograms on marine maps and in situ - about the correct behaviours to adopt in sensitive zones and protected area such as Natura 2000, where the fauna may be affected by certain types of noise. This would include appropriate speed limits, minimised access of motorised craft, anchoring regulations, specific measures on disembarking of persons, animal feedings, prohibition of waste water released and other.

[75] NMMA White Paper "Marine Mammals & Ocean Noise: Implications for Recreational Boating" (January 14, 2005)
[76] The study *Ocean Noise and Marine Mammals* by the Oceans Studies Board of the National Research Council (NRC) states that "the effect of anthropogenic noise on marine mammals is one of the least understood subjects in marine science" (2003)

C. WASTE WATER FROM RECREATIONAL CRAFT

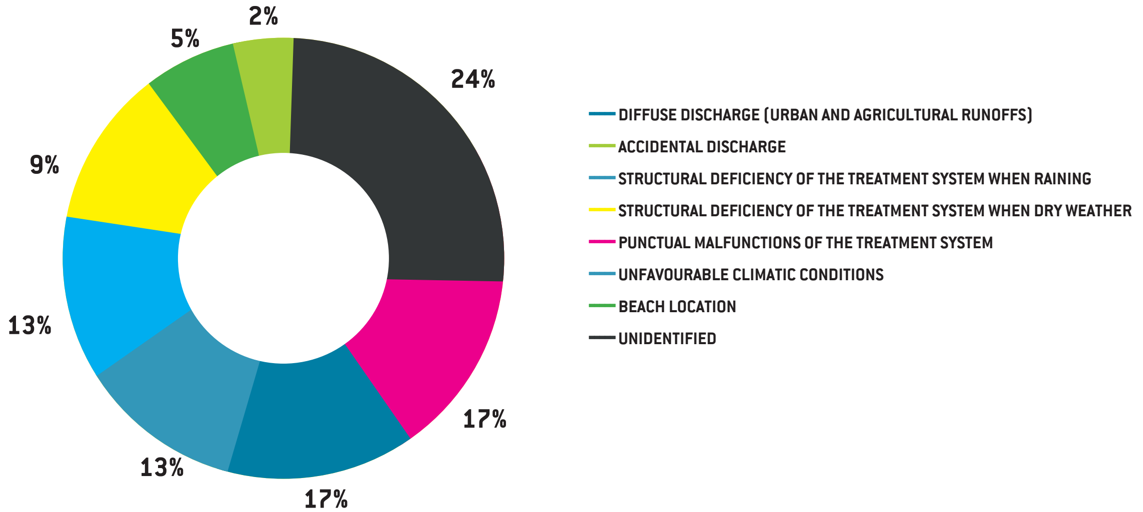
Under Annex IV of the IMO MARPOL 73/78 Convention, international legislation regulates the discharge of black water from craft over 400 tonnes or carrying over 15 passengers, and involved in international voyages. Thus, this regulation only applies to larger recreational craft. The EU directive on port reception facilities 2000/59/EC aims at reducing the discharges of ship-generated waste and cargo residue into the sea. However, the level of implementation by the ports varies significantly from a Member State to another, and some detailed guidelines would clearly help for the uniform implementation of the legislation[77].

1. DISCHARGE OF SEWAGE FROM RECREATIONAL CRAFT

Sewage (or black water) can pose the following environmental problems, when large quantities are discharged:
- **It contains suspended solids** and causes discolouration of water, reducing the amount of light that penetrates below the surface, which is a "visual" pollution,
- **It may cause eutrophication** by introducing nutrients into the water which then stimulate the growth of algae, which is an environmental problem;
- **It will reduce the amount of oxygen in the water**. Where water volumes are limited, this can cause stagnation and the development of anaerobic bacteria leading to the production of unpleasant smells and gases;
- **It may introduce pathogenic micro-organisms into the water**, which can pass on disease to humans and which constitutes a health problem.

Firstly, the **"visual"** pollution caused by water coloration and suspended solids may be annoying in areas with large numbers of craft and where water is only renewed slowly, such as inland waterways, ports and anchorages with a narrow tidal range.

The phenomenon of **eutrophication** from sewage produced by recreational craft is minor other than in enclosed areas of water. Other sources such as **agricultural run off water containing fertilisers** have far greater impact and can cause dramatic events such the **"green tides"**. Other land-based discharges are also responsible for eutrophication, either being discharged directly into the sea, or through runoff water in ports. **De-oxygenation** can be resolved by ensuring dilution of the raw sewage with well oxygenated water. At sea or in fast flowing estuarine waters this is not an issue but the oxygen demand of sewage in enclosed waters can cause damage to marine species and unpleasant side effects such as smell and gassing. Finally, the **potential existence of pathogenic micro-organisms** in sewage can raise health issues. In the past, the French Higher Council of Recreational Sailing and Water Sports concluded in its report[78] "*Objectif rejet Zéro*" (Target: Zero Emission) that the studies carried out to date failed to establish a correlation between the presence of recreational craft and bacteriological pollution from sewage. This is consistent with the rule of thumb that sewage is neutralised naturally in open water within about 20 minutes of being discharged. Moreover, it showed that urban or industrial emissions, treatment stations, agricultural emissions and runoff water are generally responsible for deterioration in the quality of the water along beaches.



Sources of bathing waters pollution during the 2006 season in France[79]

[77] Carl Bro a/s for NGO Seas at Risk, commissioned by the European Commission: *Study on the Availability and Use of Port Reception Facilities for Ship-Generated Waste* (December 2005)
[78] Higher Council of Recreational Sailing and Water Sports (France): *Rapport Objectif : rejet zéro* (Target: Zero Emissions Report), page 20 (1992)
[79] French Ministry of Health, Youth and Sports - Ministère de la santé, de la jeunesse et des sports: *Etat sanitaire des eaux de baignade en mer et en eau douce - Bilan de la saison balnéaire 2006* (France, July 2007)

The report by the French Ministry of Health, Youth and Sports for the season 2006 confirmed that pollution from recreational craft affecting the water quality is comprised in the 2% accidental discharge. Accidental discharge encompasses accidental releases from industries, agriculture, camping sites, caravanning, and leisure boating.

In Europe, the recreational craft directive[80] is the principal means of regulating the design, construction and standards of recreational craft up to 24m in length. Under this directive, there is no restriction on the discharge of used water and it is simply required that boats are capable of being fitted with a holding tank to store sewage. Some, but by no means all, recreational craft are fitted with sewage holding tanks or on-board water treatment systems. Typically such tanks are of limited capacity and are discharged at sea or, less frequently, pumped out to shoreside treatment facilities using a pump installed in the marina.

In fact, sewage discharge prohibition is imposed in ports and in sensitive areas, allowing the boats users to **discharge at least 1 mile from shore**, taking a few speed and release precautions. Regulations on sewage discharge would need taking into consideration three key criteria: the water renewal, the concentration of recreational craft, and the degree of sensitivity of the ecosystem to be protected. In order for regulations to work effectively and to ensure an effective protection of the environment, measures should be based on these three criteria and restricted to particular areas and certain times of the year.

Faced with the problem of sewage discharge from recreational craft and the lack of an effective response at EU level, regional, national or local controls are being implemented on an ad hoc basis. Such developments create a more and more fragmented legal framework in Europe and fail to tackle the issue in a uniform manner for all European waters. In the Baltic Sea, the Helsinki Commission has forbidden the discharge of any waste from ships and boats since the 1990s. Certain countries like Spain and France[81] adopted national legislation in order to tackle the issue. In other countries, measures are sometimes taken locally to prevent such discharges. The review of the EU recreational craft directive which will be launched in 2009 should be an opportunity to introduce Europe-wide a more stringent requirement to prevent pollution from sewage.

It is observed today that under the effect of regulations or voluntary initiatives, more and more recreational craft are equipped with holding tanks. These systems require pumping stations to be installed in ports and marinas, a cumbersome and costly process. They also require the boat's user to exercise considerable discipline when using cleaning and other products on-board. Consequently, the recreational marine industry decided to promote alternatives to containment tanks. **On-board sewage treatment systems** are currently being developed for use on smaller recreational craft. This solution frees the boat from dependence on pumping stations, and avoids the unpleasant aspects of storage systems.

In most case, sewage discharged from recreational craft is not a significant environmental issue. A study by the French Ministry of Health[82] showed that some 80% of the water pollution from sewage originates from land, with an significant source being inadequate inland water treatment plans. Pollution from pleasure craft affecting the water quality is below 2% and classified as accidental runoffs, together with camping and caravanning. Discharge regulations should be considered when it is necessary to protect a sensitive environment and where there are high concentrations of boats and limited water flow. The development of on-board black water management methods, such as treatment systems, should be promoted where possible. Harmonised but limited restrictions are seen as the best way to guarantee that recreational boaters use these kinds of systems, and therefore that the environment is properly respected.

80 EU Directive 94/25/EC as amended by EU Directive 2003/44/EC

81 Cf. Article 43 of French law n°2006-1772 dated 30 December 2006 which requires all recreational craft fitted with toilets and built after 1st January 2008 be equipped with holding tanks or on-board water treatment systems in order to access coastal and inland marinas and harbours, as well as mooring areas.

82 Op. Cit. French Ministry of Health: *Annual report on the quality of bathing waters (2006)*

2. GREY WATER FROM RECREATIONAL CRAFT

As for sewage, grey waters mainly originate from land. Grey water from aqueous washings carried out onboard are likely to contain a mixture of salts, fats, but most of all chemical active agents from detergents. In fact, land-based water treatment plants are not yet capable of treating the chemical agents contained in detergents. Therefore, all those chemicals which are rarely biodegradable and even bio-accumulative, coming from our daily showers, washing machines or dish washings, are released into the environment, into rivers, and as a final destination, into the sea. It is estimated that **90% of pollution in the Mediterranean Sea and along its coastline is due to land-based chemical pollution.**

On board, grey water is generated by three different types of detergents and other products used onboard:
- Domestic detergents for the household washings,
- Hygiene products, such as shampoo or shower gel,
- Boat specific detergents and maintenance products.

There are no specific regulations addressing grey water discharges at sea. Broad regulations on water quality such as the EU Water Framework Directive 2000/60/CE could be relevant in controlling such discharges. Generally, grey water is discharged directly overboard with no treatment. This results in evident pollution of the surrounding water visible as clouding and surface foam.

A holding tank for grey water may also be fitted on board. Although, this will not resolve the issue of chemical pollution, if the grey water is transferred afterwards to an inland treatment plant it will ultimately be released into the sea. It would only avoid a release in case of local high boat concentration.

Boaters who are willing to protect the environment may find an easy solution: there are now household and boat cleaning products available on the market which are **100% biodegradable within 28 days and which are based on natural agents, either vegetal or mineral**. The criterion of boat concentration is the key element as biological breakdown requires oxygen from the surrounding water. Such recommendations go beyond the current requirements in Europe. The EU Regulation 648/2004 on detergents only requires 80% of primary biodegradation, while fully biodegradable and ecological products are available today on the market. The use of environmental-friendly detergents and products which are fully biodegradable is thus indispensable, on board, as at home.

Chemical pollution which can potentially be attributed to emissions of grey water from recreational craft is mainly caused by the surface-active agents present in cleaning products and detergents. However, 90% of chemical pollution of the marine environment as a whole is, like any other type of marine pollution, due to land-based sources.On board and in ports, the solution is fairly easy. Recreational craft users should use biodegradable cleaning products and toiletries, which possibly are 100% biodegradable within a short period of time and natural. Labels on products should be carefully read. Nautical professionals have a key role to play in informing and directing recreational boaters towards more environmental-friendly products.

D. ANTIFOULING PAINTS FROM RECREATIONAL CRAFT

Nowadays, the EU directive 76/769/EEC prohibits the use of tributyltin (TBT) in paints on ship below 24 metres in length. The IMO 2001 Convention on antifouling paints prohibits its use on all ships, but it has not come into force due to the lack of ratification. Therefore, nearly **60% of the international commercial fleet is still using TBT-based antifouling paints**. In the nautical world, TBT has been replaced in antifouling paints by copper and biocides, which are much less harmful to the marine environment. However, TBT is still to be found in ports sediments, affecting dredging operations as other toxic substances.

Active elements in antifouling paints are mainly:
- **Herbicides** developed by the chemical industry for agriculture, road infrastructures and building ; for these applications, they are directly expanded on the ground and on materials,
- **Copper oxide**, which is the biocide commonly used in antifouling paints.

These biocides are slowly released along the boat hull by degradation of the resin. Copper oxide is to be found in a natural form within the environment and is even necessary to life. Its bactericide properties are used in pharmacology as well as in agriculture. However, with high levels of concentration, it becomes poisonous for the environment.

Within the framework of **EU Directive 1998/8/EC on biocides**, European Member States established a positive list of authorised biocide substances. The adoption of the **REACH system[83] for chemical substances** under the supervision of a newly founded European Chemicals Agency (ECHA) aims at consistently modernising the European framework for the control of chemical substances. It is a unique system of registration, evaluation and authorisation of chemicals. Manufacturers but also users of chemical substances (e.g. paint manufacturers) have to observe the REACH provisions. Those two major pieces of legislation are significantly modifying the composition of antifouling paints used in the nautical sector. These products are evolving towards much harmless active substances.

On the industry side, producers of antifouling paints have a **major area for R&D activities**: the development of a totally biodegradable resin, which would allow a boat to maintain its speed and manoeuvre capacities during at least a year. New types of antifouling paints are therefore considered such as fluoropolyurethanes, silicones, hydrogels, enzymes or ultras sons.

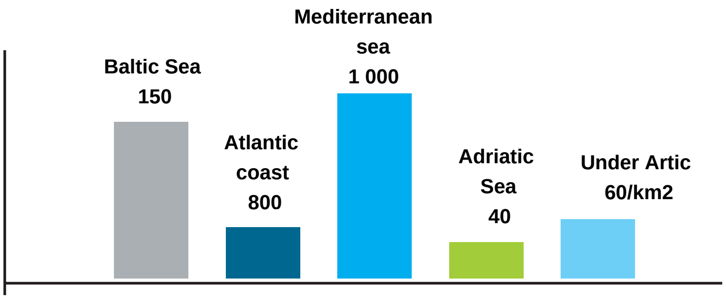
Within the European nautical community, boatbuilders, boat owners and service professionals are aware of the need of using non-damaging paints. On Lake Constance, a voluntary list of appropriate products that should be used by the boating community is prepared by IWGB[84] based on a list prepared by the Swiss Federal Office for Environment, Forests and Landscape. Looking at the operations for **paint maintenance**, it is important to note that the paint residues should be collected and appropriately disposed of - a preventive measure which is often forgotten by boaters when applying themselves the antifouling paints. One could only recommend that paint maintenance operations be performed by professionals who are adequately equipped.

[83] REACH stands for Registration, Evaluation, Authorisation and Restriction of Chemicals. The system was introduced by the EU Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)
[84] IWGB - Internationale Wassersportgemeinschaft Bodensee is the International Society for Watersports on Lake Constance

E. GARBAGE PRODUCTION AND OTHER WASTE

The pollution of the sea from garbage is a critical problem, especially regarding plastic waste. The sources of this pollution are not well known, but the quantities of waste involved show that once again, they mainly originate from land and commercial vessels, including cruise ships.

Plastic and especially plastic packaging is the most common type of waste[85]:



This situation is a cause of concern due to the slow degradation of plastic into small particles capable of poisoning the environment, as well as the physical damage to the fauna, via ingestion and trapping.

	Number of endangered species	
Number of existing species	Ingestion	Trapping
7 marines turtles	6 (86%)	6 (86%)
312 birds species	111 (36%)	51 (16%)
115 marine mammals	26 (23%)	32 (28%)
More than 1 000 fish species	33	34

86

Most of the waste produced on board a recreational craft is similar to the household waste found in any home. It is the user's responsibility to dispose of such waste responsibly on land, preferably after having first sorted it. Recreational boat users also create other types of waste such as batteries, redundant electronics and waste engine oil. Once again, they should be aware of the need to dispose of them appropriately. Finally, marinas and ports have the obligation to provide appropriate reception facilities for handling sorted waste[87].

These legal obligations are also imposed on both boat users and port by the Annex V of the IMO MARPOL 73/78 Convention. The text mentions that **in all "special zone"**, such as the Mediterranean Sea, it is prohibited to discharge at sea any plastic and any other type of waste. Food and organic waste discharged are allowed at more than 12 miles from the coast. **In all other zones,** it is prohibited to discharge at sea any plastic object, food and organic waste, metal, paper, glass, within the 12 miles zone from the coastline, and any floating waste, within the 25 miles zone from the coastline.

These regulations are the international rules applicable to commercial vessels. National rules can be more stringent. These are minimum rules that all boat users should know and observe. But boat users should also go further by applying the **3R principle:** reducing, reusing and recycling waste. Boat users should be encouraged to sort the waste onboard and marinas should provide them with separated waste reception facilities for recycling at shore.

[85] Observatory of waste in aquatic environment / Observatoire des déchets en milieu aquatique - ODEMA run by the Association MerTerre (France) on www.mer-terre.org
[86] Op. Cit. ODEMA activities
[87] EU Directive 2000/59/EC on port reception facilities for ship-generated waste and cargo residues

F. TIME-EXPIRED PYROTECHNICS

Despite the fact that there is no EU legislative framework requiring recreational craft to do so, the majority of recreational boats in the EU which venture more than a few kilometres from the coast will carry pyrotechnics of some sort. Most of these are for distress signalling although some (white flares for example) may be used simply to alert other mariners. Marine distress devices include rocket based parachute flares, hand held flares, smoke generators, line throwing devices and man overboard markers. All contain volatile, highly flammable materials and the projectile devices carry potentially explosive substances.

Due to the inherently unstable nature of the chemicals and the challenging environment in which they are stored and used, marine pyrotechnics have a relatively short shelf life of typically 36 to 48 months. After this date they cannot be used and must be disposed of in an environmentally acceptable manner. In most countries it is a criminal offence to discharge a distress flare other than to signal a genuine distress. Some countries tolerate their discharge for training purposes after notification to the appropriate authorities but this still leaves large volumes of pyrotechnics across the EU to be destroyed annually. Commercial vessels arrange for the periodic collection and destruction of their pyrotechnics by an authorised disposal agent but it is more difficult for the leisure user.

Arrangements for collection, transportation and destruction of time-expired pyrotechnics (also referred to as TEP) vary widely across the EU territory, from no arrangements in some countries (UK for example), through to the establishment of formal collection points in others (The Netherlands and Spain). The picture is further complicated by the fact that flares are classified as explosives and their transportation is governed by the EU directive on the transport of dangerous goods by road[88]. Some countries, such as Ireland, have a derogation[89] for small quantities of marine pyrotechnics being transported to a site for destruction. All other EU countries require specialised vehicles and containers for transportation; since time-expired pyrotechnics may not be sent by mail or courier. At present, there is no satisfactory EU wide system for pyrotechnic disposal.

G. PHYSICAL DAMAGE TO THE ENVIRONMENT & DEPLETION IN FISH STOCKS

Recreational boating and other nautical activities do not normally cause physical damage to the aquatic environment. Anchorages and wash could be of concern, as well as the presence of people in sensitive habitats. These are the type of environmental concerns which are addressed by the Natura 2000 network at sea in the framework of marine protected areas (MPAs).

Anchorages in areas where the seabed is sensitive, such as sea grass fields and reefs, can cause problems. The local authorities responsible for anchorages in these areas must provide sufficient buoys to guide visitors and prevent anchoring in sensitive areas. Such buoys need to be moored in a manner which avoids bottom scour possibly by means of elastic rather than chain based moorings. Additionally, **excessive wash** from recreational craft and private watercraft can cause erosion of the banks of inland waterways and lakes. This is normally controlled and reduced by imposing speed limits in sensitive areas, although this is not effective for wakeboarding boats.

Initiatives are in place to raise awareness among recreational fishing enthusiasts about the way their activity may affect **fish stocks**. These are mostly information campaigns, such as financing small items of measuring equipment which are distributed free of charge in order to gauge the size of catches and avoid juvenile fish catches.

[88] EU Council Directive 94/55/EC on the approximation of the laws of the Member States with regard to the transport of dangerous goods by road

However, it is important to add that the main threats come from overexploitation and illegal, unregulated and unreported (IUU) commercial fishing. **Over 75% of the fishing resource is currently depleted.** There is a major problem of enforcement of EU regulations[90] by technical and national agreements and measures. It is worth noting that the conclusions of a recent study commissioned by the European Commission on marine recreational fisheries consider that these activities have a negligible environmental impact, except in those situations where "commercial" gear (usually static nets or pots) is used to catch fish or crustaceans for household use. The study adds that there may, however, be considerable impact on the quality of recreational fishing due to decreased production of target species[91]. Our intention here is to put recreational fishing in proper perspective to commercial fishing roles in fish stocks depletion.

Recreational boaters and marine enthusiasts have a key personal role to play in minimising the environmental impact of their activities. However, it is the nautical industry's responsibility to provide them with environmental-friendly technologies and products. The industry is also responsible for raising awareness, regularly informing and contributing to the users' education for a sustainable practice of boating and water sports. Further research and development is required in certain areas (waste water management in particular) in order to provide the users with products and technologies which respect the environment.

[89] EU Commission Decision n°2005/263/EC authorising Member States to adopt certain derogations pursuant to directive 94/55/EC with regard to the transport of dangerous goods by road

[90] EU Council Regulation (EC) 2371/2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policies

[91] M. G. Pawson, D. Tingley, G. Padda et H. Glenn - Centre for Environment, Fisheries and Aquaculture Science (Cefas), commissionned by the European Commission: *Report on "Sport Fisheries" (or Marine Recreational Fisheries) in the EU* (2006) - EU Contract FISH/2004/011

CHAPTER 3:
THE ENVIRONMENTAL IMPACT OF MARINAS & MOORING FACILITIES

This last chapter will address the environmental impact of marinas and mooring facilities, at their creation phase and during their operations. Marinas and mooring facilities are essential to the practice and the development of recreational marine activities. However, access to water has become increasingly problematic in recent years, causing significant shortages of places in marinas and mooring facilities for boat owners.

For the long-term practice of nautical activities, it is important to mention that as far as it is known, there is no higher risk of operational pollution of the environment by marinas than from any other sport or outdoor facility located in a natural surrounding. Examples of sustainable coastal development which does not destroy the surrounding environment do exist. Moreover, sea enthusiasts are seeking to enjoy a clean and preserved environment.

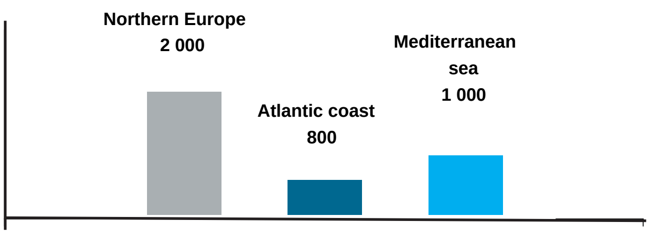
Nowadays, the possible environmental impact of marinas is well known, verified in several studies and subject to several regulations and laws worldwide. Any marina creation, building or extension is subject to preliminary authorisations which are based on one or more environmental impact assessments. During the marina operational life, possible pollutions from the boating activity are typically linked to the use and application of antifouling paints, releases of black water, oil and fuel, garbage, distinguished in onshore and marina basin pollution. But one of the main sources of oil and chemical pollution in marinas comes from the run-off waters of the surrounding city.

A. THE CREATION OF MARINAS AND MOORING FACILITIES

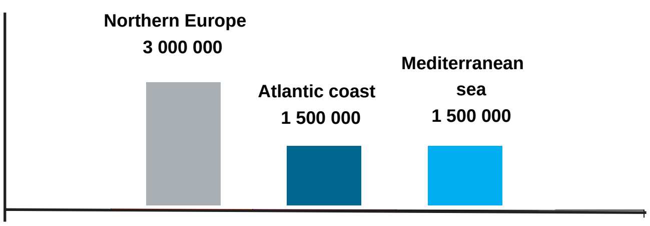
In Europe at the end of the 20th century, the growth of marinas followed the rapid development of recreational marine activities. This trend has now slowed and today the creation of new marinas or the extension of existing marinas is less common due mainly to the enforcement of protective environmental regulations.

1. AN OVERVIEW OF BERTHING CAPACITY IN EUROPE

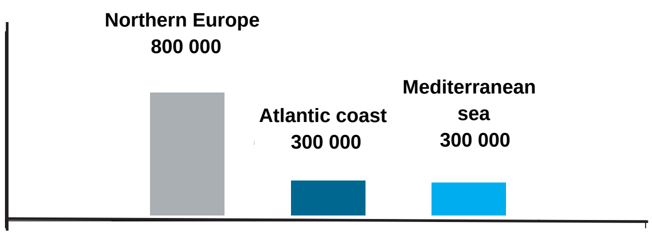
These diagrams show the geographical location of marinas, available berths and numbers of recreational craft in Europe[92].



Marinas in Europe



Recreational boats in Europe



Berths in Europe

[92] EUROMARINA: *Les ports de plaisance en Europe* (2007)

With nearly 4,000 marinas offering around 1.5 million berths for a total number of 6 million boats, European marinas are close to saturation, even taking into account the fact that a large number of smaller boats do not use them. This situation is a significant constraint to the further development of the recreational marine industry, justified in Europe by the need to ensure that further marina growth is sustainable. Outside the EU this may not be the case and damaging coastal development is still taking place.

Within the EU, numerous environmentally friendly alternatives to marina creation are being considered, such as:
- Dry ports and boats parks,
- Reclassification of fishing and commercial ports into recreational ports,
- Extensions of existing marinas,
- Rationalised marina management,
- More effective and sustainable mooring management.

The combination of these solutions will help to increase the number of berths and moorings available in Europe without threatening the coastal and marine environment but more berths will need to be created in the longer term.

2. MARINAS & THE EU ENVIRONMENTAL POLICY

There are no specific European regulations for the creation and development of marinas, since this is considered a local issue which is left to individual Member States and their local authorities. Nevertheless, such activities have to follow the environmental principles laid down by EU environmental policy, such as taking a precautionary approach, taking preventive actions, ensuring damage reparations and the principle that the polluter pays.

The European Union also seeks to increase public access to information regarding infrastructure projects[93], as well as the impact evaluation of any projects on the environment[94]. It also helps the harmonisation of national legislations. Following EU policy principles on marine environmental protection, EUROMARINA, an industry federation representing marinas in Europe, is active in facilitating information and best practice transfer among the marina community.

ENVIRONMENTAL IMPACT ASSESSMENTS:

Tourists want to see and visit pristine land and seascapes but accommodating their needs risks destroying the environment they wish to enjoy. The more beautiful the environment, the more desirable it is, and the more difficult it is to develop in a sustainable manner. Environmental impact assessments are intended to ensure that, where development is necessary, it is carried out in a manner which ensures the minimum possible damage.

Most coastal construction projects, including coastal marinas, will impact the environment in a variety of ways. Impacts can be perceived or real, and may be either beneficial or detrimental to the environment - beneficial in as much as a previously degraded environment may be restored. Adverse impacts from dredge and fill operations may include coral reefs, seagrass and other marine habitat loss or degradation, wetland alteration, destruction of shellfish beds, increased turbidity or siltation, reduced dissolved oxygen or resuspension of nutrients or toxic pollutants such as TBT.

Shoreline and protective structures affect the physical, chemical and biological components of the environment and may alienate beaches and change flooding characteristics. Adverse effects may result from alterations in water circulation, deposition/erosion characteristics, blockage of migration routes or shading in shallow water habitats or addition of toxic chemical preservatives. On the other hand, the marina structures may provide suitable habitats for colonisation which may help to compensate for natural habitat altered or lost during construction. Certain structures may also attract fish into the area.

The potential for environmental impacts is a function of many variables, including marina location, design, services offered, number and type of boats served, marina management and operational performance. As a result, the potential for, or the degree of environmental changes is not the same for all marinas. Inevitably there will be different sets of environmental circumstances for every project that is assessed. Thus the need

[93] Through the EU Directive 2003/4/EC on public access to environmental information and repealing Council Directive 90/313/EEC
[94] Through the EU Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment

for environmental studies (baseline data, planning, impact assessment, and monitoring studies) in the design, implementation and operation phases of marina development becomes apparent[95].

European States require the necessary tools to evaluate the environmental impact of any large-scale project, as well as to take the necessary steps so that new forms of leisure and tourism activities which are likely to affect the environment locally are only authorised once their impact has been assessed. Various activities require authorisation by the competent authority prior to starting work which can cause physical alterations of the natural state of the coastline or the destruction of coastal habitats.

Considering the variety of national regulations on the creation of marinas, a common requirement from all European countries is the obligation to carry out an exhaustive environmental impact assessment prior to any major capital programme. The high standards required by such assessments result in a complex and lengthy administrative procedure. This has effectively stopped the development of many new marinas in Europe as well as major commercial infrastructure projects such as Dibden Bay in the UK. Permission was denied to develop Dibden Bay as a new container terminal in 2004 after the land owner, Associated British Ports, had spent £43M on the environmental impact assessment.

The scope of an environment impact assessment is to evaluate and take into consideration the possible direct and indirect, immediate and long-term impact, including the cumulative impact of the projects being contemplated. Environment impact assessments rely on adequate scientific baseline data including:
- natural coastal physical, chemical and biological processes,
- inventories of marine plant and animal species of nature conservation importance,
- priority habitats for the maintenance and protection of biodiversity,
- sociological impact on indigenous populations.

Consequently, the national competent administrations will establish inventories of species and habitats of the zone affected by the project, the likely effects on them and the mitigation requirements to be included in the permit to operate.

With the creation of a marina, the environment impact assessment will evaluate the following characteristics:
- Choice of the site, where sites which offer the most favourable opportunities for sustainable development should be prioritised;
- Coastal geomorphological effects of breakwaters, slipways and jetties, which project seaward of high water mark, especially around highly mobile shorelines should notably be taken into consideration;
- Low environmental impact facilities which maintain and where possible, restore natural habitats would be preferable;
- Disposal and environmental burden of waste generated by the marina and its users should be carefully planned;
- Clear and financially sound plan should be presented in order to ensure that the costs of pollution prevention are accounted for;
- Marinas which are locally owned or locally managed and therefore can become an integral part of the local environment and community are preferable.

Considering the possible or indirect, long-term impact of a port project, an environmental impact assessment should take into account the downstream effects of development when facilities for nautical tourism are being proposed. Ports expand and extend cruising range. When established, they become a magnet for users who then disperse to anchorages and remote places which may be of high nature conservation interest, creating so-called “honeypot” destinations. These destinations may be uninhabited islands or small communities which are not capable of accommodating the resulting environmental stress.

The related navigation activities should also be assessed. The following aspects of such activities should for example be examined:
- Wave generation, identification of the maximum wave, at critical speed/water depths with the zone of influence of such waves;
- Jet propulsion disturbance, depth of water where disturbance from water jet propulsion will occur;
- Noise level, noise output both in terms of volume and frequency spectrum;

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[95] Great Barrier Reef Marine Park Authority: *Environmental Guidelines for Marinas in the Great Barrier Reef Marine Park* (Australia, 1994)

- Exhaust gases, fuel consumption, chemical content, and volume of exhaust gasses at the point of discharge in the atmosphere or below water level as condensate;
- Intended routing, anchorage and landing.

The potential effects of construction are likely to be confined to the immediate area of the construction activities and be relatively short term, at most for the duration of the construction programme[96].

Dredging:
The dredged spoil could be used as reclamation material. Resuspension of sediments during dredging should be localised with no significant impacts predicted. The dredging should be monitored to ensure no off-site mobilisation of significant volumes of suspended sediments. The effect of increased turbidity and oxygen depletion on migratory species should be assessed.

Piling:
The total duration of sheet piling normally takes a few months. Piling activity in the case of Pwllheli marina extension (UK) as an example would be intermittent for approximately 30% of the time during the working day (10 minutes in every 30 minutes). The total duration of pontoon piling was limited to 1.5 months, with piling activity limited to 10 to 15 minutes every 2 to 3 hours (2 to 3 piles per day).

Use of fixed or floating piers to enhance water circulation[97]:
While being mindful of the need for pier/dock systems to provide access during routine operations and under emergency circumstances (e.g. evacuation preceding or during a storm), piers, and other structures can be placed to enhance, rather than to obstruct, water circulation. Open designs can be selected for new or expanding marinas. Open marina designs have no fabricated or natural barriers to restrict the exchange of ambient water and water within the marina area. Also wave break jetties can be used to reduce the force of incoming water, if protection is necessary. Wave attenuators do not restrict water exchange nor do they interfere with bottom ecology or aesthetic view. Furthermore, they are easily removed and do not significantly interfere with fish migration and shoreline processes.

Use of environmentally neutral materials:
For new pilings and other structures that are in or above the water, materials that will not leak hazardous chemicals into the water and which will not degrade in less than ten years time, e.g., reinforced concrete, coated steel, recycled plastic, vinyl sheet piling have to be used. Shavings must be contained when field cutting plastic pilings and timbers. The use of wood treated with creosote for pilings and similar structures must be avoided if they are in or above the water. Wood should be pressure treated however there is concern that these pressure treated timbers may also contribute to water pollution. Naturally durable timbers should be used conservatively. Black locust, cedar, chestnut, and white oak are naturally durable but expensive and may be hard to find. Some tropical trees, such as greenheart and bongossi, are also naturally durable. Their harvest, however, is harmful to tropical forests. Floatable foams, that have been coated or encapsulated in plastic or wood, should be purchased. As these floats age, degraded foam is contained by the covering.

Therefore, in Europe, marinas creation and development is nowadays highly regulated and environment-friendly technologies are also available. This is not the case in developing countries where marinas are being developing with little consideration of their environmental impact.

[96] Cascade Consulting for Gwynedd Council (UK): *Pwllheli Marina Extension, Environmental Statement Non-Technical* (2004)
[97] Maryland Department of Natural Resources (USA) : *Maryland Clean Marina Guidebook* (2008)

B. THE IMPACT OF DREDGING AS MARINA MAINTENANCE OPERATION

One of the main issues of port maintenance is dredging, necessitated by natural sedimentation reducing water depth. All ports are affected and all must take steps to ensure that they implement an environmentally acceptable maintenance dredging programme. Major international conventions such as the London Convention (1972), the Oslo Convention (1972), the Barcelona Convention (1976), address the issue of dredging. These conventions were reinforced by the inclusion of further texts such as the Framework for the evaluation of rubble dredging[98]; the immersion Protocol[99] and the Guidelines for the management of dredging materials[100]. Dredging can release back into the environment pollutants which have been safely locked into the sediments such as bacteria, viruses or toxic chemicals and must be carried out in an environmentally sound manner. The pollutants found in the sediments come from both port activities and from runoff waters from land, as the port is usually the lowest point of the sloping basin. As mentioned earlier in this study, 44% of marine pollution is originated from land-based activities and the point of these releases is often the port.

$mg.kg^{-1}$	Channel Sea/North Sea	Atlantic Ocean	Mediterranean Sea
Mercury	0,15 - 1,45	0,05 - 0,19	1,16 - 2,51
Cadmium	0,5 - 0,95	0,27 - 0,64	1,0 - 1,25
Arsenic	3,9 - 13,8	4,4 - 28,7	10,4 - 11,2
Lead	36 - 59	41 - 75	93 - 357
Chrome	38 - 65	37 - 75	56 - 74
Copper	18 - 35	10 - 53	107 - 745
Zinc	105 - 175	180 - 60	274 - 506
Nickel	12 - 17	6 - 39	25
PCB	0,01 - 0,14	0,005 - 0,1	0,1 - 0,81

Concentrations of metals pollutants in dredged materials from 1986 to 1993[101]

The level of pollutants concentration determines the methods of dredging, treatment, and the final disposal site for the sediments, either dumped at sea or stored on land.

Minimise the need for dredging[102]:
New marinas should be located in areas where deep water access can be obtained with a minimum of excavation, filling, and dredging. Existing marinas that require maintenance dredging more frequently than once every four years should investigate practicable options to increase circulation or reduce sediment accumulation:

- Extend piers and docks into naturally deep waters;
- Locate slips for deep draft boats in naturally deep water;
- Dredge channels to follow the course of the natural channel;
- Provide dry storage for smaller boats.

Minimise the impacts of dredging:
Dredging should not take place during critical migration or spawning periods of important species of finfish or shellfish. Dredging in critical areas such as waterbird nesting areas and historic waterfowl staging and concentration areas should be avoided. The dredge disposal site must have minimal impact on public safety, adjacent properties, and the environment. Dredge material must be disposed in accordance with the specific guidelines or national laws. In France, the working group GEODE[103] studied state-of-the-art dredging strategies within Europe in order to harmonise and define essential strategies. They sought to balance respect for the significant environmental challenges associated with the marine environment, with the need for ongoing maintenance dredging if ports and marinas are to continue to function.

98 London Convention
99 Barcelona Convention
100 OSPAR Convention combining together, in 1998, the Oslo and the Paris Convention
101 Groupe d'Etude et d'Observation sur le Dragage et l'Environnement (GEODE) stated by IFREMER (France) in www.ifremer.fr/delst/etudes_recherches/impactdragage.htm
102 Op. Cit. *Maryland Clean Marina Guidebook*
103 Op. Cit. GEODE stated by IFREMER

C. ADDRESSING OPERATIONAL POLLUTION: THE ENVIRONMENTAL MANAGEMENT OF A MARINA

The growth of recreational boating, along with the growth of coastal development in general, has led to a growing awareness of the need to protect the environmental quality of our waterways. Because marinas are located right at the water's edge, there is a strong potential for marina waters to become contaminated with pollutants generated from the various activities that occur at marinas, such as boat cleaning, fuelling operations, and marine head discharge, or from the entry of storm water runoff from parking lots and hull maintenance and repair areas into marina basins[104]. The main risk for pollution in marinas is malfunction or misuse of facilitie s, installations or machines. Therefore, the environmental management of a marina is based on a combined mandatory and voluntary regime. Some actions such as the running of waste management plans are mandatory while good environmental management can be further improved on a voluntary basis.

1. THE REGULATORY REGIME FOR MARINAS

Beside the obligation to bring on shore all of the waste and garbage whose release at sea is forbidden, once ashore there is an obligation to dispose of them in the appropriate port reception facilities. This obligation requires ports to provide appropriate reception facilities[105]. Indeed, ports and marinas have to ensure that adequate facilities, in terms of volume and port specificities, are provided in order to dispose of oil waste and residues, black water (sewage) from vessels, and garbage waste.

These requirements apply to all sea ports, whether commercial ones or marinas hosting recreational craft. As mentioned under the section C on waste water (Chapter 2 of Part Two of this study), their implementation in European marinas is not yet fully complete with regard to the collection of black water by adequate pumping systems, while oil waste and garbage facilities are generally offered to the boat users. This lack of implementation in the first case usually reflects the fact that discharges of sewage are only prohibited inside the port's waters. This allows boat users, once at sea, to simply use the sanitary installations on board instead of installing on-board holding tanks for sewage.

2. THE VOLUNTARY ENVIRONMENTAL MANAGEMENT OF MARINAS

Within the field of marina management, voluntary initiatives are also taking place to assure a high level of environmental compliance standards. Three different types of initiatives are of interest:
- The international Blue Flag project (*Pavillon bleu*);
- National initiatives such as the French Clean Ports Operation (*Opération "Ports propres"*) or Blue Anchor (*Blauer Anker*) certificate for marinas located at the shores of Lake Constance[106];
- ISO standard 14001.

Blue Flag labelling:
Blue Flag is a marine environmental label granted to nearly 3,100 coastal localities and marinas in 35 European countries, but also South Africa, New-Zealand and in the Caribbean Sea. The Blue Flag programme focuses on the sustainable development of beaches and marinas. It imposes strict criteria on water quality, education, information and environmental management, safety and other services.

The Clean Ports Operation Initiative:
The Clean Ports Operation launched by the FFPP (Fédération Française des ports de plaisance) is a French initiative for the environmental management of marinas. This initiative focuses on all the operations needed for the improvement of marinas' environmental quality. The operation involves 4 major steps for the marina to follow: an environmental diagnosis, the implementation of a response plan on functional and accidental pollution, and the training of the marina staff together with the information of users. The project is currently being followed by nearly 100 marinas of the French Mediterranean coast and could be replicated in other marinas in Europe.

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[104] American Boating Association's initiative for *Clean Boating and Environmental Stewardship*
[105] See IMO MARPOL 73/76 Convention and EU Directive 2000/59/EC on port reception facilities
[106] Blue Anchor website on http://www.iwgb.net/blaueranker.html

The Blue Anchor Initiative:
The Blue Anchor project was initiated by the International Community of Watersports Lake Constance (IWGB)[107], with technical support provided by the Swiss organisation *sanu* which provides education for sustainable development.

ISO standard 14001 - the highest standard for environmental management:
ISO 14001 is an international standard which applies to all types of organisations regardless of their size or activities. The principle of this standard lies in a voluntary ongoing improvement of environmental performances. In this approach, 18 requirements divided into 6 chapters look at the following areas: general requirements on long term environmental objectives; environmental policy; planning of actions to implement the policy; implementation of the action plan; control and corrective measures; global audit and impact assessment of the policy. Even though ISO 14001 does not impose minimum limits in term of pollution, it does require a significant technical and financial involvement of the organization. As a result it is mainly adopted by the major marinas.

[107] Internationale Wassersportgemeinschaft Bodensee (IWGB) for Austria, Germany and Switzerland

CONCLUSIONS OF THE STUDY

The evidence reviewed during this study demonstrates that nautical activities and in particular recreational boating have a minimal and reducing impact on water and air pollution. Nowadays, the main sources of pollution of the marine environment and the ambient air come from land-based human activities. The long-term future of nautical activities and their economic sustainability however relies on a preserved environment. The attractiveness of marine and aquatic environment to people and their participation in water-based leisure activities depends on a clean, unpolluted and natural environment.

Nevertheless, the study outlines a series of areas where both the nautical industry and the users can make a difference in reducing the environmental impact of nautical activities. Making available on the market technologies and products that are energy-efficient, where the environmental impacts during the manufacturing process were minimised, products using substances that are biodegradable and less harmful to the environment, are a few examples of what the nautical industry can do to "green" its products and technologies. On the other side, improving the users' education and awareness of the possible environmental impact they can have will help reducing impacts that are linked to the user's behaviour.

The nautical industry will continue to make every effort to deliver its contribution to the protection of marine and aquatic environment. The overall impact of these environmental efforts will however remain limited in a global sense, as nautical activities themselves only account for such a minor proportion of marine and aquatic pollution. Moreover, the degradation of environmental quality is a direct threat to the future and sustainability of nautical industries and to the long-term practice of nautical activities. Nautical activities are indeed one of the most efficient ways of raising public awareness on environmental issues, with the vast majority of nautical enthusiasts being nature lovers.


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