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MEDNATURE 2

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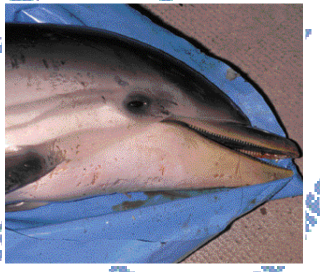
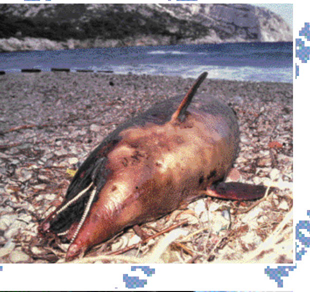
# *CETACEAN STRANDINGS IN THE MEDITERRANEAN SEA*





*SIGNIFICANCE OF STRANDINGS*

*PATHOLOGY OF CETACEANS*

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*MEDITERRANEAN DATABASE OF CETACEAN STRANDINGS (MEDACES) : A TOOL FOR THE CONSERVATION*

# Foreword

The threats facing migratory species, Inter alia during their travels, are now widely recognized: The main dangers are from pollution, deterioration of their natural stopover habitats, and direct hazards from fishing or hunting.

Elaborating and implementing an action plan to conserve one species or one group of species is an effective way of guiding, coordinating and strengthening the efforts the Mediterranean countries are making to safeguard the natural heritage of the region.

It is in this way that the Contracting Parties for the protection of the Mediterranean Sea against pollution and its related protocols included among their objectives for the period 1985 – 1995 the protection of threatened marine species (Genoa Declaration, 1985). Though some important aspects of biology, behaviour, and cetacean habitats in the Mediterranean remained poorly known, but the actual degradation of the population is such that action can no longer be postponed in line with the precautionary principle accepted by the Contracting Parties in 1989. Based on the available information, an action plan for the conservation of cetaceans in the Mediterranean was adopted in 1991.

This plan could be adjusted as necessary when more information becomes available.

To reduce the impact of those activities an important migratory species, intergovernmental cooperation had to be set up so that the monitoring of the species along their migratory routes could be done together with adequate coordinating measures.

The secretariats of the intergovernmental Barcelona, Bern and Bonn Convention focused their concern on the most suitable legal framework for the protection of cetaceans in the Black Sea, the Mediterranean and the adjacent Atlantic area. Thus ACCOBAMS was created.

This agreement, negotiated in Monaco 1996, came into force on June 1st 2001. It aims at the protection of all cetaceans frequenting the marine zones of the Black Sea, the Mediterranean and the contiguous Atlantic area. The agreement is also open to non-riparian countries, whose maritime activities are likely to threaten cetaceans. This agreement also makes states readier for the implementation of measures keeping cetaceans in a favourable state of conservation. To guide them, a conservation plan backs up the agreement.

It is in this context that this second issue has been exclusively directed at cetaceans.

It tackles very important themes in the conservation of cetaceans, such as information about their biology. Two themes are developed in this issue: cetacean strandings and the study of cetacean parasitology.

*Director of RAC/SPA*

# SUMMARY

*by Frank DHERMAIN, Doctor in Veterinary Science, Study Group for Mediterranean Cetaceans Redon Veterinary Clinic,*

# SIGNIFICANCE OF STRANDINGS PATHOLOGY OF CETACEANS

## Strandings and causes of mortality: two similar but different ideas

Our knowledge of Cetacean pathology comes almost exclusively from the study of their strandings : the arrival on land of a dead or live sea animal and the observation of it in marineland in artificial conditions of captivity that can rarely be extrapolated in the natural environment. Strandings are thus practically the only means of approaching the pathology of cetaceans in the natural environment. But strandings do not make up all the causes of cetacean mortality, far from it! If we consider the exclusively aquatic life of the cetaceans, we have to admit that only a tiny proportion of corpses reach dry land: many sink, or are eaten, in a proportion that we do not know. Most strandings are of cetaceans that have died at sea.

The following algorithm summarizes the main causes of mortality of cetaceans. Many of these factors end up sooner or later in a stranding. Strandings can concern an isolated individual or an entire group; there is no one cause of stranding, but a host of origins of varying types of strandings. Strandings and disease are not automatically closely linked.

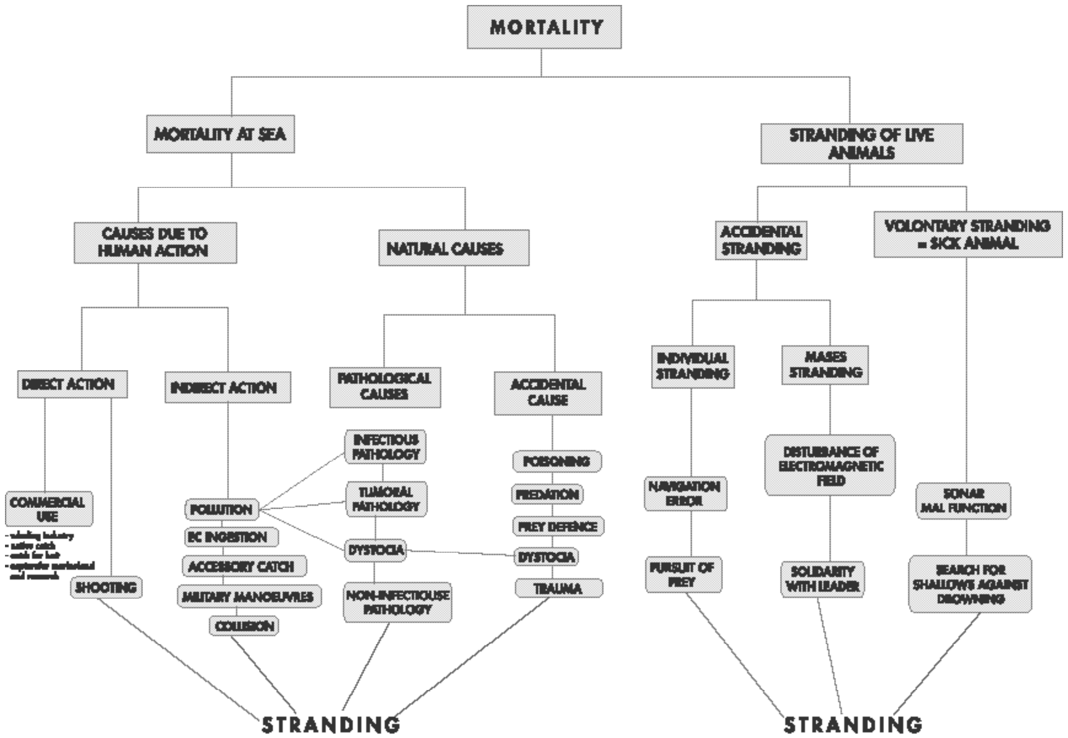



*Fig1. Causes of mortality and standings of Cetaceans.*





## Organizing monitoring networks for strandings

France was one of the first countries to possess a monitoring network (since 1971). This is at present coordinated by the Centre of Research on Marine Mammals, based in La Rochelle, an association under Law 1901 coordinating the work of dozens of volunteers throughout France. In the Mediterranean, Colonel BESSON set up in 1974 at Hyeres the first strandings unit, a structure that has never been equalled since and now unfortunately declining. We have to admit that today, unlike other countries, France (or at least Mediterranean France) has been unable to interest research laboratories in systematic analyses, or the health and administrative authorities to let us work in decent conditions. Most frequently, work done on a stranding is done as an emergency, on the beach, in often difficult climate conditions, with pressures of every kind so that the animal can be got rid of as quickly as possible to the quartering area without leaving disgusting traces of its passage. Dual legislation concerns cetacean strandings. There is an order from the Ministry of the Environment to the effect that stranded cetaceans must be examined by qualified specialists before being taken away; but the Law of 26.12.1996 on quartering obliges town councils to have the corpses taken away, free of charge, within 24 hours. Furthermore, the permit delivered by name to the specialists, personally and for a maximum one year renewable, incorporated in the famous green card, is a permit to "capture for care / marking and release on the spot and transport stranded animals", a wording which is completely unsuited to cetacean strandings. In particular, this permit thus formulated does not mention dissection, autopsy, or the taking of samples for analysis, actions which could according to the way certain articles in the Rural Code are interpreted be reserved for the veterinarians only, and not concern certain coastal species protected by other conventions, such as the Grand Dolphin, the Common Porpoise and the three French Seals, which require a special permit from the Ministry after permission has been given by the National Committee for Nature Protection (CNPN). Since January 1999, this green card has as a rule been delivered by the police headquarters of the departement for which it is valid, and not by the Ministry.

The present suggestion (November 1999), being looked into at the Ministry, is that the green card, written in more suitable terms, should be given when suggested by a centralizing body (in all likelihood the CRMM) by one single police headquarters but valid in several departements if the case arises, and allowing, according to the skills of its holder, either an examination, or an examination and the taking of some samples at the site of the stranding immediately before taking away by quartering, or again the removal of the body to a suitable laboratory where an autopsy can be carried out according to the rules.

## Reports from the networks

Annales de la Societe des Sciences naturelles des Charentes Maritimes Stenella

Need to gather together all data from cetologists working in one given area to present coherent figures. Thus, need for a wide degree of cooperation between those in charge of strandings.

## Legislative aspects

Point of view of the Ministry of the Environment and Agriculture.

The significance of strandings : why go to so much trouble for a few stinkingcorpses?

The best source of immediately accessible information on a host of data:

discovery of new species: *Mesoplodon pacificus*, which has long been known only by two pieces of skeleton, one in Somalia, the other in Australia.

distribution of species: Fraser's Dolphin, the first mention in France of which was obtained from stranded animals, *Mesoplodon europaeus*, the classic example of which was found dead in the Channel, before it was noticed that the species actually frequented the West Indies sea; or again those Mesoplodon (?) stranded at Cap Roux, in the Esterel, which were not correctly identified because there were no skilled people around.

sex: determining the sex ratio

size: biometry

age: chronodentology

anatomical material : an excellent source of apprenticeship for both anatomists and students even schoolchildren.

cause of death:

The question most people who witness a stranding ask is 'Why did it die?' as if it were inconceivable that dolphins should die. Actually, this is a nice change after years of 'Whatever is that big fish?' and then 'What is that dolphin doing here?', as though it were impossible that there were any left in the Mediterranean. Answering the question 'What did it die of?' is not always easy. The following check list reviews the elements that must be verified during the autopsy of a stranded animal, where certain external traces can diagnose the cause of death. We only take account of causes of mortality other than those due to direct commercial exploitation.

external aspect of the corpse

- gashes from drift nets, willful mutilations by fishermen to get rid of the body as quickly as possible;
- 'dolphins with holes': since 1997, mainly on the Languedoc Roussillon coast and in the winter, several dozen stranded striped dolphins showed skin damage at the base of the mandible or under the throat. Numerous, sometimes cranky, hypotheses were advanced in the media; a halieutic, post mortem, cause seems to me more likely (RIGOLLET *et al.*, 1998). The lesions are similar to those that might be caused by a fisherman's gaff used to pull tuna up out of the nets, a wound that is later enlarged by fish or sea birds that eat dead things;
- boats' propellers (a cause of mortality that is recognised as important for free whale populations, but also frequently observed for fin whales in the Mediterranean); this can also happen after the animal has died;
- killer whale bites (30 to 50% of megaptera in certain American sites); possibly, false killer whale bites and peponocephalus, even pilot whale, bites; trauma caused by Tursiops attacks on Moray Firth (Scotland) porpoises were non specific and discrete;
- shark bites; in both cases (killer whale, shark) were the bites ante" or post mortem?
- wounds left by the fierce dogfish Isistius brasiliensis and its kind, at least in tropical waters (JONES 1971);





- marks left by squid tentacles. Very frequent;
- marks left by inter group bites by cetaceans;
- scars left by detached ectoparasites, e.g. *Balanes Coronula, Conchoderma*;
- gashes due to pecking by gulls' beaks on a stranded corpse. Their work is quick, effective and astonishingly ruinous;
- traces of bullets and harpoons.

## Autopsy

Limits of our diagnostic means in cetology.

Theoretically:

| NECROPSIC DIAGNOSIS = Anamnesis + Fresh corpse + Additional examinations |
|---|

In cetology:

NECROPSIC DIAGNOSIS = ~~Anamnesis~~ + Fresh corpse + ~~Additional examination~~

- no available memory aid: generally nothing is known about what happened before the stranding
- ideal conditions of freshness and for dissection are rare. But do not then think that nothing is possible on a corpse in bad condition: the species, sex, size and teeth are important parameters which can generally be noted
- additional examination: Francois MOUTOU (unpublished) has calculated how much a detailed autopsy of a cetacean would cost, with a few simple additional examinations (bacteriology, mycology, parasitology, histology) carried out in a state laboratory. The cost (about 3,500 FF per stranding) is prohibitive for a non professional body without outside funding, and does not include the virological, pesticide (1,000 F tax exclusive for organo chloride research) or heavy metal (1,400 F tax exclusive) research that is sometimes done (MOUSSU A., 1995). It is therefore necessary to coordinate our action to benefit from different laboratories' research work and to let them make use of the cetological material that has been collected. We could also say that this is how we have become used to working here, in Mediterranean France, with few means but a lot of resourcefulness, whereas other countries have professional, university or private structures which use strandings in an apparently more rational manner
- restrictions that are inherent to the techniques themselves: isolating a bacteria, the presence of parasites, a given concentration of a toxic product, do not sign their responsibility for the death. In virology, the presence of antibodies does not signify that the cetacean is infected, and a kinetics of antibodies (2 serologies at fifteen days' interval) (obviously impossible for a corpse!) would be indispensable to draw conclusions
- finally, the knowledge itself, when available, most frequently comes from the marinelands (animals under stress, highly particular conditions of contact with various pathogenic agents) or from studies carried out in a tropical environment (parasites and other microbes that are not necessarily present in the French Mediterranean) and are thus not always suited to local problems.

- knowledge of infectious agents
- etiology of pathologies
- epidemiological alert: role of sentinel to signal epidemic diseases

• Means to be used during an autopsy

- material and method
- standard list of what to look for in a corpse in good condition
- danger of zoonoses

• limits of strandings

- percentage of what sinks or is eaten by sharks
- gradual disappearance of the body
- deterioration of samples

• procedure to be observed when live animals are stranded.

## CAUSES OF CETACEAN MORTALITY

How things have changed. Imagine the lives of cetaceans only about 200 or 300 years ago. Before men started interfering, few animals could have had life quite so easy. Higher mammals of fairly large size (and yet we talk about small cetaceans' for animals of 2 or 3 metres long!) with extremely efficient hunting techniques for some of them, food in profusion, very few climatic hazards, few natural enemies with their large size, rapidity, social cohesion or intelligence. Then modern man arrived on the scene. Today, the main causes of cetacean mortality are directly or indirectly of human provenance: directly caught in whale

hunting and hunting of small cetaceans; accidentally caught in fishing nets, every kind of pollution. Infectious pathologies, mainly viral, possibly encouraged by the degradation of the environment caused by human activity, are responsible for massive and spectacular epizootics whose importance is hard to calculate with any precision, since the percentage of corpses that disappear at sea is not known. Other causes of mortality are rather more trivial. The difficulty, in a hierarchized analysis of factors of cetacean mortality, lies in the impressive number of unknown quantities in the terms of the problem. If we envisage cetaceans as a whole, we are inclined to see a group of animals that is finally fairly heterogeneous, subject to environmental constraints that have no relationship between them. The problems of a fresh" water China dolphin has very little to do with those of a pelagic sperm whale, and it is also not possible to come up with a number for the overall cetacean population, which ranges from several hundred individuals for the rarest and many million for a few delphinidae, without mentioning the complete veil of mystery surrounding the Mesoplodons, about whom we know practically nothing. Natural mortality at sea therefore remains impossible to quantify; finally, we are only able to provide figures for causes of destruction that are directly due to man (commercial hunting and accessory catch), with the limits that we guess at about the correctness of the figures officially provided, and for the causes of identified strandings, without knowing what the number of stranded cetaceans represents compared with the number of animals that have disappeared at sea. The most spectacular figures are appalling, like the two million little dolphins caught by Pacific tunny





fishers over 20 years, and certainly concern the most massive, sudden disappearances, even destabilizing the population balance. But what about the incidence of more insidious factors, like the degradation of the environment, the dwindling food resources, or the influence of pathogenic agents, if we do not know the numbers of the initial stock and we do not know the number of dead and the resulting figures? Can we compare the 680 striped dolphins found dead stranded during the morbillivirus epidemic in the 1990s in the Mediterranean with the 600 striped dolphinscounted as accessory catch by the French tuna fishers of the North-East Atlantic? Certainly not. In the first case, we are totally ignorant of the percentage of drowned bodies, and in the other the catch is recognised by independent observers on board. The only studies that can be of use will be those on limited populations, counted over a known area. This is what we are doing in the Western Mediterranean, as in other parts of the world, with well codified counting drives which have resulted in basic figures for the numbers of striped dolphins and fin whales, for example. Only repetition of the counting will enable us to measure population variations, which could if the case arises be attributed to such and such a major pathological event.

## 1.Mortality due to human action

### 1.1 Willful destruction

*1.1.a. Gun shooting*

The destruction of dolphins, accused of indulging in unfair competition with fishermen, was frequent a few years ago, either directly by the fishermen themselves, who often had guns aboard, or by large scale military operations: porpoise beats organized in the Mediterranean and on the Brittany coast, from surface ships (de BEAULIEU F. *et al.*, 1994), destruction of killer whales from the air with machine guns in North America (KLINOWSKA M., 1991), etc. Though official protection now shelters cetaceans from such practices, personal vendettas are still to be feared, and the presence of round holes in corpses must make us suspect that bullets have been fired.

*1.1.b. Commercial whaling*

Commercial whaling has been by far the principal cause of destruction of cetaceans for two centuries. It is not restricted to the whaling industry only but also includes aboriginal catches, catch for bait (sharkfishing in South America, South east Asia...), massacres of animals driven onto land, as in the Faeroes or in certain parts of Japan (KLINOWSKA 1991), capture for marinelands or research centres, etc. Certainly, commercial whaling has not brought about any extermination of a cetacean species, but on the other hand entire populations that are totally isolated have disappeared (Atlantic grey whale) or been on the point of disappearing (Asiatic Pacific grey whale, Boreal free whale) without being at present able to reconstitute their stock (blue whale). In the inter War period, the whaling fleets officially killed up to 30,000 blue whales every year (COLLET, 1998). The ecological modifications to the food chains were considerable after the quasi disappearance of these enormous predators, the thousands of blue whales in the Antarctic, and it is possible that the balances later obtained do not encourage the return of the original species, even after the hunting stopped. Moreover, we can get a better idea today of how the various regulations and suggestions of the International Whaling

Commission have been disregarded by countries like the USSR, which today recognises that it hid 30% of its catch between 1949 and 1980, or Japan, where a survey on differing whale meat sellers' stalls showed that all species, including those strictly protected, are caught on the pretext that this is a scientific search for the minke whale. The problem is not really scientific or economic; it is a purely ethical issue. Can man assume the right to bring everything down to questions of profit alone, even while making sure that he is not squandering what he might see as 'resources', or do certain species with complex social behaviour deserve that their commercialization be forbidden simply because they are highly developed organisms and that wiping them out is not vital for humankind. It is easy to see that all the economic arguments justifying the revival of commercial whaling are merely a result of bad management of the oceans, and more fundamentally the problem of the human demographic explosion. The solution, if one does still remain, lies in mastering these threats, not by a rush towards an ever heavier exploitation of 'resources'. In 1999, 589 whales were caught by the Norwegian fleet out of a quota of 753. Bad meteorological conditions explained this moderate hunting table (Reuters, Associated Press, High North Alliance News, Environment News Service). Despite all legislative provisions, the Japanese whaling fleet set out on 9 November 1999 to catch 400 minke whales in Antarctic waters "for scientific purposes" (Associated Press). At the same time, the Japanese Government asked for point"snout rorqual populations in the West Pacific and the Okhotsk Sea and the southern hemisphere, as well as grey whale populations in the North east Pacific, to have their classification changed, so that they could start selling their take internationally again

## 1.2. Indirect action

Indirect causes of cetacean mortality due to human action are still more numerous, and sometimes of comparable importance. Regulating these is all the more difficult in that here we have insidious consequences of our present civilisation of which the entire planet, and us along with it, bears the brunt.

### *1.2.1. Accessory catch (accidental?)*

Today we can still say that several dozen thousand cetaceans are caught accidentally every year throughout the world. If there ever was a topical subject, this is it, and one must draw a distinction between various fishing techniques:

- staked nets, used in many parts of the world for coastal fishing. Can locally represent a threat for fragile populations, particularly porpoises, as well as young minke whales on the Mediterranean coasts
- straight nets, classic nets let down in the water from a low tonnage ship and raised a few hours later. In British waters, accidental takings account for 2,200 porpoises a year, or 6% of total population, which is more than the acceptable ceiling (GORDON *et al.*, 1997). Tests for acoustic signalling from these nets by 'pingers' seem promising (DAWSON *et al.*, 1997 ).
- purse seines in the South east Pacific, where the takings of dolphins, once frighteningly high, are starting to be rationally controlled by the use of suitable techniques: the number of dolphins captured has fallen from 420,000 in 1972 to 3,300 in 1995 (APOTEKER 1996). But it should be noted that the drop in accidental catches is partly due to the fact that fishing areas have moved to the West Pacific, where the tuna dolphin link up is lower; also, members of the Inter American Tropical Tuna Association are lobbying to legalize the death of 5,000 dolphins a year and ban monitoring of takings by observers on board
- drift nets, on French tunny boats in the North Atlantic, relatively modest in size and having accidental catches of dolphins without consequences for the size of stocks (COLLET A. *et al.*, 1992) (but useless deaths are still an unbearable waste). In 1992 and 1993, French tunny boats in the North east Atlantic caught in this way in small drift nets about 200 common dolphins, 600 striped dolphins, 20 grand dolphins, 30 black pilot whales, some Risso's dolphins, sperm whale, pygmy sperm whale, fin whale, minke whale, mesoplodon sp.; this 'only' represents about 1% of the present stock of small dolphins, especially very young animals, and has no effect on the viability of the species (drop of numbers induced is estimated in the medium term as between 0.5% and 1% (GOUJON *et al.*, 1994).
- pelagic trawls, with ill known, but certainly disastrous, results on the marine ecosystem (COLLET A. *et al.*, 1999: CONNELLY *et al.*, 1997). These are trawls with a 100 metre wide 50 metre high opening, trailed out at sea, sometimes anything up to 400 metres wide and 900 metres deep, drawn along by two trawlers fishing in tandem (COLLET, 1998). In the smallest of these trawls it is not sure that dolphins can be trapped as easily as fish, but it is probable that captures happen regularly, at least when the dolphins are attracted to the fish caught in the trawl, and when the trawl moves suddenly and irregularly. Lowering the nets 5 metres below the surface could be enough to lessen the accidental catches, but the IFREMER experiment of 1996, which could have tested this hypothesis, was rejected by French fishermen with evident ill will. In the biggest trawls, however, the trap dragged along in the open sea is able to trap a whole shoal. The mass strandings of common dolphins on the Atlantic beaches, brought to the coast after strong westerly storms, bear witness to this phenomenon.
- pelagic drift nets several kilometres long true walls of death responsible for the deaths of thousands of cetaceans and big marine species in the South Pacific, and, nearer home, in the Mediterranean as a result of use of the scandalous procedure by Italian swordfish fishermen. In 1996, at least 600 Italian boats fitted out with non regulation drift nets continued to devastate the waters of the Mediterranean, but the Italian Government, confronted with threats of American commercial reprisals, seemed decided to strengthen the moratorium forbidding traps of over 2.5 kilometres (source AFP, 28.6.1996, at the meeting of the International Whaling Commission at Aberdeen, Scotland).

It would seem that the dolphins are taken in the nets the moment these are let down into the water. It is possible that the sound of the windlass and the bubbles caused by eddies between the mesh are highly attractive. It is also probable that the dolphins quickly learn to come and eat from the nets; thus, the 'frightening off' signals attached because there is a fear that the dolphins will not notice the nets when not using their sonar are perhaps warning signals that a net teeming with easily caught fish is nearby. It is to be noted that in many cases the dolphins caught in the nets have been mutilated, generally after death underwater from suffocation, in order to extract them from the nets more easily (cutting off of pectoral and/or caudal fins), or to make them disappear (removal of innards either to weigh the animal down with stones before sinking it, or more simply so that gas produced by fermentation, accumulating in the larger cavities, does not bring the corpse up to the surface). When a stranded dolphin presents these mutilations it is an obvious sign of accidental capture. To put an accidentally captured dolphin back in the water fishermen usually use a hoist, after passing a rope around the cetacean's tail. According to the case, the rope is cut, and the corpse is found with a rope round its tail, or, when the rope is new and can be recuperated, the caudal peduncle is cut off, explaining the mutilated corpses found on beaches.

*1.2.2. Military manoeuvres*

explosions, mines, acoustic experiments. On several occasions a correlation has been noticed between cetacean strandings (especially of mesoplodons in the Canaries (SIMMONDS, 1991), of ziphius in the West Indies (VAN BREE P.J.H. & KRISTENSEN I., 1974) and the progress of military manoeuvres, including submarine fire, in the preceding days. Since 1996, climatological research projects aiming at calculating the temperature of the sea by studying the propagation of very high intensity sound waves through the entire Pacific Ocean could have uncontrolled results on cetaceans. Three years after the ATOC project started, there is still bitter debate on the harmlessness of the project for cetaceans (Science & Vie 941, February 1996; Marine Mammals Research and Conservation Discussion 30/06/1999: Lindy Weilgart lweilgar@IS.Dal.Ca).

The US Navy wants to test a long range sonar system (called LFA for Low Frequency Active Sonar, or SURTASS) to detect submarines lying deep down by bombarding them with low frequency high intensity sounds from several hundred miles away. Experiments are under way to discover the impact on marine mammals, an impact hard to appreciate without being a specialist in underwater acoustic physics. (Marine Mammals Research and Conservation Discussion 10/08/99: Andrew Wetzler AWetzler@nrdc.org; 04/11/1999 JBlue46498@aol.com).

*1.2.3. Ship collision*

collisions between whales and the big rapid ships that plough the Mediterranean (SNCM car ferries, but also gas tankers, etc.) seem to be a major cause of mortality for these big species; it is not known why they do not get out of the ships' path: bad assessment of the ship's speed, or deep sleep? On 10 November 1986, a gas tanker came into Port de Bouc harbour (13) with a whale on its bulb. On 9 September 1993, the 'Ile de Beaute' car ferry did the same in Toulon; in 1994 the 'Liberty' similarly; on 26 September 1995 it was the 'Japan Senator' container carrier in Fos sur mer; then another ferry, the 'Danielle Casanova', in Bastia port on 26.7.1996; on 24 February 1997 a new born whale was found dying off the Marseilles calanques and an autopsy showed a big haematoma on the right side of the thorax, caused by a collision with a ship. These figures do not take account of cetaceans that were struck and drowned at sea. Use in 1996 of ultra high speed boats (50 knots) called NGVs between Nice and Corsica in the summer is seriously worrying for whales so abundant in this area in the summer season the only area that can be exploited by these boats which cannot stand up to bad weather. In other parts of the world (particularly North America) the circulation of ships is regulated in areas where there is a high density of cetaceans. A little detail: competition yachts also regularly crash into cetaceans, which is only to be expected, given their speed and their paths through particularly rich seas. On 18 November 1998, on the Rum Run, Alain Gauthier crashed into a cetacean and damaged his boat. "It doesn't amuse me in the least," he said on the radio. Nor the whale either, doubtless.





*1.2.4. Pollution (with the collaboration of Prof. Augier, CERIMEN, Faculty of Luminy, Marseilles).*

a. Oil slick

Oil pollution is found in all the world's seas. These hydrocarbons can come from natural 'oozing' but are usually the result of human activity. Basically we are looking at accidental pollution (breaks in pipelines, drilling setbacks, oil tankers being wrecked) and chronic willful pollution (tankers getting rid of ballast, discharge from refineries and other factories, waste oil and oil change). The most abundant work is on oil slicks. Unlike what is found for other, more seriously affected, taxa (sirenians, pinnipeds, sea "otters, sea birds), the effect of oil pollution on cetaceans is rather controversial (EVANS, 1987).

Hydrocarbon toxicity for cetaceans is very little established. Although this kind of pollution is now very widespread, affecting every sea in the world (washing out of ships' tanks, pipeline leak, oil slicks etc.) a stranded cetacean covered in oil has never been found, unlike other oil daubed sea mammals and sea birds. Experiments carried out in captivity by GERACI *et al.* have shown that tursiops were able to sense the presence of a thin skin of hydrocarbon at surface level and avoid it, even at night. Despite this, *Eschrichtius robustus* grey whales or *Balaenoptera physalus* fin whales have been observed crossing oil slicks during their migration, apparently unharmed (GASKIN, 1992). HENNINGSEN & WURSIG (1991), studying grand dolphins in the Galveston Bay, Texas, made several observations of groups of dolphins spending hours in the middle of oil slicks while being in the immediate proximity of free water. Several studies have shown, a contrario, a change in behaviour and a disturbance in the distribution of many cetaceans, pelagic and coastal, faced with a sudden discharge of hydrocarbons in their ecosystem. The wrecking of the Exxon Valdez in 1989 (45,000 tonnes of oil) might have caused the deaths of many individuals of grey whale, megaptera, fin whale and minke whale, common killer whale and Dall's porpoise populations on the coasts of Alaska. But we should be clear that these studies did not take account of the long "term effects of such events, for monitoring the individuals who had been in contact with the oil slick and survived would have required sea and marking means that are particularly difficult to implement. An interesting observation has, however, been made on this subject. The Exxon Valdez oil slick invaded the territory of a group of resident killer whales. Six years after the catastrophe, only 22 of the 36 individuals formerly known remain. Various hypotheses are still being discussed on the subject: direct mortality by poisoning, destruction of the group's social structure because of the disappearance of some hierarchically important individuals, or scarcity of prey also affected by the oil slick? Hydrocarbons are also irritating to the delicate epidermis of cetaceans, and disturb the food chains. They probably present a direct pulmonary toxicity, made worse by the way cetaceans breathe right on the surface of the slick, where the concentration of hydrocarbon gas is highest. Analyses have revealed the presence of hydrocarbons in boreal free whales and grey whales, fin whales and minke whales and common porpoises. These hydrocarbons are also a cause of a more or less serious pathology, fairly often in synergy with other pollutants.

b. Pollution by pesticides, PCBs and heavy metals

*b1. General remarks*

Since the 1970s, a great many studies have been devoted to the impact of pollution on cetacean populations (SIMMONDS, 1992). World industrial growth represents a serious threat to many cetaceans, particularly in the semi closed seas of the Western countries bordering coasts where intensive agriculture and/or heavy industry are concentrated: the coasts of Japan, California, the Gulf of Mexico, the Gulf of the St. Lawrence, the Baltic Sea, the North Sea, the Western Mediterranean and the Black Sea. Despite the impressive list of alarming results, analysis of the impact of this pollution comes up against two fundamental problems: the absence of experimental data, and the uncertain sampling conditions. Nobody has ever knowingly poisoned a captive cetacean, for obvious reasons of ethics and technical difficulties; since these are protected, and often threatened, species, difficult to keep in captivity even at exorbitant cost, it is hardly possible to envisage such studies. Therefore one relies on results obtained on other groups, particularly pinnipeds, and on clinical observation, to affirm the toxicity of observed concentrations. Unfortunately for the cetaceans, the values discovered are so high that the harmlessness of these products seems fairly unlikely.

Strandings provide most of the material analysed. They have the advantage of offering researchers a complete corpse, permitting (according to how fresh it is) samples to be taken systematically from all the organs and tissues. However, they are by their very nature impossible to foresee, cannot always be used, and do not concern all species. Therefore, the most studied species are those which are most regularly stranded on the coast; in France, this basically means the *Stenella coeruleoalba* striped dolphins in the Mediterranean (AUGIER *et al.*, 1991, 1993a; VIALE, 1977), and this species and the *Delphinus delphis* common dolphin on the Atlantic coast (ALZIER & DUGUY, 1979; TOUSSAINT, 1977). Most of the other French species, such as the *Tursiops truncatus* (bottlenose dolphin), the *Grampus griseus (Risso's dolphin)*, the *Globicephala melaena* (black pilot whale), the *Physeter catodon* (macrocephalic sperm whale), the *Ziphius cavirostris ziphius*, the (port porpoise), and the *Balaenoptera physalus* (fin whale) have also been analysed, but not so frequently. Other more systematic studies have concerned the determining of the pesticide level in the dorsal fat of certain species (striped dolphin, fin whale, etc.) by biopsy with retrieval crossbow on free wild individuals (AGUILAR & BORREL, 1989, 1993). The analysis is thus limited to one single tissue, restricting possibilities of comparison.

b2. Pollution by pesticide and polychlorobiphenyl derivatives

Although their fields of use are quite different, pesticides and polychlorobyphenyls have properties and environmental consequences that are sufficiently alike for them to be dealt with together. Pesticides (or biocides) are synthetic products used by humans for their toxic effects on living beings. They are widely used in agriculture to fight against enemies of food producing crops and breeding. They are also used to fight against insects which are vectors of diseases such as plague, malaria, typhus, yellow fever and sleeping sickness. The number of selective or wide spectrum biocide preparations that can be found on the market is considerable, and the commercial quantities little known. Biocides are often classified according to the nature of the pests they are to combat. Thus there are insecticides (contact, ingestion, inhalation, systemic), ovicides, fungicides, herbicides, acaricides, slug killers, nematicides, etc. The chemical nature of biocides is extremely varied. Usually one can distinguish: organophosphorous (insecticides), carbonates (insecticides and fungicides), dithiocarbonates and organo mercury derivatives, triazines and ureas. The set of organochlorine hydrocarbons, insecticides used extremely widely in agriculture and for other purposes is chemically heterogeneous. It is these which represent the most serious pollution problems. The best "known is DDT, chlorinated aromatic hydrocarbon or dichlorodiphenyltrichloroethane, and its metabolites DDD (dichlorodiphenyldicloroethane) and DDE (dichlorodiphenyldichloroethylene). The other organochlorines are derivatives of the alicyclic group: lindane or HCH (hexachlorohexane), aldrin, dieldrin, and its stereo isomer endrin, heptachlorine, chlordane, etc. The organochlorines are toxic, usually for the nervous system. The organophosphorates (malathion, parathion, fenthion, diazinon, trichlorphon, chlorthion) have toxicities similar to the organochlorines but usually lower remanence. They are inhibitors of cholinesterases, enzymes active in the transmission of neural impulses.

The term PCB (polychlorinated byphenyl) is a collective term used for a group of chemical substances defined as halogenic hydrocarbons with high molecular weight. They are made by the progressive chloration of the biphenyl root in presence of a catalyst. Theoretically, there may be 209 distinct elements called 'congenerate' but in reality fewer constituents are marketed.

Use of PCB may fall into three categories:

- Use in controlled closed systems: dielectric in transformers and big condensers ( >1 kilo)
- Use in uncontrolled closed systems: colporteur fluids, hydraulic fluids (mining industry, aviation, etc.), vacuum pump fluids, little condensers
- Dispersive, irretrievable use: certain lubrifying and cutting oils, pesticides, plasticizers in paints, inks, photocopying paper, adhesives, putties and plastics.

Badly controlled burning of these substances can when released reduce enormous quantities of PCB into the atmosphere. PCBs possess a molecular structure like that of DDT; they have similar chemical properties and an even greater stability than DDT's.

Their remanence in the environment make these substances into unbelievably pollutant products, which tend to spread into the whole of the world's ocean; they are even found in the fat of Antarctic penguins (RAMADE, 1978). All are chemically extremely stable and last a long time in sea water. Run off waters encourage these products to be dispersed and to end up in that general receptacle the marine environment. It seems that the homogeneous distribution of biocides on the surface of the seas is a secondary effect of their pollution by oil and its derivatives, with extremely liposoluble pesticides forming an emulsion in those substances and thus being further dispersed by marine currents (RAMADE, 1989). Later absorbed by organic matter, they accumulate right through the food chains, reaching the highest concentrations in the ichthyophagous, and then the teuthophagous, cetaceans.

Most of the above mentioned substances have been found both in mysticetes and in odontocetes. PCBs have been detected in at least over 50 species of cetaceans (doubtless in all those where they have been looked for) from the poles to the equator, including in the dolphins of the Indian sub continental river systems. Though the highest concentrations have usually be found in the blubber, many other organs and samples also contained biocides: liver, kidneys, encephalon, heart, lungs, bones, muscles, skin, visceral fat, pancreas etc. Cetacean prey are also contaminated, from the krill to the principal fish. It has also been shown that a certain number of organochlorines, among them DDT and DDD, and PCBs, pass through the placental barrier and thus contaminate as yet unborn animals, which can also be contaminated by their mother's milk.

Finally, in countries which hunt whales, the presence of pesticides and PCBs has been detected in oils extracted from cetaceans that are marketed and in the meat of black pilot whales in the Faeroe Islands, which reveals the dangers involved in eating such products.

As a whole, the literature shows that the contamination of the sea by biocides and PCBs is becoming more widespread because of the continuous supply of these little biodegradable, or non biodegradable, products. Marine mammals are a particularly good instance due to their place at the end of food chains in which pollutants tend to become ever more concentrated. Contamination levels are even sometimes staggering. Rates of 50 to 500 micrograms/gram are fairly frequent in the blubber of species studied. A California grand dolphin seems to hold the record with 2,695 micrograms/gram of DDT (O'SHEA *et al.*, 1980). In the Mediterranean Alzieux and Duguy (1979) found up to 706 micrograms/gram of DDT in a striped dolphin. The levels of DDT found in common dolphins in the Black Sea during a morbillivirus epidemic in 1994 were up to 50 to 100 times higher than reference values in the North Atlantic, the North Sea and the Baltic (BIRKUN *et al.*, 1999).

PCB concentrations of the order of 100 to 500 micrograms/gram have frequently been found in the blubber of Mediterranean striped dolphins, with a record 833 micrograms/gram (ALZIEU & DUGUY, 1979). High PCB concentrations are often linked to mass deaths, the contaminated individuals seeming more vulnerable to epidemic infections: striped dolphin, common dolphin, grand dolphin, black pilot whale and the whited sided Atlantic lagenorhynic. The presence of these highly toxic and highly concentrated products in cetaceans is probably not harmless. It is, however, difficult to assess the exact consequences, since for ethical reasons, and bearing in mind the protection regulations, toxicity tests cannot be done on these animals. But numerous pieces of work have shown that the pathology of many individuals found dead when stranded was in keeping with the biocide and PCB load. Pesticides would be likely to provoke lesions, particularly of the suprarenals, lungs and liver, and effects on the lymphocytes, as well as neurological disorders and enzymatic disturbances in keeping with the biocide load. Certain writers describe inhibitor effects on reproduction, and a drop in the testosterone rate. Biocides are accused of acting as an immunosuppressant encouraging the appearance of disease, particularly the recent morbillivirus epidemic. A recent statistical study (KNIKEN *et al.*, 1994) on DDT, DDE, HCH and dieldrin content in the tissues of dead porpoises has not, however, shown higher concentrations in individuals that have died of disease than in those which died of an accidental trauma. On the other hand, experimental work done in Holland confirms the role of biocides in the reduction of natural immunity. Two groups of seals were fed in captivity, one with herrings from the Baltic, a semi closed, much polluted sea, the other with better quality fish from the Atlantic Ocean. Several changes in the immunity functions were observed in the seals fed on contaminated fish (ROSS *et al.*, 1995). Moreover, in 1992, in Texas, the deaths of several grand dolphins, linked to a high mortality of sea birds and fish, was correlated with the discovery of big concentrations of aldicarb (GERACI *et al.*, 1993). The PCBs' pathogenic action is very similar: they cause a disturbance in the immune system that is possibly fatal (LOHMAN *et al.*, 1998; AGUILAR A., 1989). The PCBs cause an induction of the hepatic monooxygenases system (KAWAI *et al.*, 1988), with as its consequence the conversion of the PCB into potentially carcinogenic compounds and a disturbance of the metabolism of the steroid hormones, including sexual hormones. Finally, high PCB contents are associated with a drop in the reproduction rate (SUBRAMANIAN *et al.*, 1987). A statistical study done in Great Britain on the state of health of porpoises found dead showed that individuals seriously contaminated with PCBs presented twice the mortality due to infectious diseases (JEPSON *et al.*, 1998).

Mobilization of blubber in case of prolonged fasting or during lactation makes these toxic lipophilous compounds pass into the blood and worsens the harmful effects of the biocides on individuals that are already weakened by malnutrition. The effect on the mother nursling couple is still more perverse. A fraction of the liposoluble biocides present in the maternal organism is eliminated during lactation or across the placental barrier. This explains why the contamination rate declines with age in females and rises regularly in males. Thus, females seem able to get rid of part of their toxic load at the expense of their progeniture, which very soon bears high concentrations. The health consequences for these young animals are probably sizeable. A newly born striped dolphin stranded at Hyeres in 1976, for example, presented concentrations of 279 micrograms/gram of DDE in its lungs (ALZIEU, DUGUY, 1979). Like the biocides, PCBs cross the placental barrier and the foetus is consequently contaminated before birth. A dead newly born striped dolphin stranded at Hyeres in 1976 presented, for example, PCB rates of 45 micrograms/gram in its liver (ALZIEU and DUGUY, 1979).

b3. Pollution by heavy metal and metalloids

Whether in elementary or in combined state, metals and metalloids present more or less toxic properties used in many marketed preparations. They have been enormously used from the start of the industrial age. Only the mortal poisonings in Japan in the 1950s and 60s, at Minamata, with organo mercury compounds, made us better aware of the problem that arises when these elements are discharged into the environment. Metals and metalloids are present in unpolluted sea water, but in very weak concentrations. And anyway, certain of these elements are vital to the functioning of the organism, since they enter into the molecular structures of enzymes that are essential for life: haemoglobin and myoglobin iron, haemocyanin copper, dehydrogenate zinc, peptide manganese, etc. But if the environment is overloaded with these elements, the living organisms absorb more than necessary and this excess can become harmful. The sources of metals and metalloids are essentially linked to industrial, agricultural, medical and urban discharge, but natural emission should also be taken into account. This is the case, for example, in the Mediterranean, where volcanic activity brings non negligible amounts of mercury, which raise the 'background noise' compared to the Atlantic (BACCI, 1989). The digestive tract is the main way these elements enter cetaceans. These stable products are increasingly concentrated throughout the food chain by factor 8 to 10 for each change of link in the food chain (VIALE, 1974). Air respiration and transcutaneous penetration could also have a role here (AUGIER *et al.*, 1993b). Certainly because of this trophic bioconcentration, the rates of metals and metalloids found in cetaceans are among the highest ever detected in living beings. The strongest concentrations are almost always found in the liver, which is certainly in keeping with its role as an organ that presents a barrier to toxic products. Next are the kidneys, which often present a heavy load of metals and metalloids, certainly in keeping with their role as blood purifiers. But these defence phenomena are very often worn down by excess, and the metals and metalloids then invade practically the entire organism, since they have been found in almost all organs, as well as in the unborn foetus and the mother's milk. A newly born fin whale calf stranded at Marseilles in 1997 presented high levels of mercury, copper and zinc, especially in its liver (AUGIER *et al.*, submitted).

In cetaceans, very numerous metals and metalloids have been identified: silver, aluminium, gold, arsenic, barium, bromine, calcium, cadmium, cerium, chlorine, cobalt, chromium, caesium, copper, iron, mercury, iodine, potassium, lanthanum, magnesium, manganese, molybdenum, sodium, niobium, nickel, lead, rubidium, antimony, scandium, selenium, samarium, tin, strontium, thorium, uranium, vanadium, yttrium, zinc, zirconium in all the mysticetes and most of the odontocetes (there too, in all likelihood in all the cetaceans studied). In the Mediterranean, the highest concentrations are met for mercury, but the values found for other metals are impressive. Work done by Augier *et al.* (1991, 1993a, b, c, 1994a, b, 1996a, b, 1997, 1998) has shown the following ceilings:

- Mercury: 4,770 micrograms/gram in the liver, 833 micrograms/gram in the lungs, 716 micrograms/gram in the kidneys, 259 micrograms/gram in the encephalon (as an indication, the maximum permitted value in tuna meat for human consumption is only 0.7 micrograms/gram and 0.5 micrograms/gram for other fish). Viale *et al.* (1998) also mention a young female grand dolphin, found 12 April 1995 on the Corsican coasts, whose liver presented 4,250 milligrams/kilo dry weight!
- Selenium: 1,320 micrograms/gram in the liver, 233 micrograms/gram in the lungs, 211 micrograms/gram in the kidneys
- Zinc: 674 micrograms/gram in the skin, 260 micrograms/gram in the lungs, 253 micrograms/gram in the liver
- Strontium: 453 micrograms/gram in the skin, 183 micrograms/gram in the liver, 146 micrograms/gram in the lungs
- Nickel: 100 micrograms/gram in the encephalon, 52 micrograms/gram in the lungs
- Copper: 48 micrograms/gram in the liver, 24 micrograms/gram in the kidneys
- Cadmium: 38 micrograms/gram in the kidneys, 23 micrograms/gram in the liver
- Arsenic: 6.2 micrograms/gram in the heart, 5.2 micrograms/gram in the encephalon.

To give its correct value to these dolphins' load of metals and metalloids, here are the minimal values obtained in other dolphins: 0.2 micrograms/gram of mercury, 0.5 micrograms/gram of selenium, 2.6 micrograms/gram of zinc, 2 micrograms/gram of strontium, 0.17 micrograms/gram of arsenic, 0.1 micrograms/gram of copper, 0 micrograms/gram of nickel and cadmium. The presence of such quantities of toxic elements in the cetaceans studied, particularly in the vital organs such as the liver, kidneys, lungs, heart and encephalon, poses a serious toxicological problem that is hard to answer with certainty. Indeed, in the absence of





experimental poisoning in vitro studies that are banned by law, lethal doses are not known. One is therefore reduced to making comparisons with other zoological groups, without knowing exactly if the same comclusions can be applied to cetaceans. Be that as it may, for most other animals concentrations of metals and metalloids that are often lower than those met in cetaceans cause serious disorders in the hepatic, renal and encephalic tissues and usually lead to the animals' death. Work done by Augier *et al.* (1993) has shown an impairment of the hepatic cells and a lysis of the renal tubules and glomerules of very contaminated dead striped dolphins found stranded on the shore. One should also bear in mind the synergic phenomena between the various elements which may increase their virulence, the resulting toxicity often being greater than the sum of toxicities of each metal and metalloid. Such synergic effects have been shown between copper and mercury, zinc and cadmium (AUGIER *et al.*, 1988). Other pollutants can play a synergic part, for example pesticides and polychlorobiphenyls, which are well known for their ability to induce dysfunction of the vital metabolisms and depression of the immune system (ARNOUX *et al.*, 1996). But also should be borne in mind the existence of protective mechanisms against toxicity of metals. They may in fact be found associated to metallothionines in a kind of protein compound (TOHYAMA *et al.*, 1986). Thus stable concretions of mercurous salts (mercurous selenates and selenures) in the hepatic tissues of dolphins have been shown (MARTOJA and VIALE, 1977, THIBAUD, 1978, AUGIER *et al.*, 1993a). This sort of fossilization of mercury and selenium (separately toxic) is, according to Thibaud (1978), a defence process which, as in tuna, makes these two elements harmless. A microscope study using a silver based developer enabled Augier *et al.* (1993b) to show that compounds formed between selenium and mercury were mainly localized in the hepatocytes and macrophages of the liver and in the tubules proximal to the kidneys. The defence process, however, seems to have been over taxed, since granules are found in the lungs, and since high mercury levels are still in evidence in the other organs, including the encephalon (AUGIER *et al.*, 1993b). Be that as it may, the rates of heavy metals found in cetaceans are among the highest ever detected on living beings. In the St. Lawrence estuary (Quebec), certain white whale corpses are considered by ecologist associations as toxic waste, so high is their mercury level! These same white whales have been affected by an abnormally high number of tumours, attributed to the river's being contaminated with pesticides, heavy metals and PCBs. A demonstration of this has been done on a white lake fish (*Coregonus clupeaformis*) but, as has been said, experimental transposition to cetaceans does not seem possible (ARTOIS & LAMARQUE, 1997). In January February 1995, high mortality affected many mainly fish eating cetacean species, and also pinnipeds and sea birds: 366 long beaked common dolphins, some grand dolphins, 3 fin whales, 2 point snout rorquals, 1 Bryde's rorqual, 51 California eared seals, some Pacific divers, black necked grebe, brown pelicans, and plumed cormorants. Only the vaquitas, blue whales and grey whales seem to have been spared. Though no definite proof has been furnished, it seems that this very high mortality is imputable to the unloading of an unidentified toxic substance near these species' fishing areas. But this still remains to be proven (VIDAL & GALLO REYNOSO, 1996).

b4. Contamination by radionuclides

No alarming report on measures of contamination by radioactive elements has been made for cetaceans. A study done in British waters concludes that the concentrations noticed on coastal porpoises cannot be responsible for any pathogenic effect (BERROW *et al.*, 1998).

*1.2.5. Ingestion of foreign body (plastic bags, wounding objects)*

Big plastic sheets have been found in the stomachs of sperm whales stranded in Corsica; other foreign objects can be accidentally ingested and cause the deaths of animals (PETIT *et al.*, 1956). In captivity, ingestion of foreign bodies is a major cause of problems; the dolphins' boredom and curiosity, plus the necessarily small surface area of the place where they are kept, explain the prevalence of accidental ingestions.

# 2. Natural causes of mortality

## 2.1. Predation

Most cetaceans have few natural predators: killer whales, sharks, sometimes false killer whales, perhaps peponocephalus and pilot whales. Transient killer whales attack virtually any species of marine mammal, from porpoises to blue whales. And it is remarkable to see that the presence of residential killer whales, fish eaters, is tolerated without the slightest fear by small cetaceans, whether *in natura* or in pools (Vancouver aquarium: killer whales and Pacific white flanked lagenorhync, Mexico aquarium: (Keiko) killer whale and grand dolphins). False killer whales have often been held guilty of attacking little Stenella and *Delphinus dolphins* by the tunny boats of the East Pacific. An apparently fruitful case of attack is also known, on a baby megaptera in Hawaii; and a harassment of an adult off Colombia. An attack on a group of sperm whales was observed in excellent conditions in the Galapagos Islands, but it is hard to say whether this was a case of attempted predation, or aggressive behaviour (competition for food) or kleptoparasitism, an attempt to force the sperm whales to regurgitate their prey, especially as the false killer whales were accompanied by tursiops, unlikely to be feeding on sperm whales. In any case, pieces of meat were snatched from the fins of the sperm whales (PALACIOS & MATE, 1996). In many parts of the world (e.g. Florida, South Africa, Eastern Australia), many big shark species are believed to be the main factor of mortality of small cetaceans, including grand dolphins. The population biology of the grand dolphins living on the Florida coasts might be dependent on the size of the dogfish population, with young cetaceans finding that living in big groups gave them better protection against predators, whereas the near absence of sharks in the Adriatic waters would explain the low average group size of the Adriatic groups (BEARZI *et al.*, 1997 )

*2.2. Inter species conflict*

Recently, young porpoises of under three years (size 140 cm.) were found dead in the Moray Firth, Scotland, with unspecific lesions (ROSS, 1993), and also in Cardigan Bay, England (JEPSON & BAKER, 1998). The field study revealed that tursiops caused the deaths of these porpoises by crashing violently into them (HARNDEN, 1995). The lesions observed on the porpoises were extremely severe: fifteen or so ribs cracked, burst spleen or sometimes kidney or abdominal wall. This aggressive behaviour seems very isolated. Some researchers compare these attacks with the infanticidal behaviour shown in some grand dolphin populations,





particularly in Australia or the American Pacific. The size of the porpoises, like that of young tursiops, would make them targets for "infanticide training" (PATTERSON *et al.*, 1998). Infanticide is a normal habit in many mammals, such as lions: it is a radical way of ensuring the supremacy of the animal's own genes. But the interest of the method remains to be demonstrated for cetaceans, whose reproductive cycle is so long and so little productive.

Sometimes clashes between swordfish and dolphins are recorded, and these belligerent fishes' long beaks have been found in the corpses of certain cetaceans.

*2.3. Predation accidents*

- Anti predator response from the desired prey : some cases are known where tursiops have died, or nearly died, because a big cephalopod that they were attempting to catch closed up their blowhole with its tentacle. In the US, ingestion of a porcupine fish may stifle the careless predator because this fish can distend itself by making its sharp spines bristle up (HULT *et al.*, 1980).
- Pursuit of prey onto land : many well documented cases indicate that certain cetaceans come to gather their prey on land, like the killer whales in the Crozet Islands (penguins, pinnipeds), or tursiops driving fish onto the shores in Florida. While learning this type of hunting, young cetaceans can get really stranded and not get back into the water. Christophe GUINET witnessed such a scene in Crozet and was able to push the young killer whale off into the sea again.

A similar case was reported in the Mediterranean, where an adult killer whale was stranded in Majorca on 26 December 1941, chasing a school of dolphins (CASINOS & VERICAD, 1976).

*2.4. Poisoning*

14 humpback *Megaptera novaeangliae* whales seem to have succumbed to saxitoxin poisoning (a paralysing toxin of the ciguatera syndrome) in the Cape Cod area, from eating contaminated mackerel (GERACI, 1989a; SAINT AUBIN, 1991); similarly, part of the mass mortality of tursiops of the American coasts in 1987 could be imputed to this phenomenon (GERACI, 1989b) : cold currents brought North Carolina a large quantity of Ptychodiscus brevis dinophycean alga, whose distribution area is normally from the Mexican Gulf to Florida. This alga is eaten by a local phytophagous fish (menhaden) that is predated by mackerel. These fish seem not to be affected by the toxin but this is not the case for the grand dolphins, which catch both kinds of fish (KLINOWSKA, 1991); moreover, 41 people who merely breathed the volatile toxin suffered from respiratory and neurological disorders (ROSSION, 1988). However, this thesis is strongly criticised by SCHULMAN F.Y. *et al.*, 1994, who impute this mortality to a morbillivirus epidemic, whose trace is immunologically confirmed in 53% of the samples kept and later analysed (LIPSCOMB *et al.*, 1994c), and suggest that the toxin hypothesis is a governmental manoeuvre to silence the rumours of pollution spread by Greenpeace!

(FL Dolphin Mortality. On Jan. 10, 2000, NOAA scientists reported that examinations of some of the 115 dolphins that died in bays along the FL panhandle since August 1999 show lung and respiratory tract lesions similar to those found in manatees determined tomhave died from red tide toxins in 1996. Red tide toxins were also found in the stomach contents in some of the dolphins (Associated Press))

*2.5. Parturition*

Parturition is always a tricky time in a female's life. Cases of dystocia are known in many species, as well as cases of multi twin bearing in species where one baby is the norm, and where the pregnancy would certainly have presented problems: 3 foetuses in a fin whale (BESSON and col. 1982); two foetuses in a Risso's dolphin, found dead on the coasts of Northern Ireland after giving birth to one of the two babies (GASSNER & ROGAN, 1997).

*2.6. Ice entrapment*

Everybody remembers those spectacular images of the profusion of means used to help two grey whales held prisoner in the Arctic ice. An unprecedented media operation basically used to break the ice between the two still greater giants (the US and the USSR) at a total cost roughly amounting to the yearly budget for American cetological research. Nearer home, BIRKUN Jr. & KRIVOKHIZHIN (1997) explain how dozens of porpoises were trapped by ice in a dead end in the Azov Sea instead of being able to migrate to the south of the Black Sea.

*2.7. Causes leading to the stranding of living animals*

*2.7.1. Navigational error*

A phenomenon that is often described in classical literature would concern pelagic species lost on gently sloping sandy coastal bottoms whose sonar echo is unfamiliar to them (DUDOCK VAN HEEL, 1974). Perhaps contributes to the efficacity of the pilot whale hunt in the Faeroe Islands.

In 1994, some Stenella seemed to be held prisoner in deep water basins surrounded by Posidonia shallows in Giens, perhaps frightened by fire from underwater mines, and were only extricated by the help of Jean Michel BOMPAR, the firemen and a team from the Antibes Marineland, who finally succeeded in getting them back into open water, from which they returned to the open seas (BOMPAR, 1996).

On 17 October 1996, a fin whale and its baby entered the Gulf of Fos and ventured into the shallows of the Port Saint Louis mussel bed; the young whale calf (6 metres long, about 5 tonnes) was stranded in a metre of water. It was set free at the cost of exhausting and troublesome manoeuvres, with the help of the firemen and the Autonomous Port, coordinated by T. RIPOLL (GECEM).

*2.7.2. Anomalies of the earth's magnetic field*

A hypothesis put forward by Margaret KLINOWSKA (1991b, 1991c) studying the distribution of pilot whale strandings on the Scottish coasts. Preferential sites for mass strandings of living animals are neither distributed haphazardly nor according to currents but are in places where lines of the earth's electromagnetic field, according to the direction of which some cetaceans are thought to navigate, are more or less perpendicular to the shore, thus causing them to be stranded. Recent counter studies in other parts of the world (New Zealand) do not confirm this hypothesis (BRABYN & FREW, 1994).

Other spectacular sperm whale strandings are thought to be linked to violent magnetic storms.





*2.7.3. Solidarity with a stranded leader or companion*

Frequently, it has been shown that a whole group of cetaceans could get stranded around a sick companion, refusing to leave it until it died. Particularly dramatic examples have been recorded with a group of false killer whales voluntarily getting stranded in the Tortugas Islands around a big wounded male, who was losing blood and was suffering from a major infestation of the inner ear (very likely Crassicauda). The other false killer whales, because of the very special shape of the beach, could easily return to the deeper waters but every time the assembled people tried to save them, they obstinately returned to get stranded around the wounded male, communicating intensely during the whole duration of the stranding (three whole days!). Only when the wounded cetacean died did the other false killer whales got back to the open sea. In other circumstances, many if not most of the stranded cetaceans would have suffered from sunburn, and the return to the sea would have been much more problematic. Many other cases are known for sperm whales, killer whales, false killer whales and pilot whales. The pilot whales which stopped in the Gulf of Saint Tropez some years ago, obstinately refusing to go back to sea, seem to fall into the same category, and two corpses were found the day after the group disappeared. On 17 April 1994, five Risso's dolphins were stranded off the Ebre delta, around a female suffering from serious respiratory difficulties. Once the female was withdrawn, to be taken to a care centre, the other grampuses went back to the open sea without any problem (ALEGRE *et al.*, 1995).

In rare circumstances, such strandings can concern many species at the same time. This was the case on the Atlantic coast of the US, with pelagic grand dolphins showing solidarity with a herd of black pilot whales (DUIGNAN *et al.*, 1996).

The intentionally provoked strandings of black pilot whales in the Faeroe Islands are like these mass strandings, but their cause is obviously completely artificial.

*2.7.4. Panic fear*

On 23 August 1987, a hundred or so striped dolphins took refuge near the coast and twice threw themselves onto the beach of Rai del Barquero, Puerto de Bares, in north west Spain, apparently to escape the greed of six killer whales (NORES & PEREZ, 1988).

*2.7.5. Strandings linked to a pathological cause*

Disturbance of the sonar system, cerebral disorders : The action of certain parasites, or the inflammations these cause, are frequently implicated. Search for shallows to avoid drowning: In some circumstances, cetacean mammals prefer stranding to having to stay on the surface to breathe (see above, Mass strandings/solidarity with a stranded leader). How often are they able to manage by themselves? Nobody knows.

## 2.8. Pathological causes of mortality

As was said in the introduction, it is often quite difficult to define the causes of mortality for a cetacean found dead. But the accumulation of studies and data on the subject permit a better grasp today of the pathology of wild cetaceans.

# NON INFECTIOUS PATHOLOGY

## 1 - VARIOUS INFECTIONS

Lesions of the bone have often been described in the literature, but care should be taken as to the real importance of this (CARUEL L., DUGUY R., 1986).

- frequent fractures of the ribs (collision with ships; e.g. Jean Louis FABRE's whale)
- frequent vertebral osteoarthritis lesions on old animals, going as far as the knitting together of the cervical vertebrae with the cranium (tursiops described by DUGUY and VAN BREE)
- abrasion of the teeth linked to wear and tear and old age. Would be responsible for the mortality of *Orcinus, Grampus, Stenella coeruleoalba, Delphinus* (TOUSSAINT P., 1977). Dubious; several cases are known of sperm whales lacking mandibles but in good health; the case of *Mesoplodon layardii*.

In captivity, many rare diseases have been diagnosed thanks to the numerous possibilities for diagnosis; their significance is certainly very trivial: Hodgkin's disease (a malign lymphogranulomatosis) in a killer whale, and *Chediak Higashi* syndrome, a hereditary immunodeficiency disease described in man, also signalled in a killer whale (BERNY, 1998).

## 2 - CARCINOLOGY

The carcinology of cetaceans is little known; the prevalence rate is said to be very low in an unpolluted natural environment. In the literature, there is mention of the presence of a squamous carcinoma of the skin of a Stenella stranded in Spain (CALZADA & DOMINGO, 1990), of renal tumours, of the pre stomach, of the lung (metastasis), of the ovaries, of the mesentery, of adenoma (a benign tumour) of the liver, of the suprarenal glands, of the thyroid, of the kidney, of the testicles, etc. GERACI *et al.* (1987) review 41 cases of tumours described in cetaceans, among which 24% are skin cancers, papillomas and fibromas. This figure, over estimated because of the ease of observing external lesions, is also explained by permanent exposure of the cutaneous tissue to carcinogenic pollutant agencies (cf. its frequency in the St. Lawrence). The frequency of tumorous lesions on cetaceans in the St. Lawrence River in Quebec, seriously affected by chronic pollution due to discharge from a big industrial basin, is well known. Moreover, the cetaceans of the St. Lawrence, first and foremost the white whales, have served as bio indicators to draw the attention of the scientific community to human health risks there (DE GUISE S. *et al.*, 1991).

## 3 - PARASITOLOGY MYCOLOGY

### PARASITOLOGY

Parasites are responsible for 25% of causes of cetacean deaths.

Most parasites are not pathogenic, it not being in their interest to kill the host species. A few parasites only are frequently responsible for deaths, but the proliferation of many species may become pathological if it happens on an organism that is weakened and immunosuppressed.

Parasite systematics can provide interesting biogeographical information (populations' isolation or contact): *Cyamus monodontis* is present on Narwhals and Belugas which share the same Arctic waters, and female and young Sperm Whales remaining in the warm South African waters are parasitized by Neocyamus physeteris whereas the males, moving down into





Antarctic waters, are parasitized by *Cyamus catadontis*.

- Parasites that are not pathogenic, or only slightly so
- Ectoparasites
- The fauna harboured on the skin surface of whales includes not only parasites strictly speaking but also epizoa like the Diatoma on the surface of the skin of Blue Whales, such as Cocconeis ceticola
- Barnacles of the Coronula and Conchoderma genus, mainly on whales with major callosities
- Xenobolanus clinging to the fins of slow-swimming species (e.g. St. Tropez Pilot Whales (Globicephala)
- Conchoderma, Lepas, clinging to the teeth
- Copepoda, Pennella sp, stuck in whales' bodies
- Amphipoda, Cyamus spp and the like, that can be pruriginous, but no worse than that. Even though up to 110,000 Cyamidae were counted on only 2 Grey Whale callosities. More usual on the big, slow-swimming whales, but also found on faster species
- Internal parasites
- Phyllobothrium delphini (Cestoda), very frequent, not necessarily pathogenic, but sometimes responsible for peri-genital abscesses when there is massive infestation
- Anisakis (Nemotoda): its pathogenic power is not known for cetaceans, but 50 kilos were found in the stomach of one Sperm Whale. Today, the Anisakis simplex group has broken up into at least five species, still awaiting description, that parasitize a great variety of cetaceans from the Porpoise to the Sperm Whale, and including Tursiops and Ziphius (D'AMELIO *et al*., 1993)
- Stenurus minor (Nemotoda): isolated on 85% of the air sinuses of Porpoises killed during an aboriginal hunt in Greenland. Cannot be very pathogenic, with such a high figure for a healthy population
- *Monorygma grimaldii* on the mesentery
- *Skrjabinalius guevarai* in the lungs
- Toxoplasma sp., little known, isolated on dolphins affected by the Morbillivirus. Generally pathogenic
- Frequently or constantly pathogenic parasites
- Various Trematoda (flukes), whose pathogenic power is little known, but some of which affect the brain (Nasitrema, invoked in 91% of strandings in California), liver, blubber, lungs, intestine, and especially the stomach (Pholeter gastrophilus, responsible for very many inflammatory reactions, sometimes extremely voluminous
- Crassicauda spp., responsible for very diverse lesions according to species and site, often thought to be a major threat to certain cetacean populations. Three main forms:
- *Crassicauda grampicola*, for the skull: inflammatory osteolytic reactive lesions, on the skull, the air sinuses, the inner ear, the jawbone. Described for Grampus, Tursiops, *Stenella attenuata* and *Stenella longirostris* and Delphinus. Thought to be a major cause of Stenella deaths in the South Pacific (15% of natural deaths, or about 2% of the population). Really impressive lesions.

- For the mammary glands: multiple abscesses of the teats, leading to a failure to reproduce, described for Porpoises and White-Sided Dolphins (Lagenorhynchus)
- For the urinary apparatus: *Crassicauda boopis* is a giant Nematoda of up to 2 metres long, which provokes renal ischaemia through obstruction, and especially an immunological reaction that is all the fiercer if the individual is immunocompetent, that quickly leads to acute kidney failure. Rate of prevalance is assessed at 95% for the Fin Whale, 98% for Blue Whales and 90% for the Megaptera, causing 50% of natural deaths and every year destroying 5% of the population, and preventing the numbers from being made up again. Young individuals are infected during gestation (trans-placental contamination) and other individuals by contamination by urine. LAMBERTSEN suggests treating the big whales by injecting them with a single dose of Ivermectine shot from an anaesthetic gun.

## MYCOLOGY

Less than 5% of the factors that help or cause cetacean deaths in marineland, and rarer still outside, in the wild.

- Distinguish between external and internal mycosis, internal mycosis being much more serious
- Influence of immunosuppressive conditions which encourage the mycosis
- EXTERNAL MYCOSIS

Case: Trichophyton sp. ringworm described in marineland on a Tursiops rostrum

- INTERNAL MYCOSIS

Candida albicans thrush, usually. Infection of the orifices: blowhole, anus, genitals, mouth, digestive mucous membranes and skin. May finally become generalised as septicaemia, with vomiting and regurgitation if the oesophagus/stomach is attacked

*Pulmonary aspergillosis*, a contaminant isolated on Stenella which have been affected by the *Morbillivirus epidemic*

- Human contamination possible! You can catch this!

Actinomycosis, an infectious germ also isolated on Stenella which have been affected by the *Morbillivirus epidemic*

Lobo's Disease (Loboa lobi), which causes chronic invasive fibrous *keloid dermatitis*, described on Tursiops and *Tucuxi Dolphins* in America (Florida and Suriname) and in some cases on Porpoises in the waters of the Gulf of Gascony (COLLET A., pers. paper)

- Human contamination possible! You can catch this!

## 4 - BACTERIOLOGY

Implicated, some think, in 25% of causes of death in the natural environment; according to HOWARD, bacterial lung infections are the main cause of mortality in Hawaiian waters (DUNN J.L., 1990).

What is certain is that bacterial infections and secondary infections are a major cause of mortality in captivity.





- distinguish between the isolated agent and the cause of death: rare are those bacteria able to cause death every time, while they can often develop on an organism that is weakened by an infection and thus help toward the degradation of the general condition. Though easy to find during additional examinations, they must not too quickly be seen as having caused the death.
- distinguish between highly pathogenic infectious agents (*Erysipelothrix, Nocardia, P. pseudomallei, Clostridium)* and infection from opportunistic germs. A necropsy can show traumatic causes that resulted in fatal secondary infection; examples in the natural environment:
- metritis with ovarian abscess in a pilot whale stranded at La Rochelle in 1973
- infection seated in the lungs in Stenella with multiple splinter fractures of the ribs that perforated the lung peri
- genital abscess in dolphins heavily parasited by *Phyllobothrium delphini*
- ingestion of wounding foreign body (porcupine fish in the US, for example) Most often, great influence on the general condition and stress factors…

4 germs particularly should be mentioned, because of possible human contamination :

*Erysipelothrix rhusiopathia*, responsible for swine erysipelas in pigs and poultry, as well as sheep, rodents and man, frequently isolated in many cetaceans, supposedly contaminated by ingestion of infected fish or crabs. In captivity, this risk is increased by transmission by flies settling on food. Two clinical forms :

- an acute septicaemic form that is asymptomatic, fatal in between several hours and three days; on autopsy, ascites, ecchymosis, internal haemorrhage, intestinal petechia, blackish stools
- a cutaneous form, characterized by lesions ranging from an area of folded or raised skin, often square or rhomboid, hot and painful, from 2 to 5 sq. cm., forming greyish raised blotches, with erythema of the underlying fatty layer, usually on the back, head and fins, able to become widespread in ulcerous or necrotic lesions (BERNY, 1998). Human contamination is frequent if the autopsy is not done in rigorously aseptic conditions, as in Brest in 1974, when several students were affected (TOUSSAINT P., 1977). A very pruriginous erythematic macula then appears within 24 hours. For dolphins kept in captivity, live attenuated vaccines exist against swine erysipelas, but with risks of sensitization for the live vaccine.

Human contamination possible!

- *Pseudomonas pseudomallei*, an opportunistic germ, especially present in South "east Asia, but recently shown in France in marineland; an opportunistic germ provoking in humans and dolphins an acute lung infection with suppurative caseous lesions of the lymph nodes and viscera and quick, fatal septicaemia. The germ is extremely resistant and is transmitted by soil and dirty water.

Human contamination possible!

*NB. A search for these two bacteria is compulsory for any dolphin dead in captivity (Order of 20.10.1991).*

- *Brucella maris (brucellosis)*, recently (1994) discovered in seals, a sea "otter and cetaceans (porpoises, Stenella, white flanked dolphins, common dolphins, killer whales, tursiops, pilot whales) in Northern Ireland, then Scotland, then the whole of Great Britain (FOSTER, 1996, JEPSON *et al.*, 1996) and finally in France on the Channel shore (MOUTOU, personal com.) and in the North Atlantic (TRYLAND *et al.*, 1999). Its pathogenic power in cetaceans and humans is not known, but, by analogy with various more common germs, particularly *Brucella melitensis* in sheep and goats, and *Brucella abortus* in cattle, responsible for brucellosis, a major breeding pathology highly transmissible to man (undulant fever), the British Government has forbidden the handling of stranded cetacean and pinnipe corpses. For research purposes, it is requested to remove the spleen from all fresh stranded cetaceans and take it frozen to the AFSAA laboratory.

Human contamination possible!

- *Vibrio spp.*, many species described in cetaceans, sometimes implicated in septicaemia. In autumn 1996, when a *Kogia breviceps* pygmy sperm whale was stranded, a person who came to help the first aid team cut himself on the rocks and died several days later of a Vibrio septicaemia (JP.W. GENIN, personal com.). *Vibrio alginolyticus* was discovered in a stranded Atlantic white flanked lagenorhync, after provoking acute necrotic hepatitis and acute focal bronchopneumonia (TANGREDI & MEDWAY, 1980).

Human contamination possible!

As well as these four pathogenic agents, many other infectious species are described in natural conditions or, more frequently, in captivity.

• Pulmonary infections are a major dominant of cetacean pathology and a prime cause of death in captivity. Several physiological features explain this prevalence: explosive respiration encourages deep installation of germs present in the inhaled spray; adaptations for diving also encourage infections to remain deep down in the breathing apparatus (BERNY, 1998). In captivity, the problem is made far worse by germs brought by the public to the pool.

Many germs, often opportunistic, have been blamed for pulmonary infections or secondary infections : *aeromonas hydrophila, Corynebacterium sp., Diplococcus pneumoniae, Edwardsiella tarda, Erysipelothrix rhusiopathiae, Escherichia coli, Klebsiella pneumoniae, Klebsiella minoscleromatis, Mycobacterium sp., Nocardia brasiliensis, Nocardia caviae, Pasteurella mulocida, Pasteurella hemolytica, Proteus sp., Pseudomonas aeruginosa, Staphylococcus aureus, Streptococcus sp. Bhemolytic, Vibrio alginolyticus, etc. (BERNY, 1998*

- Nocardia are responsible for nodular formations suggestive of a mycological infection (=mycetomes), with suppurative granulomatic pneumonia described in a dozen cetacean species.
- Cutaneous infection are often described in captivity, but the conditions lend themselves to this; the most frequent isolated germs are the same as in classic veterinary medicine: *Pseudomonas aeruginosa, Staphylococcus aureus, Streptococcus sp., Vibrio, Aeromonas,* etc.
- Muscular infections are encouraged in cetaceans by the working of anaerobiosis during diving and high glycaemia. These conditions provide an extremely fertile terrain for anaerobic germs to develop after bites (intra species fighting) and, in captivity, because of the many traumas that occur in the lives of all captive dolphins: a powerful fight when being captured, bumping into the sides of the pen, superficial wounds badly healed, injections given with insufficient asepsis, etc. A classic germ is *Clostridium perfringens*, of the tetanus and botulism etc. bacillus family.
- Digestive infections are fairly frequent, at least in captivity, where they are dominated by consequences of stress induced gastric ulcers. Nocardia (N. paraguayensis, N. asteroides) are responsible for ulcerative lesions of the mouth and beak of a captive tursiops (JASMIN *et al.*, 1972). Ulcers of the hard palate associated with cutaneous ulcers were described on 6 sperm whales stranded on the Belgian and Dutch coasts during the 1994 -95 winter (a presumption of viral origin was proposed on this occasion) (JAUNIAUX & COIGNOUL, 1996). Gastric ulcers and haemorrhagic gastro enteritis with vomiting and diarrhoea are frequent in captivity, encouraged by stress, damaged food, ingestion of a foreign body, mass parasitism worsened by stress. Opportunistic germs like *Salmonella typhimurium, Salmonella enteritidis, Edwardsiella tarda, Pasteurella multocida, Clostridium perfringens,* etc. Cases of Vivrio alginolyticus hepatitis have been described, alongside viral hepatitis.
- Cardio circulatory infections have most often been attached to septicaemic complications : *endocarditis* with *Salmonella typhimurium, Streptococcus sp.,Corynebacterium sp*.
- Urinary infections, however, seem to be rare, perhaps due to increased post "prandial diuresis. In captivity, cases of cystitis associated with septicaemia have been described.

## 5 - VIROLOGY

> What is a virus? Viruses are the smallest living beings known. Neither animal nor vegetable, viruses have no cellular core and are only made up of a genetic material (DNA or RNA) enveloped in a protein coat: the capsid. Without either active enzymes or a metabolism of their own, viruses depend totally on the host cells in which they multiply. They can thus be seen as simple parasites active at genetic level. Each group of viruses specializes in parasiting determined bacteria, vegetable or animal cells. Animal viruses are responsible for a great many pathologies against which there are few specific medicines, when the disease is declared. Only preventive vaccination allows contamination to be avoided.

Viruses are much more constantly pathogenic infectious agents than bacteria. There are two ways of determining a viral infection :

- isolating and identifying the virus by electron microscope (research centre) serological
- dosing with antibodies when reagents exist (specialist immunological laboratory).

The presence of antiviral antibodies does not mean that the animal is ill when it is being examined, but that it has been in contact with the virus during its lifetime. Two serologies at 15 to 30 days' interval would be needed to get a kinetics of antibodies and this cannot be done on stranded animals. The results of the serology should thus be considered according to memorials and necropsic symptoms. Basic significance of the study of antibodies that bear witness to the passage of the virus, in various cetaecan species. The appearance of important epizooties (Morbillivirus, Herpes virus in seals) is most suggestive of a viral episode; other viral infections offer characteristic symptoms.

The recent morbillivirus episode in Mediterranean striped dolphins, relatively well monitored, will serve as an example for a detailed study of the mechanisms of the epidemiological enquiry.

- Pox virus, known in the artifical pool and *in natura* in many species: in the North Atlantic, in tursiops, porpoises and white flanked lagenorhyncs; on the Peruvian coasts in tursiops, the common Cape dolphin, the dark lagenorhync and the Burmeister's porpoise (VAN BRESSEM & VAN WAEREBEEK, 1996) with half the studied population affected: point shaped or ring shaped lesions turning into black marks (tattoo), particularly on the back, head and fins. Opinion is divided as to the seriousness of the infection, with some seeing it as merely responsible for cutaneous lesions and others as fatal (GERACI *et al.*, 1979). Probably it is usually an endemic infection like human children's diseases (VAN BRESSEM & VAN WAEREBEEK, op. cit.). The captive individuals present these lesions for years without being infected in any other way.

Human contamination possible!

- Adenovirus (canine contagious hepatitis). Isolated in a boreal whale caught in the Antarctic; apart from this, only known as a pathogen in captive pinnipeds, where it is responsible for a hepatitis that is always fatal
- Hepadnavirus (human hepatitis B): a viral agent of the *Hepadnaviridae* family sems to have been diagnosed in 1987 in a Lagenorhyncus obliquidens Pacific lagenorhync (BOSSART *et al.*, 1990).
- Herpes virus: isolated in 2 multi infected St. Lawrence white whales (DDT, perforated gastric ulcers, peritonitis) in 1989. Provokes spherical lesions that are necrotic in the centre, 2 cm. in diameter. Can also cause interstitial pneumonia, but is usually seen as not very pathogenic. Held to have caused fatal encephalitis in the common porpoise in Sweden (KENNEDY S. *et al.*, 1992) Recently described in the genital tract of Scottish porpoises without any effect on reproduction being proved (ROSS *et al.*, 1994).
- Influenza (fowl pest): isolated in a black pilot whale stranded in the US, very much weakened, without specific signs. Better known in pinnipeds, where it causes flu like symptoms and may lead to mass deaths (seal calves in Cape Cod, Massachusetts, in 1979 and 1982 (GERACI *et al.*, 1982). Acute development, haemorrhagic lungs, hypertrophied lymph nodes. Isolated colonies in the pilot "whale are similar to fowl pest, present in seagulls.

Human contamination possible!

Many cases of conjunctivitis in humans (staff carrying out autopsies or giving health care).

- Calicivirus (feline coryza, suilline vesicular exanthema). A pathology described in tursiops (Cetacean Calicivirus Tursiops 1, or CCV1), isolated antibodies in the sperm whale, fin whale, boreal whale, grey whale and free whale. Vesicles 1 to 3 cm. in diameter which when they burst leave nummular scars. Miscarriages described. Not necessarily very pathogenic in cetaceans.
- Papilloma virus, responsible for the proliferation of small converging wartlike lesions, or papillomas, as in the 'Keiko' killer whale, principal actor in the film 'Saving Willy!'. Papillomas have been described previously in many species: genital warts in the killer whale, the white flanked lagenorhync, the sperm whale; skin papillomas in the narwhale, the common porpoise (VAN BRESSEM *et al.*, 1999), and the killer whale; oral papillomatosis in the white flanked lagenorhync, and gastric papillomatosis in the white whale. In Keiko, the symmetrical, fluctuating nature of the lesions is remarkable, suggesting the intervention of other factors, perhaps immunological (BOSSART *et al.*, 1996).





- Picornavirus, isolated in 1968 from a rectal swabbing of a grey whale (!) which was apparently healthy. Unknown pathogeneticity, but within the family of foot and mouth disease of Artiodactyls (cattle, sheep, goats, pigs), potentially contagious for humans.
- Morbillivirus (measles in man, canine distemper in dogs, rinderpest and small ruminants' pest). A remarkable epidemiological model by the quality of monitoring of the disease especially if this is continued! No potential danger described in man, but a new germ for science; in 1994, a new Morbillivirus was described in Australia in racehorses; two riders died of pulmonary and meningea disorders caused by this viral agent...

# EPIDEMIOLOGICAL STUDY OF A MASS MORTALITY IN CETACEANS: THE MORBILLIVIRUS EPIZOOTIC IN THE MEDITERRANEAN STRIPED DOLPHIN

## A. DESCRIPTIVE EPIDEMIOLOGY

### A1. Chronology of the epidemic phenomenon

In July 1990, a mass mortality of *Stenella coeruleoalba* striped dolphins was noticed on the Spanish coasts, soon extending to the whole Western Mediterranean, and then, the following year, to the central basin: the Italian and Greek coasts, before reaching the East Mediterranean and the Black Sea. Unusual strandings of striped dolphins started on the coasts of the Gulf of Valencia from 10 July 1990 on. The number grew over the following weeks, rapidly becoming an epidemic, extending in centrifugal manner from the Spanish epicentre (Fig. 1).

> BIOLOGIST IN CHARGE OF INVESTIGATION!
>
> Epidemiology is a science which deals with everything concerned with the evolution of diseases within animal, vegetable or human populations in time and space. This medical discipline often resembles a police investigation, where a culprit (the causal agent) and his accomplices are sought, and where the particular circumstances at the origin of the drama (factors that favour it) are highlighted. The epidemiological study depends on three successivestages:
>
> - descriptive epidemiology describes the observed phenomena: species involved, times and places of the appearance of the phenomena, symptoms and lesions discovered during the autopsy, etc.
> - analytical epidemiology analyses all the data gathered, and looks for an explanation of the phenomena observed: nature and mode of action of pathogenic agents, age categories involved, favourable climatic, food and environmental etc. factors. This part calls on all disciplines of medicine and naturalist observation, ecology, animal behaviour, to present a synthesis that is as wide and exhaustive as possible
> - predictive epidemiology , lastly, tries to construct models from the data gathered and analysed during the two first stages, in order to suggest hypotheses as to the disease's patterns of evolution according to the various available parameters, and possible attempts at treatment.

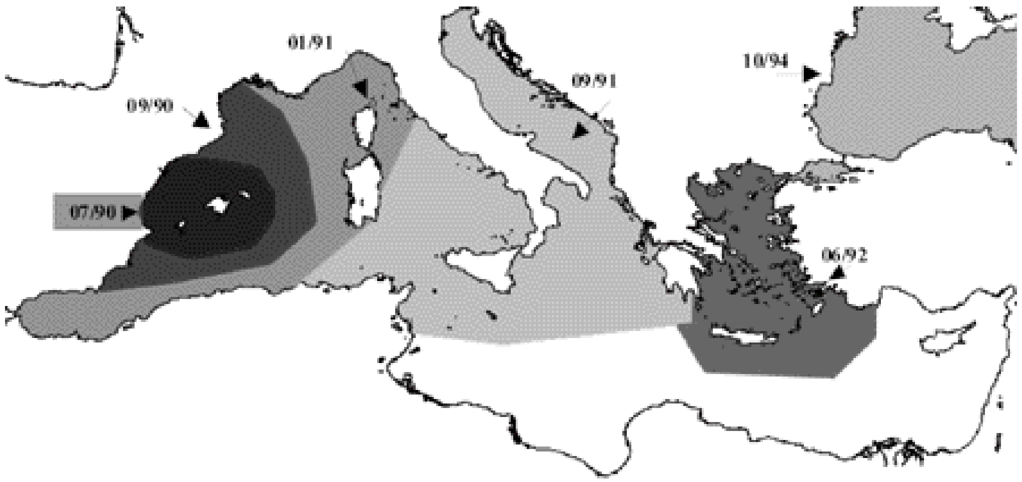



*Fig. 1 Progress of the Morbillivirus epidemic in the Mediterranean, 1990"1992. The idea taken from RAGA and AGUILAR (1992a), BOMPAR and col. 1992, BORTOLOTTO and col. 1992, CEBRIAN (1992), and BIRKUN et al. (1999). The shaded areas plot the maximum extension of the epidemic in July 1990, September 1990, January 1991, September 1991, June 1992 and October 1994.*





The number of strandings reached a peak in September, in the regions of Valencia, Catalonia and the Balearics; in October, the regions of Murcia and Andalusia were affected in their turn, and, northwards, the French coast, where the maximum mortality was noted in mid October. In November 1990, cases were signalled in the Sea of Alboran, on the North African coasts, on the Italian riviera and in Corsica. In January 1991, the epidemic crossed the Strait of Gibraltar (some dolphins stranded on the Donana coast) but did not advance into the Atlantic (RAGA & AGUILAR, 1992a).

During this epidemic, at least 450 dolphins were collected in Spain, 150 in France, and 60 on the north west Italian coasts, but these figures only reflect part of the deaths (lack of prospection, corpses lost at sea, sunk or eaten by sharks).

While everything seemed to be almost over (under 5 strandings per month in Catalonia), the epidemic took off in identical fashion in June 1991 in southern Italy, peaked in August in the southern Adriatic and in September in the Ionian Sea, bringing to the coast 200 dolphin corpses (BORTOLOTTO *et al.*, 1992).

During the first days of July, Greece (Zakinthos) was in its turn affected by the epidemic. 132 cetaceans were found dead between July 1991 and August 1992, including 63 Stenella and 56 indeterminate (probably Stenella), with a constant progression towards the north east, up to the shores of Thrace (CEBRIAN, 1992, CEBRIAN, 1995). Similar strandings were signalled on the Turkish coasts in 1992. During the summer of 1994, strandings of *Delphinus delphis* common dolphins increased suddenly on the northern coasts of the Black Sea (47 cases recorded), mainly in Crimea, Ukraine (BIRKUN *et al.*, 1999). The striped dolphin is absent from the Black Sea, where it is replaced by the common dolphin, alongside the common porpoise and the grand dolphin, the three cetaceans being represented by endemic sub species.

Finally, at the Rimmo Conference in autumn 1995, non verified information reported recent similar cases in Israel, which (if the information was reliable) would confirm an easterly advance.

Today, from the season after the epidemic peaked, strandings that could be imputed to Morbillivirus have become infrequent in the Western Mediterranean. In Spain, and France, there is still a basic morbidity, with a dying dolphin stranding frequency that is a bit higher than before, but there can be no possible comparison with the hundreds recorded before. Anatomical pathological and serological studies done during detailed autopsies on the Catalan coasts have shown that the 1990 epizootic has given way to a chronic infection by the morbillivirus, causing subacute infectious lesions of the central nervous system (DOMINGO *et al.*, 1995).

Thus, in the space of a year, the epidemic spread from southern Spain to Greece, then continued to move eastward during the following year, while deaths imputable to the Morbillivirus declined almost completely in the sectors that had been badly affected the previous season. The average speed at which the epidemic moved may be calculated at 5 to 16 km. per day, far less than the average speed at which dolphins move (5 km. Per hour). Virological studies carried out throughout the epidemic allow the virus's unicity to be affirmed from the Spanish coast in 1990 to the borders of Greece two years later.

In most sectors affected by the epidemic, the same scenario is repeated: rapid increase in the number of stranded dolphins, epidemic peak, then fall in the number of strandings, the whole process in most cases lasting for 3 to 4 months (Fig.2).

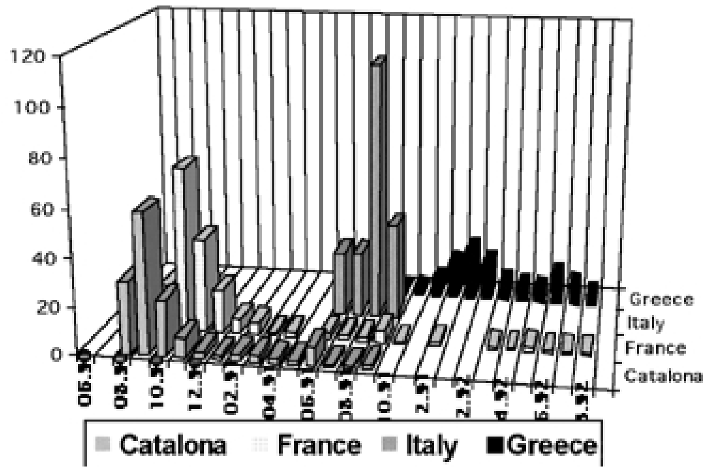



*Fig. 2 Number of Stenella coeruleoalba stranded on the Catalan (DOMINGO and col., 1992), French (BOMPAR and col., 1992), Italian (BORTOLOTTO and col., 1992) and Greek (MENCHERO, 1992) coasts, from June 1990 to September 1992.*

## A 2. Symptomatology

As well as the corpses brought to the coast by currents, a large number of live striped dolphins were stranded on the shore: over 25% in France, as against 5% usually, and 18% in Catalonia.

Most seemed exhausted, shaken with shivers, often showing neurological disorders, some throwing themselves onto rocks and boats so fiercely as to break their beaks, others apathetic, hardly swimming. Some cases of diarrhoea were reported in Spain, and one case of vomiting.

Attempts were made here and there to force them back to sea, but always in vain. The various veterinary care given was always ineffective. The dolphins died within a few hours (maximum length of survival at the health care centres: 32 hours for the Stenella, 72 hours in Crimea for the common dolphin). Health care possibilities for stranded cetaceans that are still alive seem anyway to be extremely restricted (KERSHAW & TAYLOR, 1996).

## A3. Anatomopathology

The few blood analyses carried out at the Barcelona Faculty of Veterinary Medicine and in the Catalonia Marineland most often showed leucopaenia and lymphopaenia, features of viral infections.

At the autopsy, the most important morphological changes were partial collapse of the lungs, with unequal atelectasis, subcutaneous oedema, icterus and stomatitis. From a histological point of view, the most frequent lesions were those of a bronchial interstitial pneumonia and of encephalitis (over 70% of the cases in Spain, a similar figure in France). The virus was discovered by immuno coloration mainly in the brain (77%) and lung (70%) and the lymphatic system (60%) (DOMINGO *et al.*, 1992a). Lesions of hepatic congestion, pulmonary congestion, and gastro enteritis are also reported. A necrosis of the spleen associated with a severe lymphoid depletion was also stressed by DUIGNAN *et al.* (1992). DOMINGO and col. (1992b) showed the existence of associated secondary lesions: aspergillosis, toxoplasmosis, actinomycosis, encouraged by the immuno suppression consecutive on infection with Morbillivirus and/or contamination by a PCB. Moreover, similar secondary mycological infestations were discovered in the same way in grand dolphins contaminated with the Morbillivirus in the US (LIPSCOMB T.P. *et al.*, 1994b, 1994c).



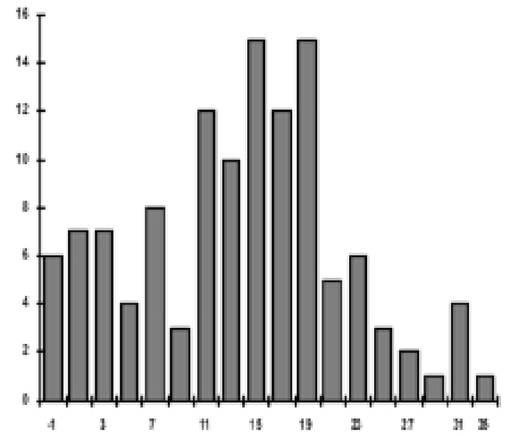
SIGNIFICANCEOFSTRANDINGS PATHOLOGYOFCETACEANS

# B. ANALYTICAL EPIDEMIOLOGY

## B1. Statistical analysis of stranded dolphins: sex ratio and age ratio

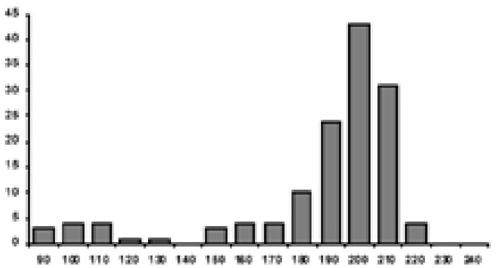
Males and females are affected without discrimination; the sex ratio of sick dolphins is nearly 1:1. The age ratio (Fig. 3) shows for both sexes an over representation of the 11 to 20 age bracket (= mature adults) and of newly born dolphins, victims of the deaths of breast feeding mothers and/or easily infected beside them. But subadult individuals seem to be under represented.

*Fig. 3 Distribution of dolphins by age bracket*



*(LOCKYER & CALZADA, 1992).*

*Fig. 4 Distribution of dolphins by size*



*(LOCKYER & CALZADA, 1992).*

A look at the size curve (Fig. 4) shows clearly an under representation of groups whose size is between 150 and 185 cm. (juvenile and subadult individuals).

## B2. Causal factor and factors that favour the disease

The size of the phenomenon, and its similarities with the epizootic which affected *Phoca vitulina* calf seals in the North Sea in 1988, quickly directed research to a viral infection, and led to the isolating of a morbillivirus, whose pathogeneticity was certainly reinforced by environmental circumstances, as has already been noticed with other species. A set of analyses was carried out on the infected dolphins' physical condition and pollutant levels to try to determine the possible influence of the disease.

Virological research done at the start of the epidemic on Mediterranean striped dolphins allowed two viruses to be isolated on the corpses: a herpes virus (whose role is discussed, possibly not pathogenetic) and, especially, a Morbillivirus (simple RNA virus of the Paramyxovirus family), the causal agent of the observed disease.

*a) Classifying Morbilliviruses*

Classification of Morbilliviruses, the identity and kinship of different viruses isolated in different mammals, has been treated in a number of contradictory publications, released one after the other at a frantic rate, and leading to radically opposed conclusions. The discovery of new epidemics and new viral agents make them topical viruses (MOUTOU, 1995).

Before 1988, Morbilliviruses were known: the agent of human and other primates' measles (MV: measles virus) and rinderpest (RPV: rinderpest virus) and small ruminants' pest (PPRV: small ruminants' pest virus), which affected various Artiodactyl Ungulata, and lastly the canine distemper virus (CDV: canine distemper virus), then described in carnivores (canine, procyonid, mustelid) and in captivity in Panthera felines. Experimentally, the canine distemper virus can contaminate species as diverse as rodents (hamster, rat, mouse) and suidae (pig, ringed peccary).

In 1988, in the North Sea, an epidemic decimated the calf seal (17,000 dead) and, but less, the *Halochoerus grypus grey* seal populations. The isolated virus, well characterized, is called Phocid distemper virus-1 (PDV$^{-1}$) and is fairly close to CDV.The year before, the *Phoca sibirica* endemic seals of Lake Baikal experienced an identical fate. A similar approach gives the isolated morbillivirus the name of PDV 2, but further research has shown it to be extremely close, if not identical, to CDV.

Other morbilliviruses are detected in six *Phocaena phocaena* porpoises stranded in the Irish Sea in 1988 at the height of the seal epidemic, and in two porpoises in the North Sea in 1990.

Finally, in 1990, the Mediterranean striped dolphin morbillivirus was isolated, the epidemic of which affected the common dolphins of the Black Sea in 1994 (BIRKUN *et al.*, 1999).

While in 1992 RIMA (1992) joined under the same term of *delphinoid distemper* virus the agents isolated in porpoises and Stenella (a term that was a source of confusion, since porpoises are not delphinidae) considering them as identical, close to the carnivore viruses (CDV, PDV) and fairly far from the viruses of humans and ruminants, present research considers that the virus detected in the porpoise (*Porpoise morbillivirus* PMV) is different, but closely related to the morbillivirus isolated in Stenella (*Dolphin morbillivirus* DMV). In fact, the variation rate in ?nucleon sequences between DMV and PMV (10%) is similar to that observed between geographically distant strains of rinderpest virus. It is thus possible that DMV and PMV are just two different serotypes of a single virus. Later research showed the existence of Morbillivirus in tursiops in the US in the form of an epidemic in 1987 -88 on the Atlantic coast (LIPSCOMB T.P. *et al.*, 1994c) and very many cases in the Gulf of Mexico, both in pelagic populations and in resident coastal groups (LIPSCOMB T.P. *et al.*, 1994b, DUIGNAN *et al.*, 1996). Moreover, very many cetaceans are carriers of antimorbillivirus antibodies, proving the chronicity of the infection in these species (DUIGNAN *et al.*, 1995), and each time the immune responses were similarly great as regards DMV and PMV (proving the very great relationship between the two strains), and less as regards the other morbilliviruses.





In February 1994, a thousand lions in the Serengeti National Park, in Tanzania, were struck by a canine distemper epidemic, certainly of canine origin. Although the prolificness of the lions allowed the species to recuperate quickly, this was not the case for the other wild carnivores affected by canine distemper around the world, such as the *Lycaon pictus lycaon* in Africa, or the *Mustela nigripes* black footed ferret in North America.

Serological research was done from 1987 to 1992 on *Thalassarctos maritimus* polar bears in Alaska and Russia. One third gave positive results, without being able to say whether the antibodies were directed against the canine distemper virus, or the PDV 1 Phocid distemper virus, which makes the conclusions of this investigation rather risky (FOLLMANN *et al.*, 1996).

In September 1994, an acute respiratory syndrome appeared in horses in Queensland province, Australia. 16 horses and a trainer died within a few days, and a second person in contact with these horses (at an autopsy, it seems) died one year later from the effects of a respiratory pathology. A new morbillivirus, rather more distant than all the other known morbilliviruses, was rapidly isolated (EDV: Equine distemper virus). It seems that megachiroptera of the *Pteropus genus* can constitute a wild reservoir of this virus (YOUNG *et al.*, 1996). Experimentally, the cat and the guinea pig have been shown to be sensitive to infection by this morbillivirus (WESTBURY *et al.*, 1996). New cases appeared in horses in Australia in January 1999.

During the summer of 1997, a mass mortality decimated the ranks of the one viable colony of *Monachus monachus* Mediterranean monk seals, eliminating 71% of adults in the Cap Blanc peninsula population, which would today contain only 90 individuals. Scientific teams sent to the spot disagree on the origin of the epidemic. It is commonly accepted that the observed mortality is due to poisoning by a saxitoxin produced by a dinoflagellate (a red tide phenomenon, proliferation of toxic unicellular algae by ingestion, accumulated in the food chains), since several bits of serological research work remained negative in Prof. KENNEDY's laboratories (AGUILAR, 1998). OSTERHAUS and col. (1997) strongly criticize this hypothesis and have been able to show the presence of two distinct strains of morbillivirus, one in Mauritanian seals, the other in Greek seals. These two morbilliviruses seem relatively distant, and the Monk Seal Morbillivirus isolated in Greece (MSMV Greece) seems closer to the Atlantic porpoise morbillivirus, while its Mauritanian opposite number (MSMV "Mauritania) would be closer to the virus isolated in Mediterranean striped dolphins.

A new morbillivirus was isolated in March 1999, in pig breeding sties in North and Central Malaysia, at the origin of several dozen cases of fatal encephalitis in humans. The health authorities immediately slaughtered a million pigs. The virus seems close to the Hendra virus in Australian horses.

Today, then, the phylogenetic tree of Morbilliviruses is radically different from that initially suggested by RIMA, cetacean viruses being close to those of ungulates, and distant from those of carnivores (Fig. 5). In passing we may remark that this corresponds much better with what we believe we know about the links of relationship existing between the present orders of mammals. Cetacean morbilliviruses provide a major database for studying the evolution of RNA viruses (RIMA *et al.*, 1995).

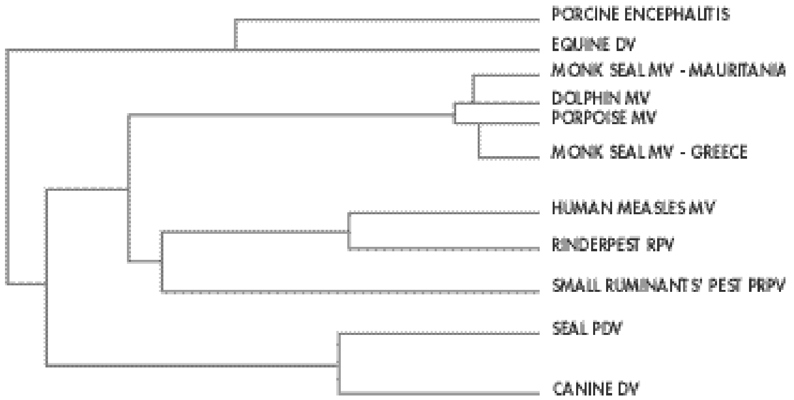



*Fig. 5 Phylogenetic tree of morbilliviruses, from BARRETT and col., modified 1993.*

*b) Cetacean morbilliviruses: species affected*

Initially considered as a new disease specific to the striped dolphin, the 1990, 2 epidemic is shown today to be an outburst of an epizootic raging quietly in a great many species in many parts of the world.

Today, the morbilliviruses have been isolated in the common porpoise, the bottlenose dolphin and the striped dolphin, and though this last species was the only one apparently affected by an epidemic in the Mediterranean *sensu stricto*, anti morbillivirus antibodies have been found in the serum of many other marine mammals.

The presence of antibodies neutralizing the DMV Dolphin morbillivirus and/or the PMV Porpoise morbillivirus has been shown in the North Atlantic in most species: the common dolphin, the *Lagenorhynchus albirostris* white beaked lagenorhync, and the common porpoise (OSTERHAUS *et al.*, 1995), and in 92% of stranded black pilot whales (BARRETT *et al.*, 1995), the *Lagenorhynchus acutus* white sided dolphin, the *Stenella frontalis* spotted dolphin, the *Grampus griseus Risso's dolphin*, the *Kogia breviceps* dwarf sperm whale, the *Feresa attenuata* dwarf killer whale, the Pseudorca crassidens false killer whale and the *Lagenodelphis hosei* Fraser's dolphin (DUIGNAN *et al.*, 1995) and very recently the *Balaenoptera physalus* fin whale (JAUNIAUX *et al.*, 1998). In the Pacific, a common dolphin stranded alive on the California coasts was found to be a carrier of the morbillivirus. Not knowing what to do with this animal, which moreover presented no disorder, the health authorities kept it in a Sea World pool in San Diego (Newsletter of the American Cetacean Society, autumn 1995). The virus was also recently isolated in a California striped dolphin. Off the coasts of Peru, VAN BRESSEM *et al.* (1997) showed that many species had antimorbillivirus antibodies: *Lagenorhynchus obscurus* dark lagenorhync, the pelagic bottlenose dolphin, *Delphinus capensis* long beaked common dolphin.

In depth studies were done on the Atlantic coast of the US and Canada. In retrospect it appears that Morbillivirus infection epidemics regularly affect coastal populations of *Tursiops truncatus* bottlenose dolphins, at least since 1982 (DUIGNAN *et al.*, 1996).

Anti morbillivirus antibodies sensu lato were found in 53% of bottlenose dolphins during a period of mass strandings in 1987 on the east coast of the US (742 stranded corpses, mortality estimated at 2,500 individuals, SCHULMAN *et al.*, 1994, LIPSCOMB *et al.*, 1994c), plus in 18 individuals in the Gulf of Mexico (Florida, Alabama, Mississippi, Texas) between 1987 and 1995 (LIPSCOMB & KENNEDY, 1994a, KRAFFT *et al.*, 1995, DUIGNAN *et al.*, 1996). Finally, a Morbillivirus disease, with histopathological and immunological confirmation, was described in tursiops in the US, both in many individuals on the Atlantic coasts in 1987 (LIPSCOMB *et al.*, 1994c) and in one individual on the Florida coasts in 1993 (LIPSCOMB *et al.*, 1994b). We shall see in the SYNTHESIS proposed in Chapter 3 how the ecology of the species concerned partially explains the modes of contamination.

In the Mediterranean, as well as the striped dolphin, a common dolphin stranded in Italy in July 1990 tested positive, and negative results were obtained on a *Ziphius cavirostris* Cuvier's beaked whale. Other negative results were obtained in Greece in 1992 on common dolphins and on a Cuvier's beaked whale (ANDROUKAKI *et al.*, 1994). The 1990, 92 Mediterranean epidemic spread to the Black Sea *Delphinus delphis ponticus* common dolphins during the summer of 1994. Although conditions of sample preservation did not allow the morbillivirus to be isolated, its signature was easy to recognize at the level of both pathogenesis and lesions, immunohistological colorations and Elisa tests, etc. (BIRKUN, op. cit.).

Serological research remains to be done on other Mediterranean cetacean species to find out their possible receptivity and their antigenic knowledge of the disease. A higher than normal number of strandings was noticed in Italy in tursiops and in Greece in *Ziphius cavirostris* Cuvier's beaked whales during the epidemiological peaks, but almost no analysis was able to be made. Obtaining exploitable serums obviously depends on a fresh, accessible carcass being discovered, which does not often happen. As to the recent argument about a "measles" epidemic in *Balaenoptera physalus* fin whales stranded in Corsica (GUIBOURGE 1996), this is purely and sadly grotesque and rests on no proved fact (PARODI 1996).

As for the mysticetes, antibodies directed against canine distemper were detected in the serum of a point snout rorqual stranded on the coast of Tuscany in 1993, but no virus could be isolated from its tissues (DI GUARDO *et al.*, 1995). But a young fin whale stranded on the Belgian coasts presented high parasitism and anatomopathological lesions suggestive of the morbillivirus, which confirms the presence of intranuclear viral inclusions and positive serologies for DMV and CDV (JAUNIAUX *et al.*, 1998).

In passing, we should remember that research done on pinnipeds after the epidemics that happened in the North Sea showed that many species were carriers of anti morbillivirus antibodies: the *Pagophilus groenlandicus* Greenland seal, the *Phoca hispida* ringed seal in Greenland in 1985-86; the Lake Baikal seal in 1987; the sea calf seal, the grey seal in Scotland before the 1988 epidemics; and even the *Lobodon carciniphagus* crab seal and the *Hydrurga leptonyx* leopard seal in the Antarctic, plus two *Cystophora cristata* hooded seals found dead in June 1990 near Huelva and Tarifa in Spain. This type of viral infection has thus happened on several occasions, and in various regions.

Given the rarity of the *Monachus monachus monk* seal and the threat a return of a morbillivirus would represent to its remaining populations, OSTERHAUS and col. (1992) have since the start of the epidemic on Mediterranean striped dolphins studied in vitro the sensitivity of monk seals' and other species' monocytes to DMV action. The results showed that the monk seal was certainly less sensitive to this infection in these conditions than various cetaceans would be.



SIGNIFICANCEOFSTRANDINGS PATHOLOGYOFCETACEANS

A vaccine was however prepared and tested on Hawaiian monk seals in captivity. Rumours of two monk seals found dead on the Andalusian coasts also circulated, without being verifiable. The argument surfaced again in summer 1997, when 2/3 of the adults of the one viable colony died on the Mauritanian coasts. Anglo Spanish teams present on the spot essentially blamed a red tide phenomenon due to the proliferation of toxic dinoflagellate algae that had accumulated in the pelagic fish on which the adults fed (ROBINSON, 1997), but OSTERHAUS and col. showed that these seals were seropositive to the morbillivirus, and drew up a necropsic table of seals they had been able to autopsy that was markedly different from that presented by the Spanish teams. In fact, Greek and Mauritian seals were hosts to two slightly different morbilliviruses (SEITRE J. & R., 1998). Today it is commonly accepted that the proliferation of red algae is the prime cause of this mass mortality, the morbillivirus merely acting as a co factor.

Having said this, CHAPPUIS (in lit.) showed that inoculating 'pathogen "free' ferrets and dogs with the DMV, isolated from a dolphin stranded on the coasts of Provence in December 1990, faithfully reproduced a fatal disease seemingly identical to canine distemper for subjects which had not been vaccinated, whereas individuals immunized by the canine distemper vaccine were perfectly protected. Although distinct, these mobilliviruses are thus still close enough to infect other species than their usual hosts. The same thing had been done, with the same results, concerning the PDV-1 and PDV-2 of North Sea and Lake Baikal seals, and have since happened with goats and dogs tested for isolated cetacean viruses DMV, PMV and PDV-1. According to VISSER (1993), transitory leucopaenia consecutive on inoculation with the virus was much more marked in the ruminants tested for DMV than in dogs, an additional proof of the relationship between cetacean morbilliviruses and ungulate morbilliviruses. Lastly, to temperate these divergences, one should remember that for reasons that have not been explained, although the viruses are extremely variable genetically, the symptoms that they produce are remarkably constant: thus, human influenza, whose causal agent, an influenza virus, generally of type A, is never identical to that of the previous year, whereas the disease it causes is very easily identifiable in a given epidemiological context (MICHEL, 1995).

Interesting remarks have been made on the origin of morbilliviruses and the risks of passing from the aquatic species to terrestrial species (domestic or not) and vice versa.

Virologists seem to agree on the fact that the rinderpest virus represents the archetype of the morbillivirus genus. RIMA (1992), whose final conclusions are certainly questioned by the latest work of the Dutch team, suggested an interesting evolutive model for the Morbillivirus genus, which would suggest that speciation between different viruses is relatively recent. Among other arguments, the fact that Hippocrates does not mention measles in his medical reports from 2,500 years ago... But we cannot guess when and where these viruses appeared. The above mentioned works, establishing the originality of the cetacean morbilliviruses, do however allow us to rule out contamination of Mediterranean striped dolphins by morbilliviruses of North Sea seals, including two hooded seals found dead in southern Spain, far south of their normal northern area of distribution, just before the start of the epidemic.

It is, moreover, established that mink farms have been contaminated in Denmark by PDV-1 and, reciprocally, that Lake Baikal seals have in all likelihood been directly contaminated by CDV canine distemper virus. It is unlikely, though, that cetacean morbilliviruses present an epidemiological danger for ruminant breeding, at least as long as cetacean carcasses do not come directly into contact with the flocks.





OSTERHAUS *et al.* (1995) think that infection by mobilliviruses evolves normally in an enzootic way, both in seals and in cetaceans, and that an epizootic can only arise in a population that has long been out of direct contact with the pathogenic agent, and then suddenly exposed, for example during a trans specific crossing. The populations, massively unprovided with specific antibodies, may at that moment suffer mortalities as a result. This is a fairly general pattern in epidemiology, which of course does not provide an answer to the question as to the origin of the 1990 epidemic.

### B3. Factors that favour the disease

The Morbillivirus is thus the causal agent, directly responsible for the disease. Basically it causes lesions of the respiratory apparatus (interstitial pneumonia) and of the nervous system (encephalitis), as well as a generalised congestion of the organs. But its pathogenic power is only fully felt when it encounters a favourable terrain for developing and spreading the disease. A whole set of encouraging factors then explain the magnitude of the development of this epidemic.

*a) Dolphins' physical condition*

Examination of the stranded individuals in Spain during the 70 first days of the epidemic shows that these were in bad physical condition: the level of lipid contained in the blubber (sampled before and after the epidemic by *in natura* biopsy), which is usually 50 to 70%, was only 30 to 60% in the first dolphins affected by the disease. The thickness of the trunk fat itself did not change significantly, the lipids being in all likelihood replaced by water to keep the body's hydrodynamic shape and thermic insulation. Thickness of the dorsal blubber is thus a parameter that is valueless for estimating the physical condition of a stranded cetacean.

*b) Environmental conditions*

In the area where the epidemic initially appears, the annual primary productivity cycle usually shows two peaks, one in late autumn, the other in spring (February to April). On the basis of partial data, AGUILAR & RAGA (1990) suggest that, because of the very low rainfall and very high average temperature the previous winter, this productivity peak did not happen in spring 1990, diminishing the fishes' and therefore the dolphins' food resources in the sector under consideration.

*c) Contamination by organochlorines and heavy metals*

Abnormally high PCB levels were detected in dolphins stranded in France and, especially, in Spain (94 to 670 ppm (KANNAN *et al.*, 1993)), sometimes over 1,000 ppm, which constitutes one of the highest values ever noted in a wild mammal. High DDT concentrations (22 to 230 ppm) were also recorded (KANNAN *et al.*, ibid.). These writers did not note a correlation between PCB level and the level of lipid contained in the fat: all the dolphins affected by the epizootic, whether in good or bad physical condition, had a significantly higher polychlorobiphenyl level (and also of DDT) than the population of reference. It could not be clearly established whether this high PCB concentration constituted one of the causes of the viral infection (PCBs are classically known for their immunosuppressive effects), or whether it was a result of it, since viral hepatic lesions can possibly hamper the degradation and elimination of these substances in the organism. Many of these pollutants are however known for their inductive role in hepatic lesions, reproductive disorders, and as an immunotoxic (KANNAN *et al.*, 1993). An experimental confirmation of the pathogenic role of organochlorines present in food chains was recently done in Holland. Two sets of seals were fed in captivity, one with herrings from the Baltic, a very polluted semi closed sea, the other with fish from the Atlantic Ocean, of better quality. Several changes in the immune functions were observed in the seals fed with the contaminated fish (ROSS *et al.*, 1995).

In France, AUGIER and col. (1991) researched the heavy metal load of tissues of dolphins stranded during the epidemic. Sizeable cadmium and copper contamination was found, while the nickel and lead levels were less high. Other analyses, particularly for mercury, were carried out. The incidence of these contaminations has not yet been clearly established.

*d) Parasite load*

RAGA and col. (1992b) made a detailed study of parasite infestation in 82 stranded *Stenella coeruleoalba*, mainly during the first part of the Spanish epizootic. 15 parasites and epizoa were recorded, including a new localization for science: *Lepas sp*. (probably *Lepas pectinata*), found for the first time in a cetacean (on the teeth) and *Conchoderma virgatum* for the first time in a striped dolphin (FERNANDEZ *et al.*, 1991).

In the fat and muscle: *Phyllobothrium delphini*, not very pathogenic, was found in great quantity in 92.4% of the specimens examined and the more harmful *Monorygma grimaldii* in 81% of mesenteries, plus *Crassicauda* in only 10% of cases.

In the lungs, small quantities of *Skrjabinalius guevarai* were detected in 78.4% of cases; its pathogenic power is hard to assess.

The gastro intestinal tract contained several species, including the *Pholeter gastrophilus* trematode in the main stomach, the pyloric stomach and the duodenum (81% prevalence), apparently not very pathogenic but able, because of the unusual size of the inflammatory reaction, to cause mechanical obstruction of the digestive tract (AZNAR *et al.*, 1995). Almost half the specimens studied presented hepatic and pancreatic lesions attributable to the *Oschmarinella mascomai* and *Zalophotrema sp. trematodes*. In the Black Sea, these are replaced by *Campula palliata* (BIRKUN *et al.*, op. cit.).

The parasite load of the specimens studied is therefore very big, but few parasites can be linked to a specific pathology.

The presence of three barnacles: *Conchoderma virgatum* (1 case), *Lepas sp.* (1 case) and *Xenobalanus globicipitis* (52.2% of cases examined instead of 33.3% usually), of *penella* (30.5% of cases) and of the *Syncyamus aequus* shellfish 19.1% of cases, certainly under estimated) is particularly interesting: usually these species only cling to floating debris or slow swimming species (whales, pilot whales). The rate of infestation of the dolphins examined would therefore indicate that they were moving abnormally slowly, certainly because of their disease.

Finally, we should remember that several dolphins developed extremely serious secondary fungal infections: aspergillosis, actinomycosis, or infections due to sporozoans: toxoplasmosis.





## 3. SYNTHESIS

Today, epidemiological studies explain the way the disease spreads, especially in North American Atlantic coast bottlenose dolphins. Most Atlantic Ocean cetacean species are carriers of Morbillivirus. Those which lead gregarious lives, like the pilot whales or false killer whales, are permanently in contact with the virus, passing it on from one member of the community to the next, and although the infestation rate is very high (92% of individuals tested), the disease is not serious, because the populations are naturally and regularly protected against this daily companion. The infection only takes on a dramatic epidemic nature if the virus meets an unscathed population, rarely in contact with this pathogenic agent. Infection by the morbillivirus seems to provoke a big production of specific antibodies in the first moments of the disease. Later, the level of antibodies drops regularly over the years so that, if there are no repeated contacts, the organism's defences are considerably weakened.

Viral ecology also explains the infection's epidemiology. Like all living beings, the virus's one 'aim' is to multiply, in order to guarantee the survival of its genes. Viral strategy may take the form of an acute infection, where the explosive multiplying of the virus rapidly destroys the host cells, but this scorched earth policy is not necessarily the one most useful to the virus. In reality, "viral disease is to the virus what pollution is to motor traffic: an ecological problem and not an end in itself" (SONIGO, 1995). Another strategy is to remain safe inside its host, thus causing a chronic infection. The other side of the problem is the speed with which mutations are observed on short sequences of viral DNA or RNA. This variability unbalances the host virus relationship, which benefitted both protagonists. If various circumstances end in the host population of a virus changing (new species coming into contact, or genetic variation of the virus permitting it to pass to another species), then the virus responsible for the benign chronic infection becomes a real killer... until the surviving host populations adapt to the new germ, and a balance is achieved once more. Its passage from one population to the next, or from one species to the next, may enormously increase the virulence of the pathogenic agent, as is shown by the example of myxomatosis in the pair *Sylvilagus*/wild rabbit, or, in all likelihood, in the case of human AIDS (DE PRACONTAL, 1995).

Cetaceans' social behaviour explains very well, then, the spreading of a virus from one group to another. On the American Atlantic coasts two distinct populations of bottlenose dolphins live. The pelagic ecotype lives in regular contact with other gregarious cetaceans, such as the pilot whales we recently mentioned. In these too the proportion of animals carrying anti morbillivirus antibodies is large but the influence of the disease is small. The coastal ecotype, however, is made up of little groups of a few dozen individuals, extremely sedentary, moving around very little. From time to time, a pelagic tursiops happens to meet individuals of the coastal ecotype, either in social interaction or during mass strandings. It carries with it the virusus which can then cause terrible losses among the group of coastal dolphins, as the explorers of the New World contaminated the Indians with smallpox, almost unintentionally. If the coastal population has had no recent contact with the disease, the appearance of a morbillivirus can cause mass deaths in that population. Because they do not all have the same genetic heritage, or the same state of health, all dolphins in the group do not react in the same way, and many survive. In tursiops, all the individuals do not present the same risk of being contaminated. In these groups of bottlenose dolphins, it was observed that females were more often carriers of antibodies than males. Bottlenose dolphin groups are organized in a matriarchal way: an old female with her daughters and their descendants. Young males are quickly chased away from the group and move from one group to another to impregnate the females, thus permitting a good genetic intermixing of populations. As the males only spend a limited time within the contaminated groups, they have a low contamination rate. But they may serve as vectors of disease if, carriers of the morbillivirus, they come into contact with a group of unscathed dolphins. The females also experience a phase of freedom, but quickly go back to their original group when they mature, and are thus newly exposed to the pathogenic agent. In a group of coastal dolphins, the older they are, the more chance they have of having come into contact with the morbillivirus. Little groups of coastal bottlenose dolphins distributed along the American coasts are thus regularly contaminated, and the disease takes a lasting hold on them, since they live in relatively closed groups. Moreover, the incidence is less in young males, which go off to other places looking for new females, than for females who go back to their original group as they approach maturity (DUIGNAN *et al.*, 1996).

Such in depth studies are lacking for the Mediterranean. Systematic research on the presence of anti morbillivirus antibodies in the serums of the various species still has to be done. Up to now, we have not found in the Mediterranean *sensu stricto* other contaminated species than striped dolphins, but the sampling is too low to draw conclusions, and the common dolphin found to carry antibodies, and the development of the epidemic in this species in the Black Sea, show that other species may be affected. The sheer scale of the 1990-92 epidemic perhaps indicates that Mediterranean Stenella had not come into contact with the virus for a very long time. Moreover, little is known about striped dolphin population exchanges between the Atlantic and the Mediterranean, and with the Black Sea, where the endemic common dolphin subspecies (the striped dolphin being absent from this area) was affected in summer 1994.

If one looks at the number of infected animals according to their age and sex, one sees that, unlike what has been shown for American bottlenose dolphins, striped dolphin males and females seem to be equally affected by the disease. This sudden epidemic did in fact quickly strike mixed groups. As regards the age of the individuals found dead, it was noticed that fully adult individuals (between 9 and 20 years old) and very young individuals were more affected than subadult individuals. The deaths of very young individuals is explained by the fact that they are quickly contaminated alongside their sick mothers, or die of starvation when their mothers die. Perhaps the subadults, swimming in same age groups, had fewer exchanges with the most contaminated groups; their resistance to infection is certainly all the greater.





# 4. CONSEQUENCES FOR THE POPULATION OF Stenella coeruleoalba

## 4.1. ASSESSMENT OF INDUCED MORTALITY

In the absence of a precise assessment of the pre 1990 numbers of western Mediterranean Stenella, and of the real number of dolphins which died in the epidemic, it is impossible to know how great an impact this epidemic had on overall population.

Between July 1990 and September 1991, at least 800 corpses were counted on the western coasts of the Mediterranean. Although everybody agrees on the fact that this figure only reflects part of the mortality, assessments vary empirically on the real size of the phenomenon perhaps ten to fifty times more, some think.

The only indications we possess on the consequences of the epidemic are those relating to the size of Stenella groups. In early October 1990, in the north "west Mediterranean, Greenpeace International and Barcelona University made several cruises and showed that the size of the groups was considerably smaller. While before the epizootic (observations made from 1982 to 1989) 70% of the groups consisted of 1 to 20 animals, with some schools containing over 50 individuals, the figures fell to 1 to 5 individuals together in 70% of the groups encountered during the epidemic, and there were no big gatherings. This big reduction in group size, and the fact that a large number of groups were met during this period, reflect the high mortality suffered by the population and suggest that survivors did not come together again to bring the groups up to their original size.

## 4.2. PRESENT STATE OF STRIPED DOLPHIN POPULATION

In August 1991, Greenpeace International, with the help of Barcelona University and the Sea Mammal Research Unit (UK) organized a 5 week cruise in the western Mediterranean in order to make a map of Stenella distribution and propose a reliable assessment of the numbers and density of groups of that species. The results of this remarkable campaign, the biggest ever organized in the field, indicate an absolute number of striped dolphins assessed at 113,000 for the western Mediterranean (at 95% margin of error = 68,000 to 215,000), the average size of groups being 12.9 individuals, after integrating the correlation between number in groups and distance of detection (FORCADA *et al.*, 1992, 1994).

Although the total pre epidemic number of striped dolphins remains unknown, the final assessment of the present population in the western Mediterranean indicates that there is still an abundant population, greater in number than the other species in every sector.

## CONCLUSION

Since 1987, several populations of marine mammals have been affected by infections caused by morbilliviruses.

Studies done to understand the causes of these epidemics have raised a number of questions to which all the answers have not yet been given. In the Mediterranean, a certain number of findings and hypotheses can be formulated:

1. Bad local climactic conditions in the winter of 1989, 1990 led to a dwindling food supply, and thus a more or less lengthy period of fasting which would have weakened the dolphins ;
2. Major contamination by PCBs and DDT, possibly due to the mobilization of fats in weakened dolphins and/or a particular sensitivity in sick dolphins;
3. Major contamination by heavy metals ;
4. A causal agent: Delphinoid Distemper Virus, in all likelihood present in other species/populations of marine mammal in the Mediterranean and/or elsewhere. This virus was able to spread first in animals weakened by PCBs or heavy metals and/or whose immunity had been suppressed by these;
5. The appearance of secondary infections: aspergillosis, toxoplasmosis, actinomycosis and a high rate of parasitism, mainly in weak dolphins who were the first to be affected at the start of the epidemic. The fact that *Stenella coeruleoalba* was the only species apparently affected may be explained by :
6. This dolphin's particular sensitivity to the virus? Apparently not, since other species are today known to carry this virus;
7. The demographic explosion of Stenella, which seem to have quickly supplanted and eliminated *Delphinus delphis* or replaced this species (perhaps the first affected by chemical pollution?) in the north western Mediterranean. This epidemic phenomenon seems in fact to arise in high density populations (e.g. North Sea seals); some writers believe that these epidemics are a natural way of regulating numbers! Moreover, this hypothesis would be strengthened by the attack suffered by the common dolphin, a vicariant of Stenella in the Black Sea.
8. The progress of the disease was, lastly, encouraged by the exchanges of individuals between groups or temporary gatherings on feeding grounds (over 500 dolphins together in late September 1990 off the Hyeres Islands). Social factors are to be taken account of in the spreading of the disease. In this species, the end of the summer corresponds both to the period of reproduction, when there are both matings and births (12 to 13 months gestation), and to a restructuring of groups, with studies done in Japan showing that young weaned animals can go back to groups of immature animals, while young adults (=9 years) move into reproductive groups. This type of exchange, if it also happens in the Mediterranean (?), could encourage the transmission of the virus and, from group to group (frequence of groups = 0.0227/km.), spread it within 3 to 4 months to the entire western, and then eastern, Mediterranean.
9. The striped dolphin remains the most abundant species in the western Mediterranean, despite big, and undefined, losses. Thus, a viral epidemic, however impressive, should not be systematically considered as an ecological catastrophe, as the media like to present it. Generally speaking, whenever a virus affects a healthy population with a big genetic diversity, there will always be a sufficient number of resistant individuals to make up within a few years, possibly by increased success in reproduction, for the losses incurred in the disease. Cetaceans are certainly handicapped in this respect for recovering the size of their original populations, since each adult female can only have one baby every 3 to 4 years. Later, the virus and its host can live on relatively good terms. The problem arises when the disease affects a species whose population has been reduced for various reasons, most often of human origin, to very low levels (as for the monk seal) or is genetically very little varied (like the leopard, in another field), or again when individuals are made artificially vulnerable by external agents, like immuno suppressive pollutant substances, or when the environment's capacities no longer allow survivors to fight their way back again quickly. Here, the Morbillivirus epidemic experienced by Mediterranean striped dolphins in 1990, 1992 reveals the pollution thresholds of the sea that nourishes us and allows the alarm to be sounded for the good of everybody.





## CAN WE VACCINATE DOLPHINS?

Faced by so many contaminated dolphins, the general public must needs ask What can we do?

Well, objectively, not much. First, the disease seems to act very quickly, leaving the sufferer little hope of cure. Second, the dolphins which come and get stranded are probably in the last stage of the disease. Their rapid deaths prove this. Here and there, attempts to cure them in captivity were improvised. But this was not very rational. There is a lack of fitting installations suited to the purpose, and sick dolphins are obviously a contagion risk for their captive fellow creatures, which already have quite enough problems without their freedom. But an American Marineland did want to attempt the experiment with a weakened tursiops. This turned out to be a carrier of the morbillivirus, and most of the establishment's other dolphins died! Care offered in the 1990 epidemic, essentially in Spain, did not allow any dolphins to survive longer than 36 hours. And anyway, we do not have any specific weapon to fight against the virus.

Preventive vaccination for dolphins in the immensity of the sea is attempting the impossible. Using an inactivated virus generally requires two administrations several weeks apart. It is impossible to envisage a vaccine bait that dolphins would eat of their own accord. Although one can imagine some dolphins being vaccinated with a hypodermic speargun, it is useless to hope to give a repeat injection. One can let oneself give a single inoculation with an attenuated live virus, but there is a strong risk of this getting out of control and introducing the virus or a variant into the natural environment once again. Happily, such experiments are forbidden.

Fears have however been expressed about the monk seal, the European vertebrate most seriously threatened with extinction, whose relic populations in the Mediterranean and on the Mauritanian coasts are extremely fragile. With the epidemic in North Sea seals and Mediterranean Stenella, the risk of contamination has been taken into consideration and a vaccine prepared, just in case. Since no case of a contaminated seal has been observed a wise decision was taken to leave these few seals quietly alone rather than enter upon a risky undertaking. A propitious decision!

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## GLOSSARY

Ankylosis: loss of mobility in a joint

Ante mortem: before death

Arthrosis: degenerative lesion of a joint

Ascites: dropsy of the abdomen

Carcinology: the study of cancers

Commemorative: all the circumstances happening before an event

Dystocia: pathological birth

Epizootic: an epidemic concerning animals

Foreign bodies: any element that does not belong to the organism

Glomeralo-nephritis: inflammation of the functional units of the kidneys

Immunosuppression: lessening of the immunity defences

Interstitial: concerning the interstitial tissue (wrapping the organs)

Keloid: fibrous granulating lesion of the skin

Lethality: mortality

Leucocytopenia: drop in the number of white corpuscles

Lymphopenia: drop in the number of lymphocytic white corpuscles

Metritis: infection of the uterus

Myocarditis: inflammation of the cardiac muscle

Morbidity: disease

Necropsic: concerning the examination of a carcass

Opportunistic: a usually harmless germ which exploits an organism's weakness to establish itself

Pathogen-free: a laboratory animal born by Caesarean from a healthy mother and raised in a sterile environment to guarantee that it has never been previously contaminated when confronted by infectious agents

Petechia: small multiple subcutaneous bleeding

Post-mortem: after death

Postprandial: after a meal

Pulmonary emphysema: permanent excessive distension of the pulmonary alveoli

Rate of prevalence: frequency of the infection

Soft tissues: muscles and viscera, as opposed to the skeleton

Supplementary tests: a set of diagnostic tests that adds precision to the clinical examination (imagery, analyses)

Traumatic: due to an accident

Tumorous: concerned with a tumour, benign (e.g. inflammatory) or malign (cancer)

Wounding : blunt, cutting

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# MEDITERRANEAN DATABASE OF CETACEAN STRANDINGS (MEDACES): A TOOL FOR THE CONSERVATION

## ABSTRACT

Cetacean strandings are a very well-known phenomenon throughout the ages. These events provide a unique opportunity to obtain biological information about animals that, otherwise, it would have been impossible. Moreover, rehabilitation efforts of live animals are directly linked to the humane concern for conservation of cetaceans and of the marine biodiversity, in general. The importance of strandings justify the setting-up of a Mediterranean Database of Cetacean Strandings (MEDACES) at the University of Valencia (Spain), under the auspices of the Barcelona Convention. MEDACES aims to co-ordinate all national and regional efforts for riparian countries. Distribution maps will be produced using a Geographical Information System (GIS).

## KEY WORDS:

Cetacean, Strandings, Networks, Biology, Conservation, Mediterranean, Database, GIS

## INTRODUCTION

A marine mammal stranding is usually a natural event as a consequence of starvation, illness or, simply, aging. The animals are brought passively to shore by wave and wind action, dead or alive. On occasions, human activities such as contamination (chemical, acoustic, etc.) (Frantzis, 1998, Simmonds and Nunny, 2002) or the incidental or deliberate captures by fisheries (Bearzi, 2002) are responsible for strandings.

Cetacean stranding is a well-known phenomenon throughout the ages and awareness of these events was shown by human cultures in drawings and collections of bones, teeth, etc. from these animals. Many primitive coastal people probably obtained the meat and blubber necessary for their diet from stranded cetaceans. This is the case of the first dwellers of the Western Mediterranean (Pérez-Ripoll and Raga, 1998). In some cases, the relationships between strandings and the onset of intentional captures by humans have been well documented. It is likely that a mass stranding of pilot whales, *Globicephala melas*, in the Medieval Age was the origin of the massive captures of these odontocetes in the Faroe Islands (Joensen, 1976).

Mass strandings of cetaceans seldom occur, compared to strandings of individuals, and the former mainly affect species with a strong social cohesion, such as pilot whales (Globicephala spp.), false killer whales (*Pseudorca crassidens*) and sperm whales (*Physeter macrocephalus*). Possible causes for mass stranding are diverse: orographic (the continental shelf), geological (the mineral composition of the coast, affecting the magnetic field), or climatological (alterations induced by storms) factors have been suggested. In some regions, the frequency of these events has increased of late which may be due to anthropogenic causes (Perrin and Geraci, 2002).

Stranded cetaceans are a very important, and sometimes the only, source of information about the anatomy, ecology, genetics, pathology, parasitology or toxicology of the species in





question. Since the scientific interest in cetaceans began, researchers have studied the curious episodes of stranded cetaceans appearing on beaches, by gathering skeletons and body parts (teeth, baleen plates, etc) for examination. In more recent times, these studies have been seen extended thanks to the employment of modern technologies, e.g. molecular tools that allow small parts of these animals to be used for genetic studies (Heyning, 2002). In addition, monitoring cetacean strandings over an area can, on occasions, provide information on the health status of populations and identify important problems, such as epizootics resulting in mass mortality (*Domingo et al.*, 1990).

In the case of some species, rehabilitation of live animals may not contribute significantly to their conservation, since the number of animals successfully rehabilitated is small and the size of wild population is large compared to the quantity of live strandings (Wilkinson and Worthy, 1999). However, in endangered species, rehabilitation is crucial for the survival of the species. Although rehabilitation and release of stranded marine mammals have scant value in terms of population conservation, the care of live stranded animals may supply useful information applicable both to maintenance of captive mammals and management of wild populations. Moreover, and probably of more importance, is the fact that rehabilitation efforts are directly linked to the humane concern for conservation of cetaceans and of the marine biodiversity, in general. People are willing to help animals found stranded on beaches or debilitated in shallow water.

## STRANDING NETWORKS

In a number of countries, where the concern for the protection of cetaceans is more apparent, stranding networks have been developed over the last decades of the 20th century to gain more knowledge on the biology and conservation of these animals.

One of the countries with exemplary historical records relating to the ancient interest for cetacean strandings is Denmark. Since 1241, as stated in the Jutish Law, stranded cetaceans were considered 'Royal Fish' and hence property of the Danish king. The duty of the finder was to report the find entitling him to take a share of it. In 1885, upon an inquiry by the Zoological Museum, the Danish Ministry of Interior Affairs set up a notification procedure for their rescue service officers, receivers of wrecks and other local representatives who by telegraph were to report strandings of "unusual sea animals" to the museum. Although the museum received frequent reports, the prime scope of this network was to obtain rare specimens, not to record all strandings, nor to provide the basis for faunistic analyses and management procedures. The more common species therefore remained unattended. In essence, this procedure lasted until about 1980, when the Zoological Museum of Copenhagen initiated a stranding network, aiming to collect as much information and as many specimens as possible. Since then, the network has been intensified several times, most recently with the launching of a contingency plan in 1993, involving the forest districts of the National Forest and Nature Agency. At present the handling of stranded cetaceans in Denmark is the responsibility of the Forest and Nature Agency and institutions authorised by the Agency (C. Chr. Kinze, Pers. Comm.).

Another early stranding program began in Great Britain, where cetaceans were also considered "Fishes Royal". In 1324, a statute gave the Crown qualified rights to cetaceans stranded on, or caught off, English and Welsh coasts. A similar situation existed in Scotland.

In 1913, by agreement with the then Board of Trade of the United Kingdom, these rights were transferred to the Natural History Museum in London, and the National Whale Strandings Recording Scheme (NWSRS) was born. Over 8,000 cetaceans have been recorded since then and the resulting database is employed to present distribution maps and analyse information about aspects of the biology of different species. The NSWRS is now the centre of co-ordinated research about cetacean populations around the British Isles, funded since April 1990 by the then UK Department of the Environment, later by the Department of the Environment Transport and the Regions, and currently by the Department for Environment, Food and Rural Affairs. Moreover, NSWRS is a contribution to the UK`s programme of research on the North Sea and linked to the ASCOBANS (the Agreement on the conservation of Small Cetaceans Of the Baltic And North Seas). Work is now undertaken in collaboration with the Institute of Zoology at regents Park, London (P.J. Chimonides, Pers. Comm.); information available at The National Whale Stranding Recording Scheme, http://www.nhm.ac.uk/zoology/stranding/index.html.

Currently one of the more highly developed stranding networks is "The Marine Mammal Health and Stranding Response Program – Marine Mammal Stranding Network" created in 1980 in the United States of America. This stranding network is formed by governmental agencies and it counts on the assistance of duly authorised volunteers. Its objectives are to (1) facilitate collection and dissemination of data, (2) assess health trends in marine mammal populations, (3) correlate health with available data on physical, chemical, environmental, and biological parameters, and (4) co-ordinate effective responses to unusual mortality events (*Becker et al.*, 1994). A Working Group on Unusual Marine Mammal Mortality Events was established in 1988 to establish criteria for determining when an unusual mortality event is underway, and provide guidance for responding to such events (Wilkinson, 1996). In support of the above network, the "National Marine Mammals Tissue Bank and Quality Assurance Program" was set up to establish and maintain a resource of selected marine mammal tissues for the purpose of providing samples for future analyses (*Becker et al.*, 1999).

Clearly the socio-economic, scientific and technological conditions in the USA are more developed than in most European and Mediterranean countries. However, some European countries, in addition to Denmark and Great Britain, have established similar networks. Stranding networks are currently on operation in Atlantic countries, such as Belgium, France, Germany, Portugal, the Netherlands and Ireland.

## THE MEDITERRANEAN EXPERIENCE

As in other regions of the World, the monitoring of cetacean strandings in the Mediterranean countries is very heterogeneous. In some countries there are no active groups devoted to cetacean research, whereas in others there have been well-established networks, some of them governmental, for at least 10 years. National, regional or local departments of the environment or fisheries, as well as public and private research institutions (Universities, Marine Institutes, etc.) and NGO's are usually involved in such networks. In the last decade of the 20th century, strandings have been monitored in countries from the South and East Mediterranean. However, there are still countries where cetacean strandings remain unattended (RAC/SPA, 1998).





Some countries have national cetacean stranding networks and keep databases encompassing either all (Italy, France, Israel, Malta, Spain), or part (Algeria, Greece, Morocco, Turkey) of the coast. The degree of coverage in other countries is either partial or episodic (e.g. Cyprus, Tunisia) (RAC/SPA, 1998). The indigenous infrastructures within each Mediterranean country produce various structures for stranding co-ordination. For example, in the case of France the "Centre de Recherche sur les Mammifères Marins" co-ordinates cetacean strandings from Atlantic and Mediterranean coasts, whereas in Italy the "Centro Studi Cetacea" organise these activities. In the case of Spain because of the decentralised government, each region organises its own stranding network.

Despite this fragmentary monitoring, extensive work has already been carried out on the biology of cetaceans in Mediterranean countries. These studies range from simple records of unusual cetaceans species, such as Mesoplodon densirostris (Casinos and Filella, 1981) to complex population studies based on DNA of the striped dolphins in Western Mediterranean (*García-Martínez et al.*, 1999). Strandings are also a source of information about pollutants affecting cetaceans and the health status of the animals (Aguilar and Raga, 1993). Aguilar and Borrell (1994) found abnormal levels of several contaminants in striped dolphins during the 1990-1992 epizootic. *Domingo et al.* (1990) described the morbillivirus affecting striped dolphin populations and producing mass mortalities. Information on food habits and prey availability may be obtained from examination of beached animals. Blanco *et al.* (2001) described the diet of bottlenosed dolphin, *Tursiops truncatus*, in the Mediterranean. Likewise, the only source of knowledge of cetacean parasites is stranded animals (e.g. Resendes *et al.*, 2002). Additional important information is that related to interactions between ships and cetaceans. Curiously, Laist *et al.* (2002) collected valuable information about mortality produced by collisions between motorised vessels and great whales. Strandings of live animals provide a unique opportunity to study aspects not detectable post-mortem. The possibility of rehabilitation (sometimes *in situ*, without transportation to any specialised centre) is, on some occasions, feasible for the animals, e.g., amazing efforts undertaken last June 2002 in Turkey to release a sperm whale that had become entangled in a fishery net (A. Dede, Pers. Comm.).

## MEDACES

A Mediterranean Database of the Cetacean Strandings (MEDACES) has been set-up at the University of Valencia (Spain) to co-ordinate all national and regional efforts for riparian countries. This database was created under the Barcelona Convention and with the support of the Spanish Ministry of Environment. Distribution maps will be produced using a Geographical Information System (GIS). Annual or biannual reports will be accessible online through a web site. Researchers, technicians, civil servants and people interested in the biology and conservation of Mediterranean cetaceans will have access to information on stranding location, characteristics of the stranded animals, and the storage institutions, where samples from these mammals are kept for future analyses and studies.

At a more advanced stage, the establishment of a Collection of Biological Samples of Cetacean Strandings from the Mediterranean Sea is recommended. This collection might be maintained in different states or, preferably, centralised at a single site furnished with adequate support structures. In this context, some initiatives are being developed at the Universities of Barcelona (Spain) and Padua (Italy).

Scientific data collection requires a detailed and carefully planned protocol which is then implemented by qualified personnel. Given the differences in the level of coverage of cetacean strandings between the Mediterranean countries, two levels of data collection are proposed. At the first level, basic information will collected and this will be common to all the stranding networks; e.g. date and location of stranding, length, weight and sex of the animal, measurements, etc. The second level concerns more complex data and may vary as a function of the logistic and technical possibilities of each country. This information deals with the collection of samples for parasitological, toxicological, bacteriological, pathological and/or virological studies. MEDACES will gather this information on cetaceans strandings provided by a National Focal Point (NFP) in every country, through the RAC/SPA.

As mentioned above, stranded cetaceans are sometimes the only source of biological information on a given species. The collection of information during cetacean strandings in the Mediterranean, albeit not carried-out systematically as is proposed by MEDACES, has already produced an extensive number of scientific papers on very diverse aspects of cetacean biology and conservation (see above).

Mediterranean countries should set up national stranding networks which take advantage of their human and material resources appropriate to consider their own particular circumstances. Although the socio-economic conditions of each country are crucial, the establishment and maintenance of a national cetacean stranding network do not require elevated expenditure nor sophisticated infrastructures, at least for the collection of basic-level data. What is crucial, however, is to achieve good co-ordination between the different authorities, experts, NGO`s and the civil society in general. A stranding network should be formed at the initiative of each state, whereas Barcelona Convention would offer advice from its scientific committee if deemed necessary. It is highly recommended to seek the collaboration of security forces (local and national police, navy, coastguard, etc.) and civil protection services. NGO`s can play an important role in stranding networks by mobilising volunteers to cover as much of the national coastline as possible, increasing public awareness on cetacean conservation, and seeking the co-operation of local fishermen. Due to the differences in the current development of national stranding networks in the Mediterranean states, special efforts are recommended to realise and consolidate such networks in countries of the Eastern Mediterranean and North Africa. It is important to consider the possibility of organising sub-regional courses for training of personnel, particularly from the regions mentioned above. This would build a critical mass of experts who would support the national stranding networks.

An agreement between the ACCOBAMS and the RAC-SPA is being developed to co-ordinate the information of cetacean strandings of the ACCOBAMS countries and the MEDACES.

## CONCLUSIONS

Cetacean strandings provide not only relevant scientific information but also the key to their conservation. The establishment of a national cetacean stranding network does not necessarily demand high expenses, but it must be adapted to the economic circumstances of every participating country. In the Mediterranean context, the Barcelona Convention represents a nucleus of coordination and diffusion of information about the strandings through the MEDACES.





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# PHOTOS

Photo by Frank Dhermain

**Black Sea Bottlenose**
Stranded Tursiops truncatus, Tuzla, Bulgaria (north of Varna), February 1993. Even on a very old carcass there is work to be done: identification, measuring, removal of teeth...

**Black Sea Bottlenose**
Stranded Tursiops truncatus, Tuzla, Bulgaria (north of Varna), February 1993. Even on a very old carcass there is work to be done: identification, measuring, removal of teeth...

**Stranded Cuvier's Beaked Whale, in garden**
Stranded Ziphius cavirostris, Saint-Tropez, Var, France, 26 September 1979. Press cutting from the Var matin. Although Ziphius strandings are rare they reveal the presence of an animal which is almost never observed.

Photo by Frank Dhermain

Photo by Frank Dhermain

**Decapitated Cuvier's Beaked Whale**
Stranded Ziphius cavirostris, Giens, Var, France, 1976. This female was in gestation and the baby was kept in a collection.

**Leaping Stenella**
Stenella coeruleoalba Striped Dolphin, off Marseilles, France, July 2000.

Photo by Frank Dhermain

Photo by Frank Dhermain

**Johnston Strait Killer Whale**
Orcinus orca Killer Whale, male resident in the Johnston Strait, Vancouver Island, British Columbia, Canada, July 1997.

**Young Minke Whale, Besson**
Carcass of a young Balaenoptera acutorostrata Minke Whale in Toulon, the 1970s, examined by Colonel Jean Besson, the founder of the stranding network for the French Mediterranean coast.

Photo by Frank Dhermain

Photo by Frank Dhermain

*Newborn common Fin Whale stranded at Pointe Rouge*

*A newborn Balaenoptera physalus, stranded at Marseilles, France, in March 1997. The autopsy showed that this 5.5 metre-long baby had been hit by a ship, causing voluminous haematoma and some broken ribs. During the night a passer-by pulled out the carcass's right eye, for some unknown reason. Newborn babies, often still with the umbilical cord attached, are regularly stranded and show that the species reproduces in the Mediterranean.*

*Newborn common Fin Whale, Sausset*

*Newborn Balaenoptera physalus stranded alive at Sausset, Bouches-du Rhône, France, on 7 November 1984. The lesions caused by its rubbing against rocks, and the fact that it was blinded in one eye, left no choice but euthanasia. Killing such a large animal (5.5 metres, weighing 1,380 kilograms) is always a delicate operation, and in this case two bullets from an elephant gun were fired into the cranium.*

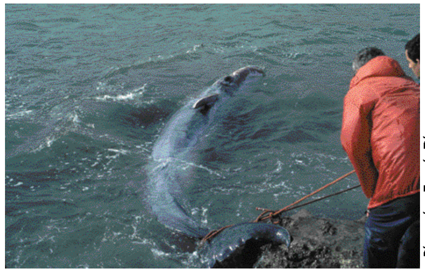

Photo by Frank Dhermain

Photo by Frank Dhermain

*When Dolphins were hunted down*

*A group of Tursiops truncatus surrounded and then massacred on land. Photo apparently taken in the 1930s in the rocky calanques near Marseilles, France. The caption does not say whether the dolphins were still being eaten at that date or simply destroyed because they were seen as engaged in unfair competition. Bottlenose Dolphins were formerly abundant on the coasts of Provence; they practically disappeared there in the 1950s, but are now making a timid comeback.*

*Seen from the front,*

*Fin Whale, Marseilles, being dismembered See photo 11.*

Photo by Frank Dhermain

Photo by Frank Dhermain

*Tail of Fin Whale,*

*Marseilles, being dismembered See caption to photo 11.*





*The Danielle Casanova*

*rams a whale calf A photo which appeared in the daily La Corse: a Balaenoptera physalus common Fin Whale calf was hit on 26/7/1996 by the car ferry Danielle Casanova outside Bastia port, Corsica, France.*

Photo by Frank Dhermain

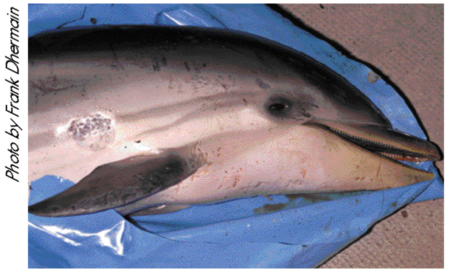

Photo by Frank Dhermain

*Dolphin, ulceration sp.*

*Exhaustive tests do not always give precise diagnoses. The marked ulceration on the side of this young Stenella coeruleoalba Striped Dolphin was subjected to anatomo-pathological study which gave no precise results. The ulceration was superficial and could be the mark left by lampreys.*

*Stranded Dolphin,*

*with Morbillivirus, Sormiou In 1990, a Morbillivirus epidemic affected thousands of Stenella coeruleoalba Striped Dolphins in the western Mediterranean. Many dolphins were stranded alive with many neurological symptoms: trembling, shivering, , bumping violently into rocks. Sormiou, the rocky calanques near Marseilles, France, September 1990.*

Photo by Frank Dhermain

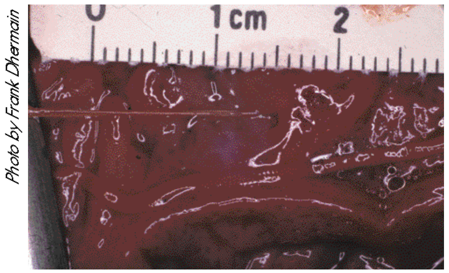


Photo by Frank Dhermain

*Strobilocephalus (photo by Jean-Michel Bompar)*

*Strobilocephalus triangularis, the rectum of a Stenella coeruleoalba Striped Dolphin.*

*Fin Whale, Marseilles, being dismembered*

*In October 2000, a Balaenoptera physalus common Fin Whale was brought into the port of Marseilles by the Egyptian container ship Fast Trader, which had hit it, as the autopsy showed, revealing several broken ribs. The high cost of dynamiting it at sea and the difficulty of bringing it to be quartered on land (15.8 metres, weight thought to be 35 tons) led the Autonomous Port to suggest an interesting solution: a team of professional butchers would dismember it on the quay, the chunks of flesh would be taken off for quartering, and the skeleton would be prepared to be exhibited in a hall of honour. This solution proved to be three times cheaper than dynamiting at sea.*

Photo by Frank Dhermain

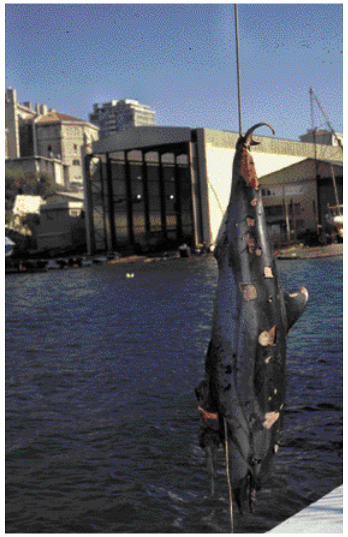

Photo by Frank Dhermain

*Suspended Stenella*

*A Stenella coeruleoalba Striped Dolphin found dead in the port of Marseilles, France, on 3 October 1998. The skin lesions are due to the decomposition of the carcass. Lacking suitable premises, it is not easy to carry out an autopsy in good hygienic conditions.*


Photo by Frank Dhermain

*Minke Whale caught at Hyères*

*A juvenile Balaenoptera acutorostrata caught in nets in 10 metres of water at Hyères, Var, France, in April 1998 (article in the Var matin). Young whales are often caught immediately off the coasts throughout the Mediterranean.*

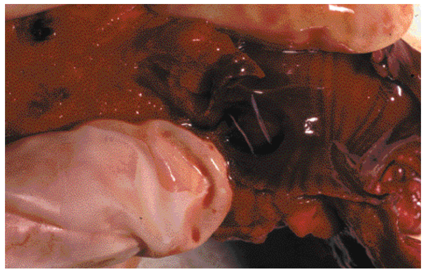

Photo by Frank Dhermain

*Metastrongylus*

*Metastrongylus sp., a nematode of the trachea of Stenella coeruleoalba Striped Dolphins.*

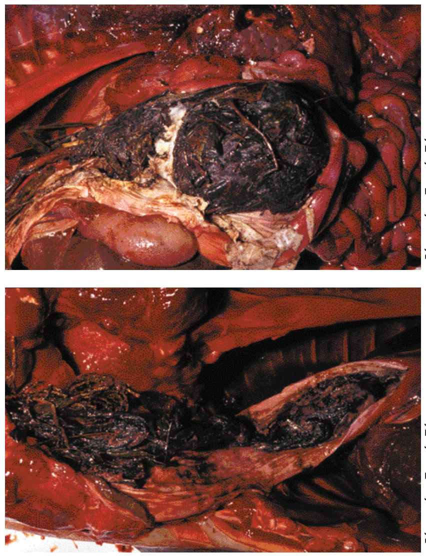

Photo by Frank Dhermain

Photo by Frank Dhermain

*Foreign body in Stenella stomach*

*In late September 2000, a school of 7 Stenella coeruleoalba Striped Dolphins entered the little port of the Ile des Embiez, Var, France, and stayed there several weeks. In the end only two individuals remained, very thin, one of which was found dead shortly afterwards. An autopsy showed that the alimentary canal from the entry to the oesophagus to the pre-stomach inclusive was filled by a mass of foreign bodies, basically Posidonia oceanica leaves, but also bits of plastic and spindle-tree, oleander and thuja leaves, etc.*





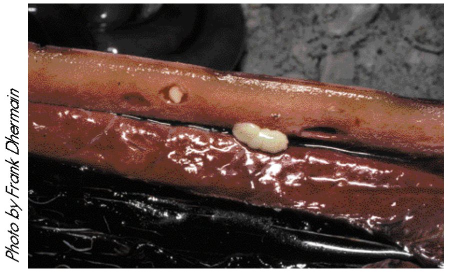

Photo by Frank Dhermain

*Phyllobothrium delphini*

*Phyllobothrium delphini, a parasitic cestode that abounds in the peri-umbilical fat of Stenella coeruleoalba Striped Dolphins.*

Photo by Frank Dhermain

*Stranded Stenella,*

*factory An old Stenella coeruleoalba Striped Dolphin female found stranded in front of factories in Martigues, Etang de Berre, Bouches-du-Rhône, France, October 2000. The autopsy revealed the presence of voluminous renal abscesses and very sizeable poly-parasitism.*

Photo by Frank Dhermain

*Fin Whale being dismembered,*

*Marseilles Phases of the Fin Whale in photo 11 being lifted by crane. The whale was placed on a base of the container ship stowed underwater by divers from the Navy, thus preventing the carcass from breaking up.*

Photo by Frank Dhermain

*Stranded Dolphin*

*in net, Sormiou The putrified carcass of a Stenella coeruleoalba Striped Dolphin, Sormiou, the rocky calanques near Marseilles, France, 23 March 2000. It is interesting to note that the carcass was stranded in exactly the same place as in the photo above, ten years later. Local currents play a major part in the distribution of strandings of individuals dead at sea. This one was caught in a fishing net, with its rostrum broken and a pectoral cleanly amputated.*

Photo by Frank Dhermain

*Captured Dolphin*

*with broken rostrum Characteristic images of a dolphin caught in fishing gear: the tail is surrounded by a piece of rope which has been used to raise it with the help of hoists to throw it back into the sea. The rostrum is broken, certainly from its fall into the hold. One can also find amputated caudals, when the end of the rope is too new to be sacrificed, or pectorals and/or the dorsal severed to free the nets more rapidly. Iles du Frioul, Marseilles, France, October 1990.*

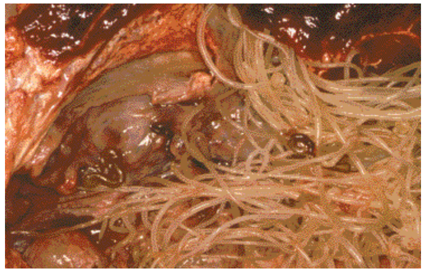

Photo by Frank Dhermain

*Crassicauda grampicola* (photo by Jean-Michel Bompar)
*Crassicauda grampicola, a formidable parasite of the sinuses and the inner ear, here on a Grampus griseus Risso's Dolphin. The base of the cranium was totally eaten away, more by the inflammatory reactions of the dolphin's organism than by the parasite's mechanical action. The parasite is in this case an obvious cause of the dolphin's death, but its action has been reinforced by environmental conditions and stresses due to pollution.*

*Dissection*
*Practical dissection work on the GECEM training course. Those responsible for the collection of scientific information on strandings come from very varied professional fields: veterinarians, biologists, doctors, amateur naturalists. Training in the techniques of dissection and the taking of samples is the best way of ensuring that the work is correctly done.*

Photo by Frank Dhermain

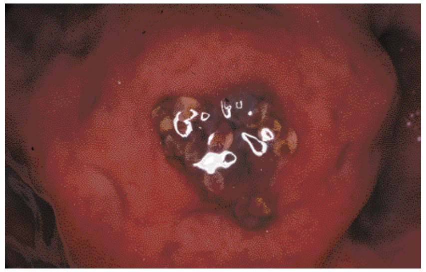

Photo by Frank Dhermain

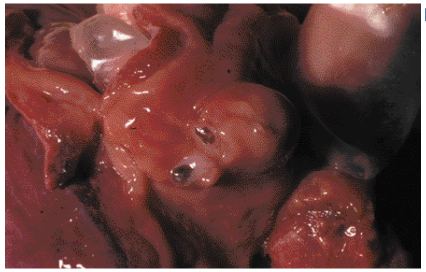

Photo by Frank Dhermain

*Pholeter gastrophilus* (photos by Jean-Michel Bompar)
*Pholeter gastrophilus, a parasitic trematode of the stomach of cetaceans, here on a Stenella coeruleoalba Striped Dolphin.*

**Le dauphin de la plage de l'Almanarre blessé mortellement par des plombs de chasse**

Photo by Frank Dhermain

*Dolphin wounded*
*by shot Shooting dolphins intentionally because they are rivals to fishermen or just for fun has become extremely rare on the continental shores of France. But this destruction sometimes continues in Corsica and seems to be more frequent on the southern shores of the Mediterranean (article in Var matin).*





Photo by Raga JA & Fernández M.

*A bottle nosed dolphin appeared off Valencia (Spain), sectioned due to human interaction.*

*Strandings awake the curiosity of the public, who often collaborate in rescue and rehabilitation efforts.*

Photo by Raga JA & Fernández M.

Photo by Raga JA & Fernández M.

Mass mortality of striped dolphins in the Mediterranean caused by a morbillivirus in 1990.

Foetus of a striped dolphin, stranding may provide information on aspects about the biology of cetaceans, such as reproduction and development.

Photo by Raga JA & Fernández M.

Photo by Raga JA & Fernández M.

Rehabilitation efforts are sometimes carried out in situ, as in the case of this Risso's dolphin at Valencia harbour.