Cetaceans of the Mediterranean and Black Seas: State of Knowledge and Conservation Strategies

SECTION 15

Natural Mortality Factors Affecting Cetaceans in the Mediterranean Sea

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Problem of definition: are natural causes really natural?

Although it is sometimes easy to establish that the cause of mortality is due to human action, e.g. a whale's collision with a ship, it is on the other hand almost always impossible to affirm that a death is natural. A fatal viral infection may be the result of an immunity deficiency resulting from pollution. Accidents when giving birth may be due to disturbance. And what about a dolphin which plays with a plastic bag, ingests it accidentally and then dies? Would he not have done the same playing with natural bodies carried by the sea?

A death is thus seen as natural when it does not seem to be linked to any non-natural factor, something extremely complex and often impossible to prove.

Death is the result of various parameters that have combined or opposite effects, and these parameters may escape notice if the investigation is not carried far enough. Here, the epidemic which affected the Mediterranean population of striped dolphins in the early 1990s is significant. Very quickly a morbillivirus was seen as responsible for the rise of the epidemic. The cause thus seemed natural. But going a bit further with their investigations, researchers discovered that this virus was only fatal for animals with high immunity deficiency (Kannan *et al.* 1993). Blood rates with extremely high PCB rating – these are substances which are known for their immunosuppressive effects – indicate this type of pollution as a co-factor in the rise of the epidemic. Environmental factors like lack of food, itself possibly linked to a rise in water temperature, might have led them to mobilize their fatty reserves, bringing into circulation the PCBs previously stored in the fat (Kannan *et al.* 1993). But these environmental variables are themselves modified by human activities (e.g., climate warming).

Through this example we can see how the further the investigations are pressed, the more the interpretation of dolphin death can be alternatively attributed to natural or other causes bound up in a complex process.

So why draw this distinction?

Because in terms of conservation of species and natural balances, this distinction is of the greatest importance. Although it does not seem desirable, except in extreme cases, to act on the natural factors which regulate populations, we must however keep the non-natural factors at a level which is tolerable for the affected population. Thus, certain fishing techniques, use of such a product or of such a sonar, could be the subject of regulation or even a ban if they have an alarming share in the responsibility for the mortality of one or several species. That is why many substances, like the DDTs, have been withdrawn from sale in many countries, and why the use of drift-nets is now prohibited by European Community law.

Hazards of life

Predation

Most cetaceans have few natural enemies, apart from the smallest species. Throughout the world, the main predators are certain big sharks and transient killer whales.

In the Mediterranean, the problem is restricted because of the rarity of possible predator species (Bearzi *et al.* 1997). But certain big sharks, including the great white shark, are present in the Mediterranean and prey on small cetaceans (four young *Stenella* in the stomach of a white shark caught at Sète on 10 January 1991) (J.M. Bompar *in litt.*).

Transient killer whales attack virtually any species of marine mammal, from porpoises to the blue whale. In the Mediterranean, where the species is not abundant, there has been some mention of predation on little dolphins and on *Ziphius* (Casinos and Vericad 1976, Notarbartolo di Sciara 1987).

Stenella, in dire panic, have twice thrown themselves on a beach in north-western Spain, apparently to escape from killer whales (Nores and Perez 1988); similar cases could occur in the Mediterranean, especially in the Sea of Alboran, where the killer whale is not rare.

In what is almost predation behaviour, some Bottlenose Dolphins kill little cetaceans by striking them violently, provoking broken ribs and burst spleen or kidneys (Jepson and Baker 1998a, Alonso *et al.* 2000). The reasons for this behaviour are not really known; it has never been reported in the Black Sea, where Tursiops and Porpoises cohabit, or in the rest of the Mediterranean between the bottlenose dolphin and another fairly small cetacean.

For most cetaceans, catching their food is usually not a dangerous activity. Accidents are the stuff of anecdote, like that enormous fishbone stuck in the tongue of a Bottlenose Dolphin, which caused an abscess (Var, France, 6.4.1988) (J. Besson *in litt.*).

Pursuit of prey may sometimes be the cause of a navigation accident. A killer whale was stranded in Majorca on 26 December 1941, pursuing a school of dolphins (Casinos and Vericad 1976).

Ingesting foreign bodies of natural origin is marginal and rarely serious. This food behaviour problem may be induced by confusing something (plastic bags) with usual food, a neurological disorder (particularly a morbillivirus), gastric ulcers, young individuals' lack of experience, a game, or a famine episode. Most of the time the foreign body is macro-waste and not a natural cause of mortality. But the ingestion of bird feathers, stones, sand, and weed has been noticed, usually without much direct consequence on the animal's health (Gonzalez *et al.* 2000). A striped dolphin which took refuge in Embiez port (Var, France) for 12 days ingested 360 grammes of *Posidonia*, oleander leaves, and various kinds of waste. The whole mass totally obstructed the digestive tract, and oleander is extremely toxic (Dhermain 2001).

Accidents when giving birth

There are known cases of pathological pregnancy and multiparous births in many cetacean species (Jepson *et al.* 1998b), like those 3 fœtuses in a Mediterranean fin whale (Besson *et al.* 1982).

Fœtal monstrosities are rarely seen in cetaceans. Birth in the open sea makes it extremely difficult to discover a malformed runt. A newly-born two-headed bottlenose dolphin was found south of Bastia (Corsica) on 24 June 2001 (Cesarini *et al.* 2002). These pathological births or pregnancies can be fatal to the mother.

Solidarity with the leader or a stranded companion

An entire group of cetaceans can be stranded around a sick companion, refusing to leave it until it dies, particularly for species with tightly-knit groups: sperm whales, killer whales, false killer whales, pilot whales, Risso's dolphins.

From 11 to 13 November 1989, a group of pilot whales stopped in the Gulf of Saint Tropez before suddenly disappearing. The next day, a corpse was found exactly where the group had stopped (Bompar 2000). On 17 April 1994, five Risso's dolphins were stranded in front of the Ebro delta round a female with serious respiratory difficulties. When the female was taken away to be put in a care centre, the other Risso's dolphins went back to the high seas without any problem (Alegre *et al.* 1995). Mass strandings of pilot whales were described in the Mediterranean in the last century, and should probably be related to this sociological phenomenon: 72 individuals stranded in September 1827 in Calvi, Corsica, 150 in Majorca on 21 December 1860, and 17 in La Nouvelle, Aude, on 19 February 1864 (Bompar 2000).

Environmental traps

Trapped by ice. Dozens of porpoises are sometimes trapped by ice in a dead end in the Azov Sea instead of being able to migrate to the south of the Black Sea (Birkun Jr. and Krivokhizhin 1997).

Navigational error in the shallows. Pelagic species that have 'got lost' in sandy shallows with gentle slopes with whose sonar echo they are unfamiliar might be surprised and stranded on shallows (Dudock Van Heel 1974).

The presence of a pelagic cetacean immediately off the coast does not automatically mean that the animal has involuntarily lost its way or that it will inevitably get stranded. Many reasons may explain its presence (curiosity, prospecting, disease, etc.), but the fact is that sometimes the animal is stranded. The accidental stranding of a live cetacean in good health is one of the rare cases where a rescue intervention can be crowned with success and must be urgently undertaken.

Striped dolphins regularly remain prisoners in basins of deep water surrounded by shallows of *Posidonia* and seem incapable of getting back to the open sea without help, especially if there is a fuss around them. A coordinated intervention of divers and inflatable craft, acting calmly, controlling the public's curiosity and sufficiently familiar with the cetaceans' behaviour to be able to anticipate their reactions, is often decisive (Bompar 1996).

A young fin whale calf was stranded in a metre of water off the mouth of the Great Rhone in the Camargue on 17 October 1996. It was strapped and pulled off to the sea thanks to major logistical means.

The cetacean's sonar system can be seriously harmed by the parasite *Crassicauda grampicola*, which provokes a very destructive exacerbated inflammatory reaction. And sometimes cetaceans prefer stranding to having to stay on the surface to breathe, and voluntarily seek the shallows. How often can they get out of them by themselves? Nobody knows.

Abnormalities in the Earth's magnetic field. In certain regions, strandings of live animals happen where the lines of the earth's electro-magnetic field are at right angles to the shore (Klinowska 1991a, 1991b). No similar study has been suggested for the Mediterranean, and other work done elsewhere in the world does not confirm this hypothesis (Brabyn and Frew 1994).

Pathology: diseases of cetaceans

Non-infectious diseases

Few studies have been done in a strictly Mediterranean context.

Food poisoning

Poisoning by various phytotoxins, described for several cetaceans, has been treated with prudence by certain writers (Gol'din and Birkun 1998). No mention is made of this for the Mediterranean *sensu stricto*. The phenomenon happens after a proliferation of a dinoflagellate phytoplanktonic alga containing toxins. Eaten by phytophagous fish, themselves predated by carnivorous fish, the toxins are concentrated along the food chain. The fish seem less sensitive to the toxin than the mammals (among them, humans) which eat the fish. At the end of the chain, the symptoms observed are varied: acute digestive troubles, or neuro-muscular disorders, even paralysis, or acute pneumopathy.

Various phenomena lead to the proliferation of dinoflagellates (red tide), such as an increase in nitrate waste near the shore (untreated waste water or leaching of over-fertilized agricultural soils), particularly in hot regions. The Mediterranean's industrialized or agricultural shores are thus potentially concerned.

During the summer of 1997, a mass mortality decimated the ranks of the only viable colony of Mediterranean monk seals *Monachus monachus*, wiping out 71% of the adults of the Cap Blanc peninsula population on the Mauritanian coasts, where there are now probably only 90 individuals (Aguilar 1997). Many factors may have intervened in this ecological catastrophe, but it is very probable that most of the mortality observed could be attributed to poisoning by toxins produced by dinoflagellates. The last Mediterranean populations of this famous mammal are thus extremely vulnerable to this factor.

Degenerative ailments

Elderly individuals present lesions caused by wear and tear and by degeneracy that are not necessarily fatal: vertebral arthrosis which can get so bad that it knits together the cervical vertebrae and the cranium (Van Bree and Duguy 1970); teeth being worn away (Toussaint 1977), cetaceans that are blind but otherwise in perfect health.

Tumorous pathology

Cancers are reputedly extremely rare in cetaceans living in an unpolluted natural environment, whereas the beluga of the St Lawrence in Canada present a large number of cancerous lesions associated with high concentrations of pesticides and heavy metals in the tissues (De Guise *et al.* 1994).

A squamous cutaneous carcinoma was described on a Stenella stranded in Spain (Calzada and Domingo 1990).

Large-scale methodical research was done (half a thousand autopsies on dolphins in Peru, for example, an equivalent number on British and German porpoises) permitting a great variety of tumours of the reproductive apparatus to be described, such as ovarian cysts and vaginal stones. Although not automatically fatal, these lesions have at least some effect on the concerned female's reproductive abilities (Van Bressem *et al.* 1998, Jepsen *et al.* 1998b, Siebert 1998). Studies of this extent are lacking for the Mediterranean.

Infectious diseases

Parasitology (Fig. 15.1)

Since cetaceans live in the marine environment, their parasites have to face up to difficult conditions to complete their life cycles. Parasites' strategies in most cases limit themselves to two main principles: a cycle that confines itself to the same host with contamination by proximity (the case for many ectoparasites), or one that is heteroxenous with several intermediary hosts and sometimes several paratenic hosts with a strategy of contamination by maximum dispersion (the case for many meso- and endoparasites).

There are no real parasite specificities for species developing in the Mediterranean. For cetaceans, the main parasite species are mostly cosmopolitan.

Epizoa and ectoparasites

As well as the commensal *Balaenophilus unisetus*, present between the whalebones of rorquals, and which feeds on micro-organisms, cetaceans are hosts to other species of non-pathogenic organisms such as certain species of Cirripedia crustaceans. *Conchoderma auritum,* a small 5-15 cm. crustacean, has been found on many species of Odontocetes, and also of *Balaenopteridae*. *C. auritum* fixes onto hard substrata such as the animal's teeth or gums. Although it is not pathogenic, it seems that it is involved in loosening the teeth or causing cracks in the jaws. *Xenobalanus globicipitis* is a non-pathogenic epizootic crustacean that fixes onto the trailing edges of dolphins' fins. When cetaceans are stranded, quite often the only thing that is found is the whitish shell still stuck in the host's epidermis.

The main cetacean ectoparasites are all crustaceans. The Pennellas, *Pennella sp*., are little-known Copepoda that are frequently parasites of big cetaceans. The female parasites dig into the cutaneous fat of the host, usually near the muscle, developing an anchor with three cephalic horns, and feed off the surrounding tissues. The pathological impact is limited to a local reaction. The *Cyamidae*, or 'whale fleas', are Amphipoda that are specific of the Odontocetes and Mysticeta. These are monoxenous parasites without an active swimming stage. Certain species of Cyamidae are specific of species, such as *Cyamus catodonti* or *Neocyamus physeteris* specific of the sperm whale, *Physeter macrocephalus*. Transmission occurs during bodily contact made between cetaceans. The Cyamidae dwell in the natural orifices or in wounds where they take refuge. They provoke small cutaneous lesions likely to become infected with a secondary infection, but the pathological impact remains limited.

Meso- and endoparasites

Most of these parasites, whatever their class, have a common strategy and an indirect cycle. Cetaceans are contaminated by their food, traditionally made up of fish.

Parasites of the digestive tract

Anisakis sp., a Nematode, and *Pholeter gastrophilus,* a Trematode, are very frequently found in the stomachs of Odontocetes. The first is well known, for it is cosmopolitan, and human beings can be contaminated by ingesting the larvae, usually in fish, even if this represents an epidemiological dead end. *Anisakis* are found free or attached to the mucous membrane most usually of the mechanical stomach, in which they are likely to provoke ulcers, exceptionally perforating. *Pholeter* is a fluke that can be seen in cysts of the chemical and pyloric mucous membrane of stomachs. These cysts, rarely obstructive, present a channel along which the parasite eggs are sent. Studies on fish in the market confirm the considerable frequency (sometimes 100%) with which *Anisakis* occurs. For dolphins, the occurrence varies from 30 to 60%, with more frequent infestations in adults. These parasites provoke lesions that are rarely likely in themselves to cause death but work towards weakening the populations.

In the intestine, several Cestode species may be found, but the easiest to identify is *Strobilocephalus triangularis*, a parasite of dolphins' (particularly *Stenella coeruleoalba*) rectums. Its major feature is an enormous scolex that it sticks in the mucous membrane, provoking a local inflammatory reaction that is usually very slight.

A family of flukes that are specific to cetaceans, the *Campulidae*, are regularly found in the liver or pancreas of cetaceans. They provoke lesions characteristic of fibrosis of the canals and parenchyma that can impair the animal's general health.

Parasites of the respiratory system

A specific family to cetaceans, the *Pseudaliidae*, parasitises the respiratory tracts. These Nematodes, close to the respiratory strongyles of the ovine race and pigs, may sometimes be found in impressive quantity in the bronchia and bronchioles. The wormy bronchopneumonia engendered, aggravated by the absence of the coughing reflex, may be fatal. porpoises, *Phocoena phocoena*, and also many dolphin species are frequently parasitised by this kind of strongyles.

Parasites of the urogenital system

Close to the Spirura Nematodes of domestic animals, the *Crassicaudidae* exclusively parasitise cetaceans. The parasite species are not specific to the host-species but rather to their microhabitat. *Crassicauda boopis* parasites the rorquals' kidneys, but *Crassicauda carbonelli* parasites the dolphins' penises, while *Crassicauda grampicola* parasites the dolphins' mammary glands. *Placentonema gigantisima* is the biggest known parasite, specialised in the placenta of sperm whales. As well as their immediate pathogenic aspects (obstruction, fibrosis), these parasites can have an impact on populations (weakening young nurselings, reproductive difficulties).

Soft tissue parasites

The most common are cysts of the plerocercoides larvae of Cestodes. Cetaceans are intermediary hosts for these parasites, the definitive hosts most probably being sharks. *Phyllobothrium delphini* parasitises the fat of Odontocetes in the ano-genital area. *Monorygma grimaldii* parasitises the mesozoa of the peritoneal organs. These parasites have a low pathological impact unless they cause lesions to the epididymic or ovarian parenchyma, for example.

Parasites of the nervous and sensory systems

These parasites are rare but also exceptionally sought. Whether the Trematode *Nasitrema*, never yet found in the Mediterranean, or the Nematode *Crassicauda,* these two parasites usually frequent the air sinuses of the Odontocetes. But by erratic migration (the first), or an exuberant inflammatory reaction on the part of the host (the second) these parasites can provoke irreversible, spectacular lesions of the cerebral hemispheres or the tympanic sacs. *Crassicauda* is known for *Grampus* or *Tursiops*, in which considerable osteolytic lesions of the bones of the cranium have been found, able to cause death.

Conclusion

Cetaceans are rather less parasitised than land mammals. Few of the parasites identified have an important pathogenic action. But the *Anisakis* in the stomach, the *Pseudaliidae* in the respiratory system, and if possible the *Crassicaudidae* either in the urogenital sphere or near the cranium should be systematically researched.

Mycology

Infections due to pathogenic fungi are not very common for cetaceans in the natural environment. Lobo's Disease, a basically tropical infection due to *Loboa loboi*, provokes invasive cutaneous lesions that can be transmitted to humans during autopsies.

Cetaceans' health conditions are decisive in the development of mycotic infections. Thus, cases of pulmonary aspergillosis have been found on striped dolphins infected by the morbillivirus epidemic.

Other anecdotal mycoses are especially described in captivity: *Candida albicans* candidosis, *Trichophyton sp*. ringworm, *Rhizopusmycosis* necrosant orchitis (Siebert *et al.* 1998).

Bacteriology

A major cause of mortality in captivity, bacterial infections are rarer in wild Mediterranean cetaceans. Certain infectious agents are highly pathogenic (*Erysipelothrix, Nocardia, Burkholdesia pseudomallei, Clostridium*), while many others are opportunistic germs: bacteria that are isolated during post-mortem examinations are not necessarily the primary cause of the death, many of them merely developing on an organism that is weakened by an infection, or after a physiological, parasitic or traumatic problem (e.g. pulmonary seat of infection consecutive to fractures of the ribs that have perforated a lung). But they do contribute to a worsening of the general condition.

Populations exposed to high levels of pollution, particularly PCB, DDT, butyl-derivatives, mercury derivatives which are very probably immunosuppressive, show a higher prevalence of suppurative seats of infection than populations living in protected areas (De Guise 1996, Pecetti *et al.* 1999, Wunschmann *et al.* 2001).

Little systematic bacteriological research has been done in the Mediterranean, but knowledge gained elsewhere can probably be transposed, for many of the germs are cosmopolitan. Getting results implies a research effort that keeps pace with ambitions: for example, for the time being, no analysis of Brucellosis has been found positive on the half-dozen dolphins tested in Mediterranean France (Moutou, *pers. comm.*); for the Spanish coasts, 24 serologies of 4 species have supplied 2 *Stenella* and 1 *Tursiops* that tested positive (Van Bressem *et al.* 2001), while in Canada 2,470 serologies of 14 different species were done, giving some hundred positive results, a third of which were for cetaceans (Nielsen *et al.* 2001). A medical adage has it: you only find what you are looking for, you only look for what you know.

Five germs must be especially mentioned, because of the possible human contamination, particularly during autopsies:

Erysipelothrix rhusiopathiae, frequently isolated in many cetaceans, supposedly contaminated by ingestion of infected crabs or fish. Two clinical forms: *acute septicaemic* and *subacute cutaneous* (Berny 1998). Human contamination is frequent if the autopsy is not carried out in rigorously aseptic conditions.

Burkholdesia pseudomallei, formerly *Pseudomonas pseudomallei*, an enzootic that is chronic in South-East Asia, but sometimes met with in captivity in Europe. Its presence in the Mediterranean is not known. It provokes acute pneumonia followed by fatal septicaemia, including for humans.

Brucella maris, discovered in 1994 on several marine mammals in Great Britain (Foster 1996), and in fact present in many marine mammal species around the world. Its presence in the Mediterranean has just been confirmed in Spain on two Striped dolphins and one bottlenose dolphin, a low prevalence compared with 100% of the adults examined in Peru! (Van Bressem *et al.* 2001). As for most other species of the genus *Brucella*, the germ may be responsible for cetacean abortions (Miller *et al.* 1999). During an accident in a laboratory, a researcher was contaminated by this new form of brucellosis (Brew *et al. 1*999) and other technicians presented symptoms that were suggestive after carrying out many autopsies on positive animals (Van Bressem *et al.* 2001). A certain transmission to humans is thus possible.

Vibrio spp., many species described for cetaceans, sometimes implicated in septicaemias. Human contamination is also possible during manipulation.

Nocardia spp., of which one serious case on a striped dolphin was described in the Girona area in Spain (Degollada *et al. 1*996).

In addition to these five major pathogenic agents, many other infections are known:

- pulmonary infections are a major dominant of cetacean pathology, encouraged by the respiratory system's being adapted to diving (De Guise 1996, Berny 1998)

- cutaneous infections on wounds of live stranded dolphins

- muscular infections are facilitated in cetaceans by the special features linked to diving, providing an extremely favourable terrain for the development of anaerobic germs. The points of entry are bites (intraspecific attacks) or wounds made by rocks (stranding of a live cetacean) that can be complicated by tetanus (Fernandez 2000)

- digestive infections are facilitated by the ingestion of foreign bodies, massive parasitism aggravated by stress and the accumulation of pollutant substances

- cardio-circulatory infections are usually complications of septicaemia

- genital infections are quite common. Infectious vaginitis, often associated with struvital vaginal stones, do not seem to affect the females' health. Infections of the penis and testicles for males are more often complicated by septicaemia. Cetaceans' intense sexual activity may have an important role in spreading these venereal diseases (Van Bressem *et al.* 1998, Jepsen *et al.* 1998b, Siebert 1998)

- urinary infections, however, appear to be rare.

Virology

Viruses are infectious agents that are much more constantly pathogenic than bacteria. Laboratory tests are done to:

- isolate and then identify the virus with electronic microscopes
- immunological doses, where reagents exist.

The presence of antiviral antibodies does not mean that the animal is ill at the moment of the test, but that it has been in contact with the virus during its lifetime. A kinetics of antibodies obviously cannot be envisaged on strandings. Thus the serological results must be considered from the viewpoint of memorials and necropsic symptoms or of the detection of viral antigens in the cetacean's tissues.

The spectacular epidemics recorded in the last few years have stimulated intense research work on the morbillivirus. Few other virological studies have been done in the Mediterranean outside this disease. Many viruses have been isolated for various cetaceans: *Poxvirus*, provoking benign cutaneous lesions (tatoo) like chickenpox that can potentially be passed on to humans (Van Bressem and Van Waerebeek 1996), observed in the Mediterranean in several species (Cabezon *et al.* 2000); *Calicivirus*, described for several cetacean species, provoking 1-3 cm.-diameter cutaneous vesicles that after bursting leave scars that remain without pigmentation. Abortions described. Not necessarily very pathogenic for cetaceans; potential agents of viral hepatitis but never found associated with pathologies for cetaceans; *Herpesvirus*, provoking varied disorders: gastric ulcers, interstitial pneumonia, encephalitis (Kennedy *et al.* 1992), infection of the genital tract (Ross *et al.* 1994); *Papillomavirus*, responsible for the proliferation of invasive confluent small verrucous lesions on the skin and the digestive mucous membranes (Bossart *et al.* 1996), and the genital mucous membranes, where they can hinder reproduction (Cassonnet *et al.* 1998); and other species that are perhaps not very pathogenic: *Adenovirus* and *Hepadnavirus* (Bossart *et al.* 1990); *Influenzavirus* (Geraci *et al.* 1982); *Picornavirus*.

As for other health problems, the influence of a polluted environment is decisive, and many factors act simultaneously to set up an explosive epidemic phenomenon. The study of the *Morbillivirus* epidemic which appeared in 1990 in the Western Mediterranean is particularly instructive on the many-factored nature of the unleashing of an epidemic. (see Fig. 15.2)

In July 1990, mass deaths of *Stenella coeruleoalba* striped dolphins were noticed on the Spanish coasts, soon spreading to the entire Western Mediterranean basin and the next year to the Central basin (Italian and Greek coasts) before reaching the Eastern basin in 1992 and the Black Sea in 1994. Some cases were found west of Gibraltar from the first year on, but the disease did not propagate itself in epidemic form in the Atlantic. Throughout the progress in the Mediterranean the same scenario was repeated from place to place: a rapid increase in the number of stranded dolphins, an epidemic peak and then a decline in the number of strandings, in most cases the entire process lasting from 3 to 4 months (Dhermain *et al.* 1994). In all, over 1,200 corpses were collected during the epidemic, and these figures do not reveal the whole tale (lack of prospecting, carcasses lost at sea, sunk or eaten by sharks). (Raga *et al.* 1992, Bompar *et al.* 1992, Bortolotto *et al.* 1992, Cebrian 1995, Birkun *et al.* 1999).

Today, from the season following the epidemiological peak, strandings that can be attributed to morbillivirus have become infrequent again in the Mediterranean. Strandings of moribund dolphins are a little more frequent than formerly, but nothing like the hundreds recorded when the epidemic was at its height. The 1990 epizootic was replaced by a chronic morbillivirus infection that caused subacute infectious lesions of the central nervous system (Domingo *et al.* 1995).

Symptomatology

The morbillivirus provokes neurological and pulmonary disorders that cause an unusually high number of live animals to be stranded. Most seem to be exhausted, shaken by shivering, affected by nervous troubles: some throw themselves onto the rocks to the extent that they break the rostrum while others are apathetic. Breathing is difficult and irregular. Some cases of digestive problems (diarrhoea, vomiting).

Attempts to take them forcibly back to the open sea were made here and there but always failed. Various forms of veterinary care were always useless.

On autopsy, pulmonary lesions (bronchiolar-interstitial pneumonia) and neurological lesions (encephalitis) are the most important.

Associated secondary lesions are very common: aspergillus, toxoplasmosis, actinomycosis, encouraged by immunosuppression consequent on infestation by the Morbillivirus and/or contamination by PCB and DDT: (Domingo *et al.* 1992).

Sex ratio and age ratio

Males and females are indifferently affected. Mature adults and new-born individuals whose nursing mothers are dead and/or easily infected alongside them, are the most affected.

Causal factor and encouraging factors

The causal agent of the disease is a Morbillivirus, isolated in the first months of the epidemic and new to science. Since 1987, new epidemics and the discovery of new viral agents have made the Morbilliviruses modern viruses (Moutou 1995). We mention in particular the mass deaths of Lake Baikal seals in 1987 (Canine Distemper Virus) and the North Sea seals in 1988 (17,000 dead). In summer 1997 a mass mortality decimated the ranks of the one viable colony of Mediterranean monk seals *Monachus monachus*, wiping out 71% of adults of the Cap Blanc peninsula population. Osterhaus *et al.* (1997) showed the presence of the Morbillivirus on Mauritanian seals and on some Greek seals in the Aegean Sea. (Monk Seal Morbillivirus MSMV).

Certain atypical morbilliviruses (on horses in Queensland, on pigs in Malaysia) are at the origin of a form of encephalitis fatal to humans.

The *Morbillivirus* is thus the *causal agent*, directly responsible for the disease. It essentially provokes 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 unleashed if it meets a terrain that is favourable to the spreading of the disease. A whole set of favourable factors explain the importance of the development of this epidemic:

a) An examination of the subjects stranded in Spain during the first 70 days of the epidemic shows that they were in bad physical condition.

b) Aguilar and Raga (1990) suggest that the peak of primary planktonic productivity did not occur in spring 1990 off Spain, reducing the food resources of fish, and therefore of dolphins, in the sector under consideration.

c) Abnormally high PCB levels were detected on dolphins stranded in France – and especially in Spain – (94 to 670 ppm), sometimes rising above 1,000 ppm, which represents one of the highest values ever found for a wild mammal. High concentrations of DDT (22 to 230 ppm) were also recorded (Kannan *et al.* 1993). In France, Augier *et al.* (1991) showed high cadmium, copper and mercury contaminations. On species on which they had been tested these pollutants cause hepatic lesions, affect reproduction, and are immunosuppressive. It is accepted that the same holds good for cetaceans.

d) The parasite load of dolphins suffering from the morbillivirus is particularly heavy. Fifteen parasite and epizootic species have been recorded, among these one localisation new to science, with very high prevalences for many parasites; disproportionate inflammatory reactions (Aznar *et al.* 1995); parasites that are absolutely unusual for striped dolphins, even for cetaceans (Raga *et al.* 1992, Fernandez *et al.* 1991); parasites that are usually associated with slow-swimming species, indicating that the dolphins were moving abnormally slowly, doubtless because of their disease. Several dolphins developed extremely serious secondary infections due to fungi (aspergillus), bacteria (antinomycosis) or sporozoa (toxoplasmosis).

e) The progress of the disease was also encouraged by the exchange of individuals between groups or temporary gatherings on feeding grounds (Bompar *et al.* 1991).

Later studies have shown that many, if not all, species were sensitive to the morbillivirus and yet only the striped dolphins, it seems, were concerned by this epidemic. Why? Firstly, perhaps because there were so many of them. Viral epidemics occur in high-density populations (e.g. North Sea Seals), certain writers seeing these epidemics as a natural population-regulating factor (Harwood *et al.* 1990)! This hypothesis could moreover be strengthened by the infecting of the common dolphin, a vicariant of *Stenella* in the Black Sea.

Osterhaus *et al.* (1995) think that infection by morbilliviruses evolves normally in enzootic fashion both for seals and cetaceans. Most species of Atlantic Ocean cetaceans are carriers of the Morbillivirus. Those which live gregariously, like the pilot whales and false killer whales, are in permanent contact with the virus, passing it from one member of the community to the next, and although the rate of infestation is very high (92% of individuals tested), the disease remains very mild because the populations are naturally and regularly protected against this everyday companion. The infection only takes on a dramatic epidemic character if the virus meets an unscathed population that is rarely in contact with this pathogenic agent (Duignan *et al.* 1995), *a fortiori* if their immunity defences have been weakened by other encouraging factors.

Population exchanges between groups, even temporary gatherings in multi-specific or not pelagic groups, explain quite well prevalences of the infection in different population studies across the Atlantic (Duignan *et al.* 1996).

<u>Consequences for the *Stenella coeruleoalba* population</u>

In the absence of a precise assessment of *Stenella* numbers in the western basin before 1990, and of the true numbers of dead dolphins during the epidemic, it is impossible to grasp the impact of this epidemic on the overall population.

Between July 1990 and September 1991, at least 800 carcasses were counted on the shores of the Western Mediterranean, and over 1,200 for the whole epidemic in the Mediterranean, and this figure only reflects part of the mortality, which (according to some) may be 10 to 50 times higher.

The only indications we possess on the consequences of the epidemic relate to the size of *Stenella* groups, which went down sharply after the epidemic. This reflects the high mortality of the population and suggests that the survivors did not immediately regroup to bring the groups up to their original strength.

The first counting campaigns, carried out in 1991, indicate an absolute figure of 68,000 to 215,000 striped dolphins for the Western Mediterranean (Forcada *et al.* 1994), i.e. a population that was still abundant and preponderant over other species in every sector.

Thus, a viral epidemic, however impressive, must not systematically be seen as an ecological catastrophe. When a virus affects a healthy population with a sizeable genetic diversity, there will always be enough resistant individuals to make up within a few years – possibly by increased reproductive success – the losses due to the disease. Cetaceans are certainly disadvantaged from this point of view for recovering the size of their original populations since they can only produce one baby per adult female every 2-3 years.

The problem arises when disease, usually of human origin, affects a species which, for various reasons , has very low population levels (like the monk seal) or has very little genetic variety (endemic sub-populations on restricted territories), or again when the individuals are made artificially fragile by outside agents, such as immunosuppressant pollutant substances, or when the environment's capacities no longer permit survivors to quickly fight their way back again. Here the Morbillivirus epidemic that hit the Mediterranean striped dolphins in 1990-1992 reveals the pollution thresholds of the Sea that nourishes us, and permits us to sound the alarm, in the interests of us all.

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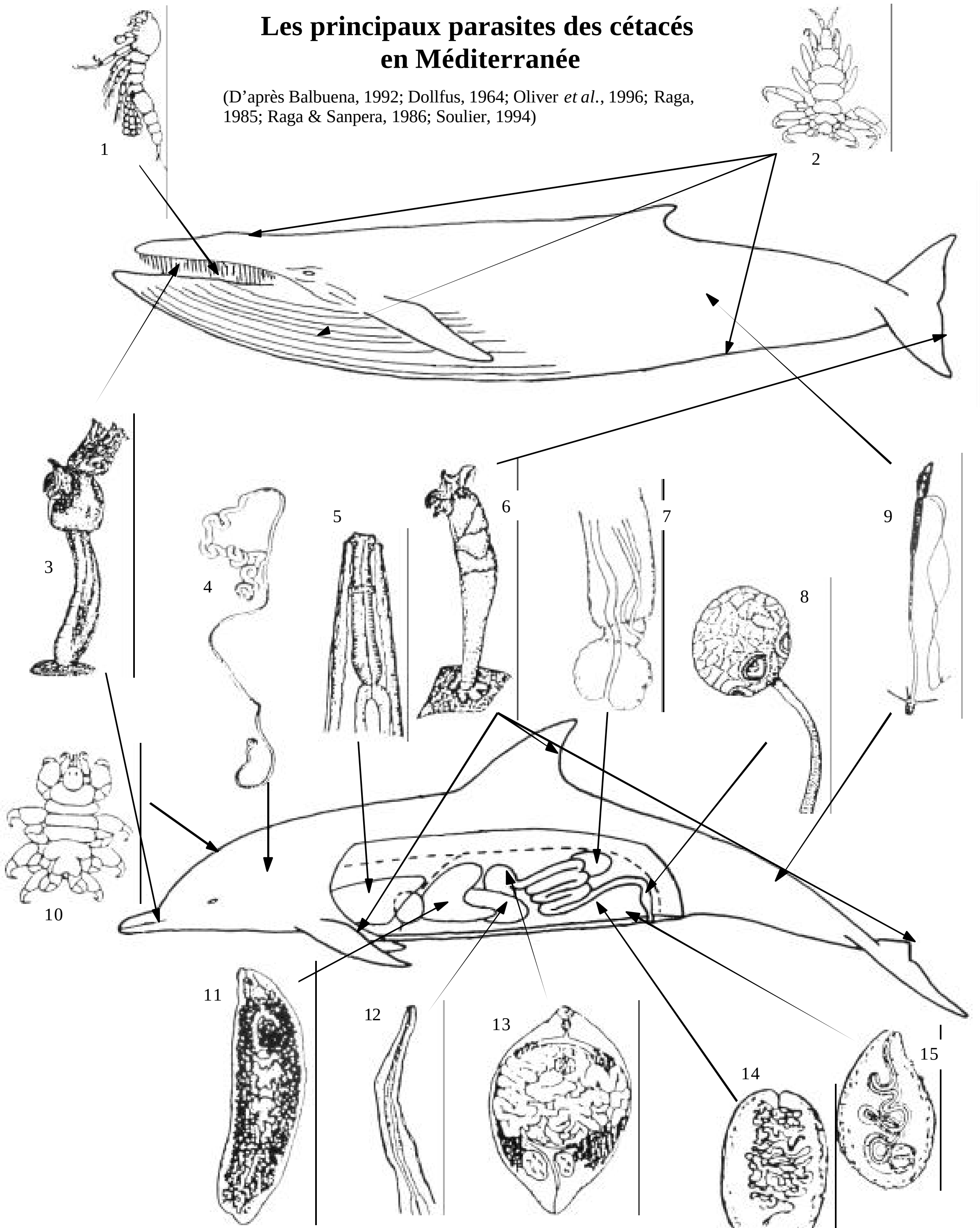

1-*Balenophilus unisetus*; 2-*Cyamus balaenoptera*; 3-*Conchoderma auritum*; 4-*Crassicauda sp*.; 5-*Pseudaliidae*; 6-*Xenobalanus globicipitis*; 7-*Crassicauda anthonyi*; 8-*Strobilocephalus triangularis*; 9-*Pennella sp*.; 10-*Syncyamus aequus*; 11-*Campulidae*; 12-*Anisakidae*; 13 *Pholeter gastrophilus*; 14-*Monorygma grimaldii (larvae)*; 15-*Phyllobothrium delphini (larvae)*

Fig. 15.1 – Main cetacean parasites in the Mediterranean.

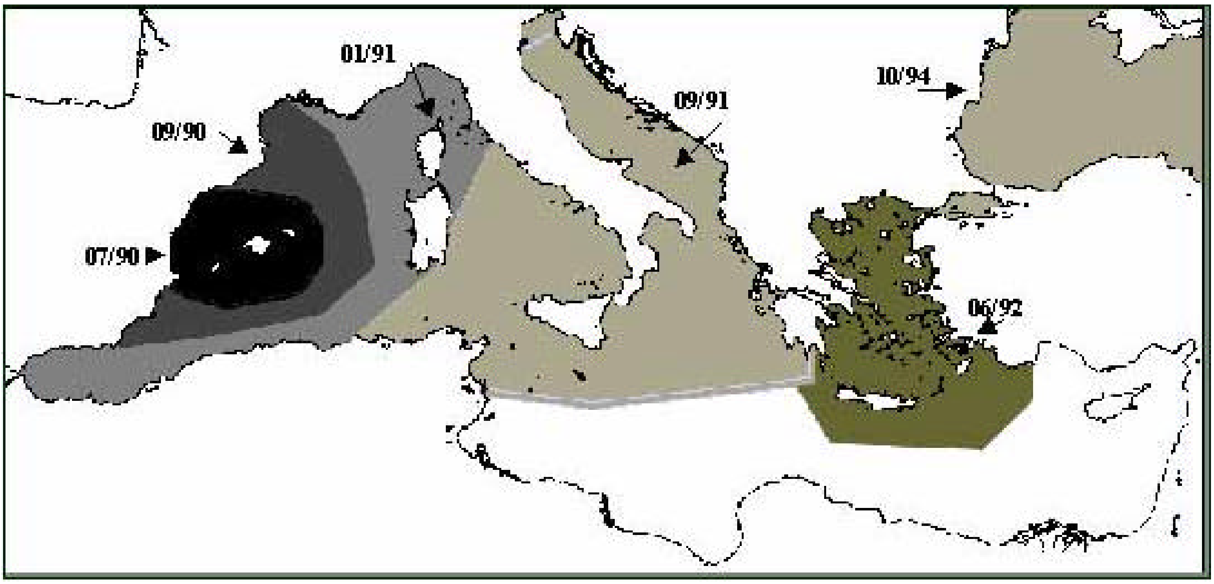

Fig. 15.2 – Progress of the Morbillivirus epidemic in the Mediterranean, 1990-1992. Taken from Raga and Aguilar 1992a, Bompar *et al.* 1992, Bortolotto *et al.* 1992, Cebrian 1992, and Birkun *et al.* 1999. The various shadings show the maximum extent of the epidemic in July 1990, September 1990, January 1991, September 1991, June 1992 and October 1994.