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Norwegian Scientific Committee for Food Safety

Human pathogens in marine mammal meat

Opinion of the Panel on Biological Hazards

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Persons working for VKM, either as appointed members of the Committee or as ad hoc experts, do this by virtue of their scientific expertise, not as representatives for their employers. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

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The Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM) has appointed an ad hoc group consisting of both VKM members and external experts.. The members of the ad hoc group are acknowledged for their valuable work on this opinion.

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Summary

Background:

Norway conducts commercial hunts for seals and whales, and since marine mammal meat and products are distributed to the public, these products are covered by the general hygiene control regulations. The control of meat from marine mammals is based primarily on organoleptic and microbiological spot tests.

There is a general lack of knowledge available on the presence of potential zoonotic pathogens in marine mammal meat and products and on the potential risk for humans. The Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen; VKM), Panel of Biological Hazards (Faggruppe hygiene og smittestoffer) took the initiative to develop this risk assessment in order to identify possible risks associated with human consumption of meat and products from seals and whales. The risk assessment is based on scientific publications and reports, and documents that have been used for training of veterinary personnel in meat control. Animal welfare is not within the scope of this assessment.

Main conclusions:

It is documented in this assessment that marine mammals may harbour several pathogens with the potential of giving disease in humans, and there are some reports on the transfer of such agents via meat from seals and whales.

The Panel of Biological Hazards has not been able to document that human consumption of meat from seals and whales is associated to a risk of exposure to human pathogens in Norway, but the data on which this conclusion is build, is scarce and are too limited to draw firm conclusions. There are almost no data documenting the microbiological status of seal and whale meat that is distributed for human consumption and the control is ad hoc, based on spot tests and few animals.

The general trend of increased consumption of raw or lightly cooked food may increase the risk for transmission of pathogens to humans. Considered suboptimal conditions for hygienic treatment of meat on board, as compared to abattoir conditions, as well as a long storage time in a non-frozen state (whale meat), it is crucial to secure the hygienic quality of the meat.

The training of personnel in slaughter hygiene should be strengthened, and if meat is not frozen, an unbroken cold-chain should be documented through the production line from the slaughter to the retail level.

A more systematic meat control practice (routine control) should be established. Broad-scale research projects, focusing on human pathogens in seals and whales, as well as monitoring and collating of data on contamination, are needed to further explore the risks of transmission of human pathogens from marine mammal meat.

Sammendrag

Bakgrunn:
Norge gjennomfører kommersiell jakt på sel og hval. Ettersom kjøtt og produkter fra sjøpattedyr distribueres til forbrukere, omfattes disse produktene av bestemmelser for generell hygienekontroll. Denne kontrollen er imidlertid begrenset med hensyn til antall kontroller, antall dyr undersøkt og antall parametre det undersøkes for, og er i hovedsak basert på sensoriske og mikrobiologiske stikkprøver.

Det er en generell mangel på data om forekomst av zoonotiske patogener i kjøtt og produkter fra sjøpattedyr og dermed også om den potensielle risikoen for mennesker. Vitenskapskomiteen for mattrygghet (Vitenskapskomiteen; VKM), Panel of Biological Hazards (Faggruppe hygiene og smittestoffer) tok initiativet til å utarbeide risikovurdering for å identifisere mulig risiko forbundet med konsum av kjøtt og produkter fra sel og hval. Risikovurderingen er basert på vitenskapelige publikasjoner og rapporter samt litteratur brukt til opplæring av veterinært personell i kjøttkontroll. Dyrevelferd er ikke innenfor rammen av denne vurderingen.

Hovedkonklusjoner:
I denne vurderingen er det dokumentert at marine pattedyr kan være bærere av flere patogener med potensialet til å gi sykdom hos mennesker, og at er det finnes noen rapporter om overføring av slike patogener via kjøtt fra sel og hval.

Faggruppe for hygiene og smittestoffer har ikke kunnet dokumentere at konsum av kjøtt fra sel og hval er knyttet til risiko for eksponering for humanpatogener i Norge, men data som denne konklusjonen er bygget på er få og for begrensede til å trekke bastante konklusjoner. Det er nesten ingen data som dokumenterer den mikrobiologiske status for sel og hvalkjøtt som er distribuert til konsum, og kontrollen er ad hoc, basert på stikkprøver av få dyr.

Den generelle trenden med økt konsum av rå eller lite kokt mat kan øke risiko for overføring av patogener til mennesker. Tatt i betraktning vilkår for hygienisk behandling av kjøtt om bord, som er utilstrekkelige i forhold til slakteriene, samt en lang lagringstid i en ikke-frossen tilstand (hvalkjøtt), er det avgjørende å sikre hygienisk kvalitet på kjøttet.

Opplæring av personell i slaktehygienen bør styrkes, og hvis kjøttet ikke er frosset, bør en ubrutt kjølekjede dokumenteres gjennom produksjon fra slakting til sluttbrukernivå.

En mer systematisk kjøttkontroll praksis bør etableres. Bred skala forskningsprosjekter, med fokus på humanpatogener i sel og hval, samt overvåking og kartlegging av data om kontaminering, er nødvendig for å gi et mer korrekt bilde av risiko for overføring av humanpatogener fra sjøpattedyr.

Keywords

Whales, seals, zoonoses, pathogens, bacteria, virus, parasites, food-borne, meat hygiene, commercial hunt.

Contents

1 Background

There seems to be a general lack of knowledge on the presence of potential zoonotic pathogens in marine mammal meat and products and the potential risk for humans. Norway conducts commercial hunts for whales and seals, and marine mammal products are sold on landing and are available through food stores and restaurants. The meat control is generally restricted and based on spot tests, with focus on only a few infectious agents (bacteria). The Norwegian Scientific Committee for Food Safety (VKM), Panel of Biological Hazards took the initiative of suggesting that a risk assessment on human pathogens in seafood, including marine mammals, should be conducted. The Norwegian Food Safety Authority (Mattilsynet) initially responded that there was a need for such knowledge on marine mammals, but that the knowledge on seafood in general was sufficient for the time being. VKM thus suggested a report focusing specifically on human pathogens in marine mammals, but Mattilsynet responded that they currently would not prioritise this issue. Based on the initial recognition of a lack of knowledge on this field, VKM decided to produce a self-initiated risk assessment of human pathogens in marine mammals.

The assessment contains definitions and background information on marine mammals and commercial hunt in Norway, with support from the white paper (2009) on Norwegian marine mammal management policy. Due to a generally limited knowledge on the presence of human pathogens in marine mammal meat and the risk of human exposure, the risk assessment is qualitative and based upon Norwegian and international scientific reports as well as some findings from bacteriological spot test controls of seal and whale meat. The report also refers to meat control practices for marine mammals in a few other countries where this issue is relevant.

Since much of the background data is of a scientific character, published in international journals, and since the accrued knowledge may be relevant and of interest for other countries involved in marine mammal harvest and consumption, this risk assessment is written in English.

2 Terms of reference

Meat products from seals and whales are offered for general consumption in Norway, and are therefore subject to hygiene control. However, due to the particular circumstances during sealing and whaling, hygiene control of these animals is not properly comparable to that during slaughter of domestic animals (abattoirs). Seal meat is normaly controlled on board by a veterinary inspector. This is compulsory if the meat is to be processed onboard, such as salting. In addition, a bacteriological spot test on land may be conducted by the Norwegian Food Safety Authority (Mattilsynet). Whale meat is not frozen onboard but is cooled outdoors on-deck and subsequently kept cool on ice. Meat from whales is controlled by veterinarians (organoleptic) at commercial plants authorized for processing and distributing whale meat, and bacteriological investigations are rarely conducted. No thorough investigations have been published on meat hygiene in seal and whale meat and products, nor on potential pathogens or agents that are known to impact on the quality of the meat/products.

Research on infections in marine mammals, and human pathogens in particular, is scarce and often anecdotal, and data are separated by species, populations/geography, and time. However, there is evidence of the presence of parasites, bacteria, and viruses in marine mammals that can be transmitted and be infectious to humans (zoonoses).

The aim of this risk assessment was to identify possible risks associated with human consumption of meat and products from seals and whales. Animal welfare issues are not within the scope of this assessment.

Questions to be answered in this risk assessment:

1. Which human pathogens can be present in whale and seal meat?
    a. Pathogens present in seals and whales.
    b. Contamination of meat during hunt, handling and storage.

2. Which factors during seal and whale hunts can impact on the contamination of meat, the survival of infectious agents, and transmission to humans?

3. To what extent do the regulations address these issues and which measures can be implemented to limit the risk of transmission of pathogens from marine mammal meat to humans?

3 Introduction

Marine mammals

Marine mammals consist of a diverse group of roughly 120 species that live in, or depend on, the ocean and the marine food chain. This group of mammals includes cetaceans (whales, dolphins, and porpoises), pinnipeds (true seals, eared seals, and walruses), sirenians (dugongs and manatees) and otters (sea otters and marine otters). Usually, polar bears (*Ursus maritimus*) are also included as marine mammals as they spend all or most of the year on sea ice, dependent on the marine food chain. Seals and whales are descendants of land-living mammals of the order *Artiodactyla*, but have adapted to a life in the sea, in terms of a hydrodynamic body shape, modified limbs, and specific physiological adaptations regarding thermoregulation and diving. The cetaceans and the sirenians cannot live or stay on land and are thus the marine mammals that are most adapted to the marine environment.

Many marine mammal species are currently endangered, mostly due to a history of international commercial exploitation (meat, blubber, fur, skin, teeth, and baleens) from the 1700s to the mid-1900s. Ship strikes and entanglements are probably the most common causes of unnatural mortality of whales currently, except from hunting, and in some places and for some whale species, mass strandings occur, as multi-factorial events or without known reasons.

Of the approximately 32 species of seals and 78 species of cetaceans that have been described, only a few are represented in Norwegian waters and some have only a seasonal or occasional appearance. Presently, Norway commercially hunts only one whale species, the minke whale (*Balaenoptera acutorostrata*), which is the smallest of the baleen whales in our waters. Of seals, Norway conducts commercial hunts for two species, the harp seal (*Phoca groenlandica*) and the hooded seal (*Cystophora cristata*). In addition, there are regular hunts for two coastal seal species, the harbour seal (*Phoca vitulina*) and the grey seal (*Halichoerus grypus*), based on annual quotas. Along the coast of Northern Norway, regulations also allow hunting of harp seals (*Phoca groenlandica*) and ringed seals (*Pusa hispida*).

In this risk assessment, the issue of human pathogens in marine mammals is focused on the commercial species and the coastal seals mentioned above, that may be consumed by people. Two geographical terms, representing the traditional hunting grounds for harp and hooded seals, are used in this report and need to be defined. These are: ”Vesterisen” (West Ice), which refers to the drift ice in the Norwegian fishery zone at Jan Mayen, outside the Greenland and Icelandic economic zones, and "Østisen" (East Ice), which refers to the sea area west of Novaja Zemlja and southwest to White Sea, east of 20 ºE in the Russian economic zone.

Norwegian commercial whaling

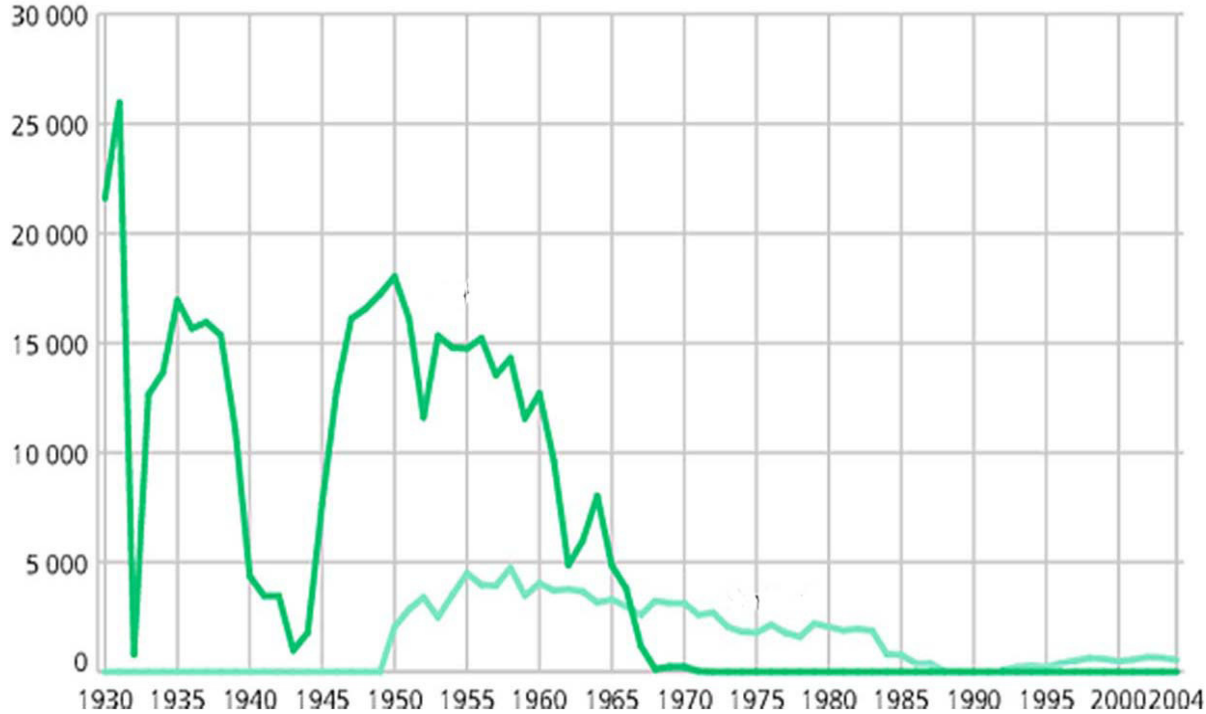
Together with other countries, Norway was previously an important participant in the whaling industry, especially in the southern hemisphere, where the hunt was based on large whale species. Due to exploitation and decreasing populations of these species, this Norwegian whaling stopped in 1967 (Figure 1).

The minke whale hunt has probably been conducted in Norway since ancient times. The minke whale is the smallest species of the *Balaenopteridae* family (Finnhvalfamilien). They can be up to approximately 10 m long, usually around 8.5 m for females and 7.9 m for males, with a weight of around 6-9 tonnes, but heavier minke whales are also caught. They give birth to one calf per year. The minke whale has a seasonal appearance along the Norwegian coast and visits these waters for feeding during spring summer and early autumn.

The first regulation of the minke whale hunt came in 1937, when a licence was required to be allowed to participate in the hunt. Today, the Norwegian minke whale hunt is regulated by quotas, from the North Sea and north along the Norwegian coastline, and off the coasts of Bjørnøya and Spitsbergen (Svalbard) and Jan Mayen. The Norwegian minke whale hunt is mainly conducted on the North-East Atlantic minke whale population.

The quota for 2009 was 885 animals, of which only 484 (54%) were caught. Therefore, the quota for 2010 was increased to 1286 animals, and stays unchanged for the season 2011, with a maximum of 65 animals in the Svalbard region. Approximately 25-30 vessels are active in the annual hunt. The boats are 40-80 feet long, and the hunt is traditionally based on a family business with fishing as the main activity and minke whale hunt as an additional and seasonal income (May-August).

Figure 1: Norwegian commercial whaling 1930-2004, number of animals including large species in the southern hemisphere (dark line) and small species (light line) which today is only the minke whale (*Balaenoptera acutorostrata*) (Modified from Statistics Norway).



Whales are shot by a harpoon with an exploding device (penthrite grenade) that is triggered once the harpoon is inside the animal, resulting in immediate death in more than 80% of the animals. If death is not achieved immediately, another harpoon can be fired, or the animal can be killed by rifle. The whale meat is air-cooled as luns of 50-100 kg on deck on wooden racks. When the meat reaches the ambient temperature, it is packed with ice in the cargo hold onboard with plastic sheeting between the meat and the ice, until delivery to approved land-based stations (Picture 3 and Picture 4). At landing, the meat is subjected to a compulsory organoleptic control; appearance, smell and taste (Picture 5) Superficial parts of the meat luns are usually discarded and the rest is sorted into different qualities. Bacteriological tests are only conducted on suspicion of contamination or as spot tests. Whale meat is sold, either fresh or frozen, via grocery chainstores and fresh produce wholesalers, both as 5-10 kg packages for purchase by hotels and restaurants, and as smaller consumer packages.

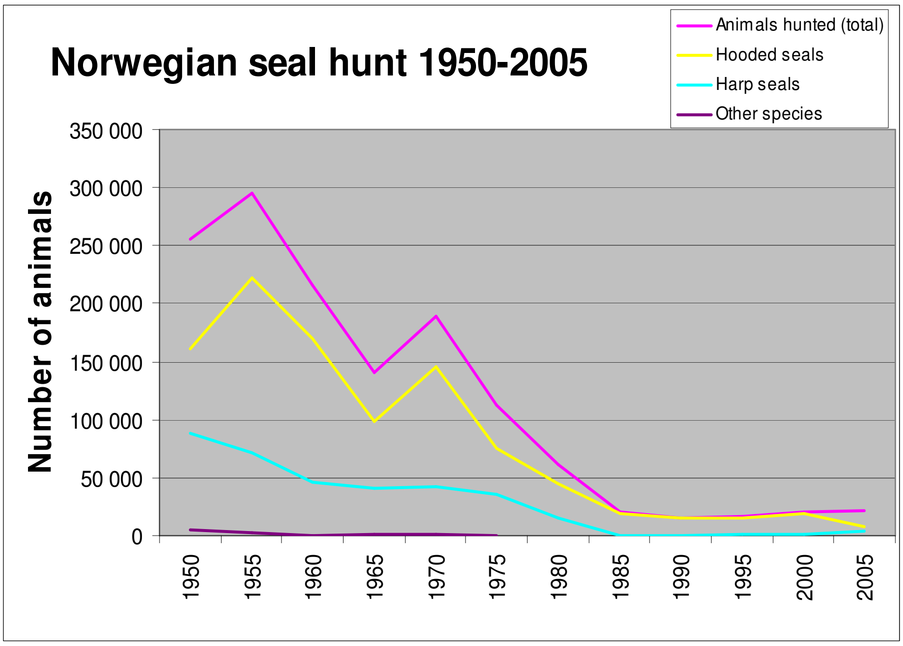
Norwegian commercial sealing

Norway conducts an annual commercial hunt of harp seals and hooded seals in the West Ice and of harp seals in the East Ice area. Seal meat, i.e. from the back of the animal (beef), as well as front flippers and ribs (salted) have traditionally been consumed by a minority of the population, as a seasonal food in local communities with a tradition of sealing, such as the cities of Tromsø and Ålesund and their surrounding regions. Lately, seal meat has also become popular in some restaurants, as beef, but also salted and smoked.

The harp seal is about 1.5-2 meters long, weighing 100-150 kg; females are slightly smaller than males. The newborn pup is white ("kvitunge") and used to be the major economic product from the seal hunt, as fur. The harp seal is a pelagic seal species, but gathers on the pack ice for giving birth, mating, and moulting. Two different populations of harp seals have traditionally been hunted by Norway, in Østisen and in Vesterisen. From time to time, harp seals invade coastal waters of Norway, where they become a problem for the fisheries – approximately 60 000 seals were estimated as bycatch in 1987.

The hooded seal male is 2.5-3 m long and weighs 400 kg or more, whereas the female is about 2 m long and weighs 150-350 kg. The pup changes hair coat in the uterus, and is born with a blue coat ("blueback") and with a blubber layer. The suckling period is short, only 3-5 days, and the pup is left on the ice floe. The hooded seal is also a pelagic species, and is hunted only when gathered on the pack ice for giving birth and mating.

Figure 2: Norwegian commercial seal hunt 1950-2005.



The numbers of seals hunted have varied substantially over time (

Figure 2). Sealing was once an important source of income for coastal people. In 1955, 64 vessels caught close to 300 000 animals. Today, only a few boats (1-5) participate, and, due to a decline in the hooded seal population, the hunt for hooded seals has been stopped since 2007, and only a very limited number of animals have been caught for scientific purposes. In 2010, 4 678 harp seals (of a quota of 42 400) were caught in Vesterisen and 115 (of a quota of 7 000) in Østisen. For 2011, the total allowable catch (TAC) have been set to 42 400 harp seals in Vesterisen, whereas a quota of 7 000 animals has been allocated in Østisen (Russian economic zone). As for previous years, there will be no commercial hunt for hooded seals in 2011. The most important products from seals have traditionally been the skin, which is used as a material for fur coats etc., but also the meat. Meat from the backs of the animals is usually vacuum-packed onboard and frozen, whereas ribs and foreflippers traditionally have been salted in barrels. Bacteriological meat control is conducted at landing as spot tests, focusing on indicators of faecal contamination. The meat products are sold to local shops, restaurants and directly to the public.

Coastal seal hunt

Based on counts from land and aerial surveys, the populations of harbour seals and grey seals have been estimated at approximately 6700 individuals (2006) and 6200 (2003), respectively. The hunting quotas (2011) are set to 460 (470 in 2010) and 460 (1040 in 2010) for harbour seals and grey seals, respectively. The quota for harbour seals are distributed between Counties (no hunt in Lysefjorden and Porsangerfjorden) and the hunt takes place in two periods, 2. January - 30. April, and 1. August - 30. September. The grey seal hunt takes place 2. January - 15. September (north of Stadt) and 1. February - 30. September (south of Stadt). In addition to the hunted seals, it is estimated (Institute of marine research; IMR) that there is a bycatch in fisheries (fish nets etc.) of approximately 400 harbour seals and 100-200 grey seals annually. Persons approved for participating in the coastal seal hunt can also hunt harp seals along the Norwegian coast and ringed seals along the coast of Nordland, Troms and Finnmark counties (no quotas). As with other game, there is no organized meat control for hunted coastal seals.

Norwegian marine mammal policy

In a recent white paper on Norwegian marine mammal policy (Anon. 2008), it is stated that Norway will strive towards developing an ecosystem-based management of marine mammal populations, and that the harvest of marine mammals will be conducted in a sustainable manner, based on scientific platforms regarding population assessments and ecological perspectives (Anon. 2008).

Challenges for marine ecosystems and mammals

Through their varied prey species, such as fish, squid, crustaceans, shellfish and plankton, marine mammals have a broad contact with other species in the marine food chain. The coastal seals usually establish local colonies, whereas the pelagic harp and hooded seals and minke whales have a wide range and also undergo seasonal migrations over huge distances, thereby coming into contact with a range of ecosystems. They are thus exposed to compounds and infectious agents that may originate far from our own coast and waters. This has the potential to contribute to transport of possible pathogens between ecosystems of different regions. In addition to these "new" infectious agents that are introduced to marine mammal populations through migration, such agents may also change their distribution through changes in the ecosystems. Climate change and higher water temperatures have probably increased the northern distribution of several fish species, and this may also affect marine mammals that prey on fish, and probably contribute to a different distribution of infectious agents. The use of ballast water in boats, increased cargo transport at sea, such as the Northeast Passage, and tourism may also impact on the transport and introduction of infectious agents in marine ecosystems in different ways. The exposure of marine mammals to compounds like oil, heavy metals, and persistent organic pollutants (POPs) may, through mechanisms such as immunomodulation, affect the ability of marine mammals to combat infections. Marine ecosystems and the infection biology of marine mammals are thus not preserved and static systems, but rather subjected to dynamic processes that may represent continuous challenges for these animals, as well as for consumers.

Human pathogens

In this risk assessment, human pathogens are defined as infectious agents (parasites, bacteria, and viruses) that are associated with products from marine mammals for human consumption and that have the potential to be transferred to, and cause disease in, humans. Such pathogens can either be associated with the animal as a host, including the gut flora, or be transferred to the animal or animal products from an environmental source, such as freshwater ice, seawater, contamination by faeces from sea birds, and other types of contamination during handling and storage of the products, including transmission from humans.

Transmission of infectious agents from marine mammals to man has occurred through consumption of animal products, as well as through contact between humans and marine mammals during feeding, training, and handling of captive animals, and during hunting activity (Table 1). Some larger outbreaks of foodborne human disease have been reported, after consumption of whale and seal meat. This has mostly affected Inuit people in Greenland, Canada and Alaska, and has involved agents like *Trichinella* sp., *Toxoplasma gondii*, and *Salmonella* spp., as well as botulism, the latter being an intoxication after ingestion of meat in which the bacterium *Clostridium botulinum* has produced toxins. In some cases, tens or hundreds of people have been involved. With respect to salmonellosis, the direct cause has usually been consumption of meat from animals that have been dead for some time in the field or from animals in a moribund state. Another factor has usually been undercooked meat, as exemplified by outbreaks of trichinellosis after consumption of undercooked/raw meat, typically from walrus.

Blubber finger (spekkfinger) is maybe the most common occupational disease in people handling seals and seal products, also during the Norwegian commercial sealing activity and research expeditions. Other, less well-defined, infections may also occur through direct skin contact with seals and whales.

On the other hand, and as far as we know, there are no reports of food-borne disease outbreaks in Norway that can be linked directly to the consumption of marine mammal meat or products. However, many of the infectious agents that can be associated with marine mammal meat and products do not result in diseases in man with specific clinical signs, which can link the symptoms with specific pathogens. Thus, it is usually a difficult task to associate such a disease with contact with or consumption of marine mammals, and knowledge about such relationships is scarce. It should also be added that the control of meat and products from whales and seals can be characterized as limited, being generally based upon spot tests and a narrow spectrum of infectious agents. As stated in a recent white paper on Norwegian marine mammal policy (Anon. 2008), Norway should, as a nation that hunts marine mammals and that has the responsibility for management of several marine mammal populations, have a certain responsibility regarding research on health and diseases in marine mammals, as well as the zoonotic potential of infectious diseases in marine mammals.

4 Hazard identification

A wide range of zoonotic or potentially zoonotic parasites, bacteria, and viruses have been detected in seals and whales, and in some cases, transmission of pathogens from seals and whales have caused human disease. In the following, some infectious agents are discussed that should be under particular focus as possible zoonotic pathogens associated with marine mammal meat and products.

4.1 Parasites

***Cryptosporidium* spp.**

Little research has been published on the occurrence of *Cryptosporidium* spp. in marine mammals. The first report of *Cryptosporidium* in a marine mammal was in a terminally ill dugong, that was found on necropsy to have a heavy *Cryptosporidium* infection in its lower intestine, that was postulated to be the probable cause of death; intriguingly, subsequent molecular analysis demonstrated the species of *Cryptosporidium* to be *C. hominis*, a species which generally is associated with only human infection (Applebee *et al.,* 2005; Hill *et al.,* 1997; Morgan *et al.,* 2000). Since then, *Cryptosporidium* infections have been reported from ringed seals (Dixon *et al.,* 2008; Hughes-Hanks *et al.,* 2005; Santin *et al.,* 2005), right whales (Hughes-Hanks *et al.,* 2005), California sea lions (Deng *et al.,* 2000) and Bowhead whales (Hughes-Hanks *et al.,* 2005), with prevalences of over 20 % in some of the studies. Other studies of marine mammals, including Pacific harbour seal, northern elephant seal, bearded seal, harp seal, hooded seal, and northern bottle-nosed whale, have failed to identify infection with *Cryptosporidium* (Applebee 2006; Applebee *et al.,* 2005; Gaydos *et al.,* 2008). Molecular studies to identify the *Cryptosporidium* to the species level have been even less extensive, and although the California sea lion isolate was reported to be *C. parvum* (Deng *et al.,* 2000), the genetic characterisation is not considered to have been sufficiently extensive to exclude the possibility of this being a host-adapted genotype (Applebee *et al.,* 2005). Another genetic study of *Cryptosporidium* isolates from ringed seals, indicated the presence of two novel genotypes and *C. muris*, which is not normaly infectious to humans although individual cases have been reported (Santin *et al.,* 2005).

No cases of transmission of *Cryptosporidium* to humans via infected sea mammals have been reported, and it is difficult to see how this might occur except via ingestion of uncooked intestine of infected animals (as practiced by some Inuit people) or from contamination from the faeces/intestinal content of infected animals. It is perhaps more likely that *Cryptosporidium* may occur by onboard contamination of seal/whale meat from infected humans or via contaminated water.

Giardia duodenalis

The first study (Olson *et al.,* 1997) that investigated the occurrence of *Giardia* in sea mammals was prompted by the high prevalence of giardiasis in native Inuits on Baffin Island and epidemics of giardiasis in northern communities in Alaska, in which the origin of the infections were not identified, and the speculation that marine mammals be important reservoirs of infection. This study identified *Giardia* cysts in 3 of 15 ringed seals (20 %), but not in any of 16 beluga whales. Other studies have detected *Giardia* in other pinnipeds, including harp seals, grey seals, hooded seals, harbour seals, bearded seals and California sea lions (Applebee 2006; Applebee *et al.,* 2005; Dixon *et al.,* 2008; Gaydos *et al.,* 2008; Lasek-Nesselquist *et al.,* 2008; Measures & Olson 1999). *Giardia* have also been detected in bowhead whales and right whales (Hughes-Hanks *et al.,* 2005), and the short-beaked common dolphin, the Atlantic white-sided dolphin, Risso's dolphin, and the harbour porpoise. Prevalences in some species were rather high, with 64.5 % prevalence in ringed seals and 71.4 % prevalence in right whales in one study (Hughes-Hanks *et al.,* 2005) and 80 % prevalence in ringed seals and 75 % prevalence in bearded seals (Dixon *et al.,* 2008) in another study.

Whilst Lasek-Nesselquist et al (2008) suggest that the detection of *Giardia* cysts in faecal samples from sea mammals may be indicative of passive transfer, rather than infection, the high prevalences of *Giardia* in some marine mammal species, and serological data indicating *G. duodenalis*-specific IgG suggest that several cetacean and pinniped species can be infected (Applebee 2006).

Genotyping studies to the Assemblage level have mostly detected zoonotic isolates, with Assemblage B detected in ring seals (Dixon *et al.,* 2008), the harp seal, harbour seal, and some dolphin and porpoise samples (Lasek-Nesselquist *et al.,* 2008), and Assemblage A detected in *Giardia* isolated from harp seal and porpoise (Lasek-Nesselquist *et al.,* 2008), and harp and hooded seals (Applebee 2006). Another study, in contrast, found no zoonotic genotypes, with 11 isolates considered to be of a novel genotype, and 3 isolates a canine genotype (Gaydos *et al.,* 2008).

No cases of transmission of *Giardia* to humans via infected marine mammals have been documented, although some researchers have speculated that the high prevalence with zoonotic genotypes provide the potential for this route of infection (Dixon *et al.,* 2008), particularly via consuming uncooked seal meat or dried intestines. However, it should be noted that associating an outbreak of giardiasis with food is particularly difficult (Escobedo *et al.,* 2010). As with *Cryptosporidium,* in the Norwegian situation transmission of *Giardia* via marine mammal meat is probably more likely to occur due to onboard contamination of seal/whale meat from infected humans or via contaminated water, than via consumption of raw meat or dried intestines.

Toxoplasma gondii

Cases of symptomatic toxoplasmosis have been reported from a range of different species of marine mammals including seals, dolphins and other whales, as summarised in (Dubey *et al.,* 2003)) whilst various surveys have reported serological evidence of *Toxoplasma* infection in a range of marine mammals. Seropositive results indicative of exposure have been reported from grey seals (9 %), harbour seals (9 %) and hooded seals (2 %) from the east coast of Canada, but not from harp seals (n=112) (Measures *et al.,* 2004), whilst investigation of stored sera from stranded beluga whales from St. Lawrence Estuary, Canada, indicated 27 % seropositivity (Mikaelian *et al.,* 2000), and *Toxoplasma* seropositivity in stranded/bycatch cetaceans in British waters has been reported from a single humpback whale, 1 out of 71 (1.4 %) harbour porpoises, and 6 out of 27 (28.6 %) short-beaked common dolphins (Forman *et al.,* 2000). A survey of 380 harbour seals in southern Puget Sound Washington, USA reported antibodies to *T. gondii* in 7.6 % (Lambourn *et al.,* 2001), whilst a survey of various marine mammals including sea otters, whales, sea lions, walruses, seals and dolphins, reported variable seropositivity, with a notably high prevalence amongst bottlenose dolphins from California (91 of 94), and sea otters from California (82 of 100) (Dubey *et al.,* 2003). Sporadic infections of Kuril harbour seals (*Phoca vitulina stejnegeri*) and spotted seals

(*Phoca largha*) with *T. gondii* have also been reported from Japanese waters (Fujii *et al.,* 2007). More is known about *T. gondii* infections in sea otters than any other marine mammal, because the parasite has been isolated from tissues of many naturally exposed sea otters, and the serologic status has been verified by bioassay data (Dubey *et al.,* 2003; Lindsay *et al.,* 2001; Miller *et al.,* 2002a; Miller *et al.,* 2002b). However, sea otters are not under consideration in this risk assessment. Similarly, polar bears are not under consideration in this risk assessment, but a relatively high seroprevalence (over 20 % in subadults and adults) has been reported, including in polar bears from Svalbard (Oksanen *et al.,* 2009), and in walruses, a 6 % prevalence has been reported from Svalbard (Prestrud *et al.,* 2007). Regarding marine mammals in the North Atlantic, a survey including 316 harp seal, 48 ringed seal, 78 hooded seal, and 202 minke whale reported all samples to be seronegative (Oksanen *et al.,* 1998).

The mechanism of *T. gondii* infection in marine mammals has been debated considerably by researchers without clear resolution. It is unknown whether vertical (transplacental) transmission is a significant path of infection in these mammals (Fujii *et al.,* 2007), although it appears to play a minor role in maintaining infections in sea otter populations (Conrad *et al.,* 2005). For postnatal *T. gondii* infection, the ingestion of oocysts in contaminated food or water or the ingestion of *T. gondii*-infected tissues are the two main sources, but the dietary habits of most marine mammals (eating fish or invertebrates, or are exclusively herbivorous) means that ingestion of *T. gondii*-infected meat is unlikely (Dubey *et al.,* 2003), although has been postulated for transmission of *Trichinella* to seals and walrus (see section below). This means that oocysts excreted from felids are the most likely source of infection, possibly concentrated in transport hosts such as filter-feeding molluscs for some species, possibly in marine invertebrates (although there is no evidence of this), or in sea water. Experimental trials have demonstrated that *T. gondii* oocysts can establish viable infections in grey seals (Gajadhar *et al.,* 2004). It is noted (Dubey *et al.,* 2003) that *T. gondii* infection of dolphins is perhaps the most intriguing aspect, as these mammals derive their nutritional requirements from fish and squid and other cold-blooded sea animals, and drink little or no water, whilst, nevertheless, some studies demonstrate a high prevalence of infection. Regarding infection of seal species with *Toxoplasma* in Japanese waters (Fujii *et al.,* 2007), it has been suggested that a possible route of infection may be that *Toxoplasma* in the marine environment may be concentrated by shellfish. These are ingested by the North Pacific giant octopus, which, in turn, is the main prey of Kuril harbour seals and spotted seals (Fujii *et al.,* 2007). That large quantities of *Toxoplasma* oocysts should reach the marine environment at all, has also been a matter of speculation, as the oocysts are only excreted by felids, the definitive host in the parasite lifecycle. However a survey among 212 health service employees in UK, demonstrated that 12 % of all respondents dispose of cat faeces by flushing them down the toilet, thus providing a route, via sewage effluent discharge, for contamination of the marine environment. Recent studies on the ability of northern anchovies and Pacific sardines to act as transfer hosts for *Toxoplasma* have provided interesting results, indicating that both species of fish can filter *T. gondii* oocysts out of seawater under experimental conditions and accumulate them in their alimentary tracts, that the oocysts persist in the alimentary canal for at least 8 h (anchovies) and that the oocysts remain infectious (sardines) (Massie *et al.,* 2010). Thus, fish may also have a role in the transmission of *Toxoplasma* infection to mammalian hosts, including marine mammals.

Thus, as marine mammals are clearly at risk from infection with *T. gondii*, there is the potential for zoonotic infection by ingestion of *T. gondii*-infected of meat which has not been sufficiently cooked to inactivate the parasite.

Inuit communities are considered to be particularly at risk from zoonotic infections, due both to their nutritional habits and their intimate contact with the environment, and a

seroprevalence survey showed almost 60 % seropositivity amongst a representative sample of Inuit adults living in Nunavik, Quebec (Messier *et al.,* 2009). This is considered to be relatively high considering that there is a general absence of felids in the region. Multivariate analyses demonstrated that risk factors for seropositivity included consumption of potentially contaminated drinking water, frequent cleaning of water reservoirs, consumption of feathered game, and consumption of seal meat. Furthermore, an outbreak of toxoplasmosis amongst a small group of pregnant women in Nunavik, identified skinning of animals for fur, frequent consumption of caribou meat, consumption of dried seal meat, and consumption of seal liver, as risk factors for becoming seropositive (McDonald *et al.,* 1990). Indeed, the epidemiology of toxoplasmosis in the Arctic is intriguing. Presently, consumption of seal meat seems a much more important risk factor for human infection than drinking untreated water. Serological surveys suggest widespread *Toxoplasma* infection in marine mammals (Dubey *et al.,* 2003), and high human occurrence was recorded in Kuujjuaraapik, North Quebec, where 80% of Inuit (with dietary preference for raw, dried meat from sea mammals) were found seropositive, as compared with 10% in the ethnic Cree population in the same community (with dietary preference for cooked terrestrial mammals) (Levesque *et al.,* 2007; Messier *et al.,* 2009).
In an earlier study from Japan, consumption of raw meat was considered to be associated with seropositive results, in which the raw meats included beef, chicken, horse, boar, venison, and whale (Konishi & Takahashi 1987). In combination, these data suggest that the conclusion reached by Okansen et al (1998), that eating the meat of seals and whales does not predispose the consumer to acquiring toxoplasmosis, may have been too hasty. Nevertheless a study on the infectivity of traditional northern foods (a fermented product, a dried product, and a salted and spiced product) prepared with meat from seals experimentally infected with *T. gondii* were found to be non-infective for cats, despite the source seal meat resulting in infection (Forbes *et al.,* 2009). It is postulated that the temperature and duration of storage were the factors that reduced the infectivity.

***Trichinella* spp.**

Due to the lifecycle of *Trichinella* spp., transmission must generally be between carnivorous or omnivorous hosts, and therefore, with regards to marine mammals, most infection occurs and most information is available regarding polar bears and walrus, although benthic bivalve molluscs are the preferred diet of the latter.

Of the cetaceans, species such as killer whales and grey whales are likely candidates for *Trichinella* infection, due to their carnivorous diet. However, there is no evidence for *Trichinella* infection in these whales, nor clinical cases of human trichinosis associated with them (Forbes 2000). Pozio (2005) cites a circumstantial report of presumptive *Trichinella* larvae in the muscles of a beluga whale, but is of the opinion that cetaceans do not have an important role in the epidemiology of these parasites.

As seals are generally piscivorous, they are unlikely to be infected with *Trichinella*, however various older studies have suggested that bearded seals and ringed seals may be occasionally infected (as reviewed by (Forbes 2000), whilst a more recent study (Moller 2007) identified *T. nativa* larvae in muscle tissue samples from 1 ringed seal and 5 hooded seals, giving a prevalence of 0.2 % and 2.3 % respectively. Two studies have been conducted on harp and hooded seals from Norwegian hunting areas. Examination of diaphragms from 1955 harp seals and 192 hooded seals between 1949 and 1953 were found negative by trichinoscopy (Thorshaug & Rosted 1956), whilst a study from 1992 including 1000 harp seals and 174 hooded seals hunted north of Jan Mayen, and 175 harp seals from the Barents Sea, in which diaphragm samples were analysed using the digestion method, also gave no indication of *Trichinella* infection (Handeland *et al.,* 1995). An experimental study on grey seals (Kapel *et al.,* 2003) demonstrated that they were indeed susceptible to infection with *T. nativa*. It is speculated that natural transmission to seals may occur from occasional scavenging on small amounts of infected tissue from other Arctic mammals, particularly pieces discarded by hunters or left by predators (Kapel *et al.,* 2003), although it has also been postulated that seals may be infected by ingestion of crustaceans and fish containing low numbers of *Trichinella* larvae, as these have been shown experimentally to have the potential to act as passive vectors (Hulebak 1980).

The prevalence of *Trichinella* infection in walrus is higher than in other seals, and there have been various outbreaks of trichinosis associated with walrus consumption (see later). Older survey data (reviewed by (Forbes 2000), report prevalences ranging up to 10 %, whilst more recent data from a Canadian survey (Gajadhar & Forbes 2010) report a *Trichinella* prevalence in walrus of over 40 %. Although preferring a mollusc diet, walruses are both facultative and obligate carnivores, with seals as their main prey. However, the low prevalence of *Trichinella* in seals, combined with the relatively high prevalence in walruses, suggest that other transmission routes must be involved, and it has been proposed that polar bear carcasses, and perhaps sled dog carcasses, may be a possible transmission route (Forbes 2000). As with seals, transmission via shellfish acting as passive vectors cannot be excluded for some cases of infection.

Of the marine mammals, the polar bear has the highest prevalence of *Trichinella* infection. Surveys generally report prevalences of between 25 and 60 % (Forbes 2000; Rah *et al.,* 2005), and a more recent Canadian survey (Gajadhar & Forbes 2010) report a *Trichinella* prevalence in polar bears of over 65 %. Although seals are probably the major food source for polar bears, the low prevalence of *Trichinella* in seals, combined with the relatively high prevalence in polar bears, suggest that other transmission routes must be involved, and it is considered that bear to bear transmission is probably the major cycle, as intra-species aggression and cannibalism in polar bears is well-documented (Forbes 2000).

A seroprevalence survey in a hunting community in Greenland was highly age-related, being less than 1.4 % in persons under 40 years, but over 12 % in persons over 60 years. Risk factors were found to be, as well as older age, consumption of polar bear meat and occupation as hunter or fisherman (Moller *et al.,* 2010). Although the prevalence of *Trichinella* infection is usually at least 10 times higher in polar bears than in walrus, most outbreaks of trichinosis are associated with consumption of walrus meat rather than that from polar bears, as the latter is usually cooked whilst walrus is often eaten raw, or fermented or air-dried (Moller *et al.,* 2005; Proulx *et al.,* 2002). Indeed, several outbreaks of trichinosis associated with consumption of walrus meat have been documented (MacLean *et al.,* 1989; Margolis *et al.,* 1979; McDonald *et al.,* 1990; Moller *et al.,* 2005; Serhir *et al.,* 2001; Viallet *et al.,* 1986), to the extent that a trichinellosis prevention program has been implemented (Proulx *et al.,* 2002) that is specifically oriented towards investigating the occurrence of *Trichinella* in harvested walrus and disseminating information on positive samples to communities at risk. However, although one field investigation has suggested that traditional preparation processes of walrus meat, especially aging, may result in *T. nativa* larvae being inactivated (Leclair *et al.,* 2004), another study in laboratory-controlled conditions suggested that *Trichinella* larvae from experimentally infected seals survived in traditionally prepared foods (fermented, air-dried, spiced) for at least 5 months (Forbes *et al.,* 2003).

Of particular relevance to this risk assessment is that some species/genotypes of *Trichinella* larvae are resistant to freezing; indeed it is well-documented that *T. nativa* larvae are freeze-tolerant for prolonged periods, and it has also been demonstrated that they can survive repeat cycles of freeze-thaw (Davidson *et al.,* 2008). The geographical distribution of cold-tolerant vs. freeze-tolerant *Trichinella* species follow January isothermal lines, ca. -5°C for *T. nativa* (Malakauskas *et al.,* 2007), but the underlying cold tolerance of the muscle larvae depends on several factors, including temperature fluctuations around freezing point (Davidson *et al.,* 2008), host species (Gottstein *et al.,* 2009), and infection duration (Kapel *et al.,* 2003).

4.2 Bacteria

Salmonella

Salmonella has been isolated from many animal species in the marine environment, such as marine mammals, reptiles, fish and shellfish and fish-eating birds (Minette 1986). From published reports, it is clear that whales may be hosts for *Salmonella*. In Umanak, Greenland (1969), 400 inhabitants were sick with salmonellosis after consumption of meat from a dead and stranded white whale (*Delphinapterus leucas*) (Boggild 1969). In Tununak, Alaska (1972), 99 persons consumed meat and blubber obtained from a stranded whale, and 93 of them became ill, with various symptoms including fever, shivering, sickness and diarrhoea. *S.* Enteritidis was cultured both from the food and from rectal swabs from the patients (Bender *et al.,* 1972). In Japan (1950), 172 persons developed gastroenteritis and salmonellosis after consumption of meat obtained from a moribund whale found floating in the sea (NAKAYA 1950). These examples shows that whales may have infections with *Salmonella*, that these bacteria also cause disease in these animals, and that whales can be a source of infection for humans.

A wide range of *Salmonella*, including *S.* Enteritidis and *S.* Typhimurium, which are known human pathogens, have been isolated from many different seal species (Aschfalk *et al.,* 2002; Foster *et al.,* 1998; Stoddard 2005; Stoddard *et al.,* 2008). *S.* Newport, *S.* Bovismorbificans, and *S.* Typhimurium have been isolated from harbour seals, and *S.* Typhimurium also from grey seals, but such isolations have not been reported from the two commercial seal species for Norway, the harp and the hooded seals. However, a serological survey for *Salmonella*-specific antibodies in 93 harp seals from the Greenland Sea, using a mixture of LPS-antigen from *S.* Typhimurium and *S.* Cholerasuis, revealed a seroprevalence of 2.2 % (Aschfalk *et al.,* 2002), indicating that *Salmonella* spp. may be present, but are not common pathogens in these seals.

It is also possible that *Salmonella* can be transferred to marine mammal meat from a local human source. This can be due to a combination of inadequate personal hygiene routines and storage of whale meat on-deck, or due to water used for cleaning the deck, contaminated with sewage from the boat. Examples from *Salmonella*-outbreaks in hospitals and other institutions have shown that one person can transmit the bacterium to a number of recipients.

***Brucella* sp.**

Brucellosis and infections with different *Brucella* bacteria have been associated with a wide range of wild animal species (Davis 1990), including marine mammals (Godfroid *et al.,* 2005). *Brucella* bacteria were isolated for the first time from a marine mammal in 1994, from an aborted foetus of a bottlenose dolphin, California, USA (Ewalt *et al.,* 1994), which indicated that in marine mammals *Brucella* bacteria may also be associated with pathological changes in reproductive organs. Bacterial isolates were at the same time recovered from harbour seals, harbour porpoises and a common dolphin (*Delphinus delphis*) found dead on the seashore on the Scottish coast (Ross *et al.,* 1994), followed by isolates obtained from hooded seal, grey seal, Atlantic white-sided dolphin (*Lagenorynchus acutus*) and from an European otter (*Lutra lutra*) in British waters (Foster *et al.,* 1996; Ross *et al.,* 1996). Since then, *Brucella*-bacteria or antibodies specific to *Brucella* sp. have been detected in a wide range of marine mammals (Foster *et al.,* 2002; Jepson *et al.,* 1997), including walrus (*Odobenus rosmarus*), polar bears (*Ursus maritimus*), and seals from the Antarctic territories (Retamal *et al.,* 2000; Tryland *et al.,* 2001).

In the North Atlantic Ocean, antibodies against *Brucella* sp. have been detected in minke whales, fin whales (*Balaenoptera physalus*), and sei whales (*Balaenoptera borealis*), as well as in harp, hooded, and ringed seals (Tryland *et al.,* 1999). *Brucella* bacteria have been isolated from a minke whale (Clavareau *et al.,* 1998; Tryland *et al.,* 1999) and from hooded seals, in which they had a prevalence of 38 % in 29 animals, and were distributed in a wide range of organs, with the spleen and lung lymph nodes as the tissues that were most often infected (Tryland *et al.,* 2005).

Characterisation of isolates obtained from a wide range of marine mammal species, by conventional typing methods, as well as by restriction length fragment polymorphism (RLFP) and PCR, has revealed that they should be classified as distinct species of *Brucella*, and not regarded as classical species from terrestrial mammals invading new host species (Bricker *et al.,* 2000; Clavareau *et al.,* 1998; Jahans *et al.,* 1997).

The pathogenic potential of the marine *Brucella* species for man is not evident, but a few cases associated with marine *Brucella* bacteria have been reported. A lab worker in England was infected while working with marine *Brucella* strains (Brew *et al.,* 1999). The symptoms lasted for a week and consisted of headache, weakness and severe sinusitis. Bacteria, indistinguishable from the marine isolates in the lab, were isolated from a blood sample. Two cases of community-acquired human infections with marine mammal-associated *Brucella* spp., identical to isolates previously obtained from seals, were reported in 2003 (Sohn *et al.,* 2003). The two patients both had neurobrucellosis and intracerebral granulomas, but were separated geographically and in time, and had no known exposure to marine mammals or marine mammal meat and products (Sohn *et al.,* 2003). Another human case was reported from New Zealand. A 43 year old male presented after 2 weeks of symptoms of spinal osteomyelitis, fever, rigors, and lumbar spinal tenderness. A bacterial isolate obtained from the blood of the patient was identified by different methods to be closely related to a *Brucella* sp. originating from a bottlenose dolphin (*Tursiops truncatus*) and common seals (*Phoca vitulina*) (McDonald *et al.,* 2006). Characterization of 295 marine mammal *Brucella* isolates, based on multiple-locus variable number of tandem repeat analysis (MLVA-16), revealed 7 major bacterial groups, 3 groups consisting of whale (*Brucella ceti*) and 3 of seal (*Brucella pinnipedialis*) isolates, as well as one isolate standing alone, originating from the New Zealand patient (Maquart *et al.,* 2009). Another characterization, including isolates from all three naturally acquired human infections, found that they were closely related organisms, genotype ST27, which is rare among marine mammals investigated so far. It is also noted that none of the three patients had direct contact with marine mammals, but all had consumed raw sea food (Whatmore *et al.,* 2008). It is thus concluded that we should be aware of the potential zoonotic nature of marine *Brucella* bacteria, especially when occupational lifestyle may increase the probability of exposure (Whatmore *et al.,* 2008).

Since the incubation time can be long and clinical picture can be expected to be of a more general character, it may be difficult to associate clinical cases specifically with *Brucella* infections, and it is thus possible that other human cases have passed unrecognised. However, there are no reports of human cases of brucellosis caused by exposure to *Brucella* sp. through handling or consumption of seal and whale meat. Meat from terrestrial mammals infected with *Brucella* sp. is considered safe to eat if properly cooked.

Mycobacteria

Tuberculosis caused by *Mycobacterium tuberculosis* and *M. tuberculosis*-like organisms has been identified in a wide range of domestic and free-ranging animal species, including marine mammals, and disease associated with *M. tuberculosis* has occurred mostly within captive settings (Montali *et al.,* 2001). Tuberculosis was reported as the cause of death of a Californian sea lion in Bremerhaven Zoo, Germany (Ehlers 1965). Tuberculosis was also diagnosed in New Zealand fur seals (*Arctocephalus forsteri*) and sea lions (*Neophoca cinerea*) in a marine park in Western Australia in 1986. Isolates were originally identified as *M. bovis*, and no obvious source of infection was found, indicating that one or more of the animals brought the bacterium into the facility at the time of capture (Cousins *et al.,* 1990). Another report documents the transmission of *M. bovis* from seals to a seal trainer in a marine park (Thompson *et al.,* 1993), where three of the seals died from tuberculosis, and where the seal trainer developed pulmonary tuberculosis, caused by the same strain as detected in the seals. Altogether, mycobacteria have been detected in a range of marine mammal species, both captive and free-ranging, confirming that these bacteria are also present among wild seals (Bastida *et al.,* 1999; Bernardelli *et al.,* 1996; Cousins *et al.,* 1993; Forshaw & Phelps 1991; Hunter *et al.,* 1998; Romano *et al.,* 1995; Woods *et al.,* 1995). However, a thorough characterization of a panel of mycobacterial isolates obtained from several outbreaks in seals in Australia, Argentina, Uruguay, Great Britain and New Zealand, some of which previously were thought to be *M. bovis*, has grouped them as being a novel member of the *M. tuberculosis* complex, *Mycobacterium pinnipedii* sp. novum (Cousins *et al.,* 2003).

Tuberculosis has also been diagnosed in a colony of 29 sea lions kept in an outdoor facility in a zoo in The Netherlands (Kiers *et al.,* 2008). The sea lions were tested with a tuberculin skin test (TST) using avian and bovine purified protein derivative (PPD) and necropsied if positive. Necropsy revealed tuberculosis in 13 animals, three of them with pulmonary tuberculosis, one of which was infectious. The causative bacterium was identified as *M. pinnipedii*. Six of 25 animal keepers were shown to be exposed (TST-positive), indicating that cleaning of the enclosures was the most likely cause of transmission to humans (Kiers et al., 2008).

Atypical (nontuberculous) mycobacteria, found in soil and water and that are not obligate animal pathogens but have a more opportunistic pathogenic nature, have caused disease in captive seals of different species. *M. marinum*, *M. fortuitum* and *M. chelonae* are commonly associated with piscine tuberculosis, which has been reported in more than 150 fish species. These bacteria are also known to infect man (Decostere *et al.,* 2004; Piersimoni & Scarparo 2009).

M. marinum has been isolated from caseous lung lesions in an Amazon manatee, the lesions also being present in the testes (Morales *et al.,* 1985), and *M. chelonei*, *M. fortuitum* and *M. smegmatis* have been isolated from captive southern and California sea lions and a natterer manatee (*Trichechus inunguis*) respectively, the former having cutaneous mycobacteriosis and the two latter generalised infections, with dermal and lung abscesses (Boever *et al.,* 1976; Gutter *et al.,* 1987; Lewis 1987). Infections of marine mammals with atypical mycobacteria may be restricted to animals in captivity, the bacteria being present in the water supplies, and where the development of disease may depend also on stress factors and water quality, as well as the nutritional and immunological status of the animals.

Experience from the outbreak of *M. pinnipedii* in captive seals in The Netherlands (Kiers *et al.,* 2008) indicates that people in close contact with marine mammals should be aware of this potential zoonosis and the possibility of contracting mycobacterial infections (Hunt *et al.,* 2008). Such infections, however, are probably mostly transmitted by aerosols and may not be linked to human consumption of marine mammal meat or products.

***Campylobacter* spp.**

There are only two reports in the literature demonstrating the presence of *Campylobacter* spp. in marine mammals. One report described the isolation of a new species, *Campylobacter insulaenigrae* sp. nov., from three harbour seals (*Phoca vitulina*) and a harbour porpoise (*Phocoena phocoena*) in Scotland (Foster et al., 2004), and the other described the isolation of *Campylobacter jejuni*, *Campylobacter lari*, and an unknown *Campylobacter* species from northern elephant seals (*Mirounga angustirostris*) in California (Stoddard 2005). Prevalence of *Salmonella* and *Campylobacter* spp. was higher in juvenile northern elephant seals that became stranded along the coast of central California than in seals on their natal beaches that had never entered the water. A potential explanation for this difference is that stranded seals may have harboured bacteria but were not shedding them while they were in good health on their natal beaches (Stoddard 2005).

***Leptospira* sp.**

The first reported case of leptospirosis in marine mammals was published in 1971 (Higgins 2000). Since then many reports on leptospirosis in pinnipeds have been published, but so far no infections in cetaceans have been described. Infections by *L. interrogans* serovar Pomona include the pinniped species as sea lions (*Zalophus californianus*) (Gulland *et al.,* 1996) and northern fur seal (*Callorhinus ursinus*) (Smith *et al.,* 1974). In pinnipeds, typical symptoms include haemorrhages in foetus and neonates, and fever, reluctance to use rear limbs and icterus among adults. In a study conducted by Bogomolni et al. (2008), tissue from a total of 109 animals, either marine mammals or birds, were examined for *Leptospira* spp. by molecular methods involving PCR of 16sRNA genes. Of these samples, a total of 11 from nine species showed to be positive for *Leptospira* spp. Positive samples were collected from the birds common eider (*Somateria mollisima*), herring gull (*Larus argentatus*), northern gannet (*Moras bassanus*), and greater shearwater (*Puffinus gravis*), and the mammals common dolphin (*Delphinus delphis*), humpback whale (*Megaptera novaengeliae*), and harp seal.

***Nocardia* sp.**

Several *Nocardia* species have been reported to be involved in infections in pinnipeds and cetaceans, and have been isolated from the respiratory organs, intestinal tract, or from abscesses (Higgins 2000). *N. asteroides* has also been isolated from the respiratory system of diseased pilot whale (*Globicephala melaena*), pacific bottlenose dolphin (*Tursiops truncatus*), killer whale (*Orcinus orca*), and dolphins, whereas *N. brasiliensis* and *N. caviae* have been found in pacific bottlenose dolphins (Migaki & Jones 1983). The number of registered cases among humans has increased during the last two decades, due to a higher number of immunocompromised persons and better diagnostic tools (Sorrell *et al.,* 2010). So far there have been no reports of animal-to-human transmission of infections by *Nocardia* sp. (Sorrell *et al.,* 2010).

Clostridium botulinum

Several authors have reported on the prevalence of *C. botulinum* in fish and marine mammals (Cann *et al.,* 1966; Fach *et al.,* 2002; Gram 2001; Hielm *et al.,* 1998; Hyytiä-Trees 1999). When found in seafood products from cold-water areas such as Scandinavia, Canada, Alaska, Russia and some parts of Japan, *C. botulinum* type E is reported to be the most prevalent type (Huss 1994). *C. botulinum* type E is considered to be a true aquatic organism based on the widespread distribution reported (Huss & Pedersen 1979). Eklund et al. (1982) cautioned that the non-proteolytic nature of type E organisms would not result in the development of odours indicative of spoilage. Thus toxin could be formed with little evidence to the consumer that the product was spoiled and possibly unsafe. In a 1963 outbreak described by these authors, only 3 of 16 affected people reported any unusual flavours or off-odours.

Occupational illness: Seal finger (blubber finger) agent (*Mycoplasma* spp.)

"Seal finger", or "spekkfinger" (literally: blubber finger), as it is known in Norway, is a severe and extremely painful local infection on the hands of persons handling seals or seal products. This disease has been described in the medical literature since the beginning of the 20th century (Bidenknap 1907; Candolin 1953). Most clinical cases have been reported from Scandinavia, Canada, and Greenland, but also Alaska, Falkland Islands, and South Georgia (Hartley & Pitcher 2002). The infectious agent enters through abrasions or skin wounds, and, after an incubation period of 3 days to 3 weeks, the involved finger become red, oedematous and tender. The whole arm and the axillary lymph nodes may become swollen, and as a complication, adjacent finger joints are involved. If untreated, "seal finger" may lead to permanent stiffness of interphalangeal joints.

The aetiology of seal finger has never been obvious. *Micrococcus* sp. was suggested over 50 years ago (Thjotta & Kvittingen 1949), and also *Staphylococcus aureus* and *S. albus*, isolated from a case of seal finger associated with a bite from a seal (Eadie *et al.,* 1990). The bacterium *Erysipelothrix rhusiopathia*, associated with whales and other wildlife species (Hjetland *et al.,* 1995; Wood & Shuman 1981), causes the condition erysipeloid, which may resemble seal finger, with local cellulitis on fingers and hands. All these agents, however, are normaly penicillin-sensitive, suggesting another causative agent for seal finger, since the treatment of this condition with penicillin has not been a success.

In 1990, two identical isolates of *Mycoplasma phocacerebrale* were obtained from a seal trainer with seal finger and from the mouth of the seal which had bitten her (Baker *et al.,* 1998; Madoff *et al.,* 1991). This suggested *Mycoplasma* sp. as the causative agent of seal finger. Three species of mycoplasma, *M. phocidae*, *M. phocarhinis*, and *M. phocacerebrale* were isolated from harbour seals, during an epizootic in which more than 300 animals died of pneumonia along the coast of New England (USA) in 1979-80 (Madoff *et al.,* 1982), and from seals in the Baltic and North Seas in 1988-1989 (Kirchhoff *et al.,* 1989), and it has been suggested that mycoplasma infection in seals, as co-infections with other agents, may have contributed to the pneumonia (Stadtlander & Madoff 1994).

Personal hygiene (hot water, soap, brushing) after handling seals or seal products is important in order to prevent seal finger. Different types of antibiotics have been used, such as penicillin, sulphonamides, and erythromycin, without great success, and the drug of choice when seal finger is suspected is tetracycline (Baker *et al.,* 1998; Hartley & Pitcher 2002; Krag & Schonheyder 1996), which should be brought along during sealing and scientific expeditions handling seals.

4.3 Viruses

Influenza virus

Influenza A virus is one of few zoonotic pathogens known to have caused epizootics in marine mammals. In 1979-80, more than 400 harbour seals died of acute pneumonia associated with influenza A virus along the coast of New England, USA (Geraci *et al.,* 1982). Two major strandings of pilot whales occurred at the coast of New England, USA, in 1984, during which isolates of influenza A virus were obtained. A comparison of the proteins haemagglutinin and neuraminidase from these isolates with viral isolates from gulls revealed a close relationship, and it was concluded that the whale viruses probably originated from gulls (Hinshaw *et al.,* 1984). Other studies have also supported this theory. Characterisation studies, including isolates from seals and whales (Lvov *et al.,* 1978), have revealed that the nucleoproteins of the marine mammal influenza viruses are avian-like. Influenza A viruses of apparent avian origin have also been isolated from harbour seals in 1991-92 along the Cape Cod peninsula of Massachusetts, USA (Callan *et al.,* 1995), supporting the theory of interspecies transmission of influenza A virus from the avian host reservoir to marine mammals (Mandler *et al.,* 1990).

No epizootic suggesting influenza A virus among seals has been observed in the North Atlantic Ocean or the Barents Sea, which host the commercial seal stocks harvested by Norway. However, a serologic screening of harp (*n*=183) and hooded (*n*=100) seals from the North Atlantic Ocean and the Barents Sea, revealed an overall prevalence of 18 % and 8 % of antibodies against influenza A virus, respectively, indicating that influenza A virus is circulating in these seal populations (Stuen *et al.,* 1994).

A direct transmission of influenza A virus from seals to man was recorded during the epizootic among harbour seals in USA, causing conjunctivitis among persons handling diseased and dead seals (Webster *et al.,* 1981). Interspecies transmission is an important factor in the evolution and ecology of influenza viruses. Transmission of influenza virus between avian and marine mammal species, for example during co-feeding on fish or krill species, may represent an important step in the evolution of new mammalian viral strains.

Influenza B virus is a human pathogen with an unknown reservoir in nature. An influenza B virus isolate was obtained from a naturally infected harbour seal in The Netherlands, which was closely related to virus strains that had circulated among humans some years before (Osterhaus *et al.,* 2000). The study revealed 2 % seroprevalence in harbour seals sampled after 1995, whereas no influenza B virus specific antibodies could be detected in animals sampled before 1995, and seals may thus be one species that can harbour influenza B virus in nature (Osterhaus *et al.,* 2000).

Poxvirus

The disease "sealpox", nodular proliferative lesions in the skin of seals, was first reported in Californian sea lions (Wilson *et al.,* 1969), followed by other reports including South American sea lions (*Otaria byronia*), northern fur seals, harbour seals, and grey seals (Simpson *et al.,* 1994; Wilson 1972; Wilson *et al.,* 1972a; Wilson *et al.,* 1972b; Wilson *et al.,* 1972c; Wilson & Poglayen-Neuwall 1971). However, a retrospective study on archival tissue material of northern fur seals from the Pribilof Islands in 1951 also revealed poxvirus infection (Hadlow et al., 1980).

The diagnosis has been based on the presence of 1.0 to 2.5 cm in diameter, single or coalescing skin nodules, with a characteristic histopathologic appearance (Okada & Fujimoto 1984) and the finding of typical parapoxvirus particles by negative contrast transmission electron microscopy (Wilson & Sweeney 1970). Parapoxvirus particles have been isolated from sealpox lesions in several seal species, both from the family *Phocidae* ("true seals") and from *Otariidae* ("eared seals") (Table 1). Parapoxvirus isolated from seals belongs to genus *Parapoxvirus*, family *Poxviridae*, and Sealpox virus is a tentative species of this genus.

Poxvirus infections have been found in both captive and free ranging animals. During the epizootic (phocine distemper) caused by morbillivirus among harbour and grey seals in north west Europe (Heide-Jorgensen *et al.,* 1992), a high prevalence of pox-like lesions were found in grey seals, suggested to be induced by an immunosuppressive effect of the morbillivirus infection. One of these individuals also had a mixed parapox and orthopoxvirus infection (Osterhaus *et al.,* 1990).

Following transfer of free-ranging harbour seals from the coast of Germany into a facility, an outbreak of parapoxvirus infection occurred in which 26 animals were affected (Muller *et al.,* 2003). In addition to the well-described skin lesions, some animals also had proliferative nodules also in the mucosa of the oral cavity, especially the tongue.

Two persons handling grey seals with sealpox lesions were infected and developed typical nodular lesions on their hands, similar to lesions in persons infected with another parapoxvirus species (i.e. pseudocowpoxvirus; milker`s nodules). The lesion on the finger of the first person resolved over a period of 3 to 4 months, whereas the other experienced several relapses during a period of several months (Hicks & Worthy 1987). Another marine mammal technician developed orf-like lesions on the hand, after being superficially bitten by a captive grey seal, and PCR amplicon analysis indicated stronger homology to parapoxvirus previously isolated from seals than to other parapoxviruses (Clark *et al.,* 2005). Persons involved in handling and care of captive seals should thus be aware of the zoonotic nature of parapoxvirus.

In small cetaceans (*Delphinidae* and *Phocoenidae*), a skin disease called «tattoo lesions», or dolphin pox, has been described, associated with virus particles with a typically poxvirus morphology (Flom & Houk 1979). The lesions are 0.5 to 3 cm, round or irregularly shaped, flat or slightly raised, and with a grey or yellowish appearance, being solitary or confluent and generalised. It normaly seems to appear in otherwise apparently clinically healthy individuals, and have been detected in many species and waters (Van Bressem *et al.,* 2009). Reports of human infections from dolphins are not known to the authors.

Calicivirus

Calicivirus has been isolated from a wide range of seal and whale species, including the Californian and Stellar sea lion, the northern fur seal, the northern elephant seal, the walrus and the Pacific dolphin (*Tursiops gilli*). Specific antibodies against caliciviruses have been detected in blood of the same species, as well as in the bowhead, gray, fin, sei, and sperm whales (Barlough *et al.,* 1986; Barlough *et al.,* 1987; Barlough *et al.,* 1998; O'Hara *et al.,* 1998; Smith & Boyt 1990) (Table 1).

After handling northern fur seals (*Callorhinus ursinus*), a researcher developed flu-like illness followed by fluid-filled blisters of 1 cm in diameter on all four extremities, from which a calicivirus was isolated. A comparison of amplicons of a reverse transcriptase PCR conducted on the isolate and on the calicivirus San Miguel sea lion serotype 5 revealed that these viruses were of the same genotype (Smith *et al.,* 1998). The San Miguel sea lion virus, as well as possibly other caliciviruses in seals and whales, may thus be regarded as potential human pathogens.

Rotavirus

Rotavirus-specific antibodies have been detected in blood from pups of Galapagos sea lion (*Zalophus wollebaeki*) and Galapagos fur seals (*Arctocephalus galapagoensis*), and rotavirus-specific RNA was detected in a rectal swab obtained from a Galapagos sea lion pup (Coria-Galindo *et al.,* 2009). Whether this rotavirus, or other rotaviruses in marine mammals, has the potential to cause human infections is unknown.

Table 1. Evidence of infection of marine mammals with pathogens of potential public health significance

Infectious agent	Marine mammal species found positive/exposed in studies [1]	Marine mammal species found negative in studies	Potential risk to public health from marine mammals
Parasites			
***Cryptosporidium* spp.**	**Ringed seal**[2] California sea lion Right whale Bowhead whale Dugong	**Harp seal** **Hooded seal** Bearded seal Harbour seal (Pacific) Northern elephant seal Northern bottlenosed whale	No case reports, but *C. hominis*, regarded as usually infecting only humans, have been isolated from dugong.
Giardia duodenalis	**Ringed seal** **Harp seal** **Hooded seal** **Grey seal** **Harbour seal** Bearded seal California sea lion Bowhead whale Right whale Short-beaked common dolphin Atlantic white-sided	Beluga whale (white whale)	No case reports, but isolates considered zoonotic have been detected in a range of species

	<u>dolphin</u> <u>Risso`s dolphin</u> <u>Harbour porpoise</u>		
Toxoplasma gondii	**Harbour seal** **Hooded seal** **Grey seal** Walrus Beluga whale (white whale) Humpback whale Harbour porpoise Short-beaked common dolphin Bottlenose dolphin <u>Sea otter</u> Polar bear	**Harp seal** **Ringed seal** **Minke whale**	High seroprevalence in Inuit communities. Uncooked (dried etc.) or undercooked meat and products
***Trichinella* spp.**	<u>Atlantic walrus</u> <u>Bearded seal</u> <u>Ringed seal</u> **Hooded seals**	**Harp seals**	Outbreaks reported, particularly from consumption of walrus.
Bacteria			
***Mycoplasma* spp.**	**<u>Harbour seal</u>**		Assumed cause of seal finger, a frequently reported zoonosis. Local infection of hands Based on evidence of occupational illnesses harp and hooded seals are most likely carrying *Mycoplasma* spp. (not investigated/reported)
***Salmonella* spp.**	**Harp seal** **<u>Grey seal</u>** <u>White whale</u>	Status unknown for hooded seals	Older reports of large outbreaks of human salmonellosis after consumption of marine mammal meat
***Brucella* sp.**	**<u>Hooded seal</u>**		One laboratory infection and three

	Harp seal Ringed seal **Harbour seal** **Grey seal** Atlantic walrus Steller sea lion Hawaiian monk seal Weddell seal Antarctic fur seal Leopard seal **Minke whale** Fin whale Sei whale Pilot whale Bryde`s whale Killer whale Harbour porpoise Common dolphin Atlantic white sided dolphin Striped dolphin Bottlenose dolphin Other dolphin species		cases of CNS infections reported (*B. pinnipedialis*) – zoonotic potential uncertain
Mycobacteria	California sea lion New Zealand fur seal Australian fur seal Australian sea lion South American sea lion Subantarctic fur seal	Status for Norwegian commercial species unknown	A seal trainer developed tuberculosis – aerosol transmission. Probably bacteria belonging to the *M. tuberculosis* complex
***Campylobacter* spp.**	Harbour seal (*Phoca vitulina*) Harbour porpoise (*Phocoena phocoena* Northern elephant seals (*Mirounga angustirostris*)	Status for Norwegian commercial species unknown	No case reports. Mainly non-pathogenic species, but *C. jejuni* has been isolated.
***Leptospira* sp.**	Sea lion	Most Cetaceans	Zoonotic isolates detected in a range of

	Northern fur seal Common dolphin Humpback whale Harp seal		species
***Nocardia* sp.**	Pilot wale Beluga whale (white whale) Pacific bottlenose dolphin Killer whale		Zoonotic isolates detected in a range of species
Clostridium botulinum	Ubiquitous in the marine environment		Marine mammal meat has been the source of botulism among northern native humans
Viruses			
Influenza A virus	**Harbour seal** **Hooded seal** **Harp seal** Pilot whale		Contact transmission and conjunctivitis reported. Potential for aerosol transmission
Influenza B virus	**Harbour seal**		Seals may be a reservoir species
Poxvirus	**Harbour seal** **Grey seal** Weddell seal California sea lion Steller sea lion Sout American sea lion Spotted seal Mediterranean monk seal		Transmission through bites or contact with saliva and skin (lesions), especially people caring for seals in captivity. Single cases, no documented spread between humans.
Calicivirus	Walrus Californian sea lion Steller sea lion Northern fur seal Northern elephant seal Pacific dolphin Bowhead whale		One confirmed human case reported – skin infection in animal handler

	Gray whale Fin whale Sei whale Sperm whale		
Rotavirus	Galapagos sea lion Galapagos fur seal	No serological screening of commercially harvested marine mammals reported	Oral infection. Zoonotic potential unknown

[1]Isolation of agent (underlined) or detection of specific antibodies (serology).

[2]Commercial and hunted species (Norway) are in bold.

4.4 Hygienic aspects regarding slaughtering and dressing of seals and whales

Compared to common slaughterhouse conditions and standards, slaughtering and dressing of seals and whales allows only partial control with human pathogenic bacteria, and the ability to eliminate risks is limited. Based on existing reports on bacteriological whale and seal meat control relatively limited volumes of such meat are consumed (Table 2 and 3). The general trend of increased eating raw or lightly cooked food may however increase the risk for transmission of pathogens to humans.

Clostridia, especially *C. perfringens*, and fecal streptococci are of particular interest in whale meat control, due to the long term storage on ice before processing. If the shot hits the intestinal system, contamination with these bacteria might be significant. Contamination by the removal of intestines and poor hygiene in addition to depletion of glycogen reserves during displacement and agony (which leads to a higher pH) may play a large role as one of the prerequisites for growth of these bacteria on the luns. If contamination with clostridia is significant and growing conditions are favourable, the result can be considerable production of butyric acid and so-called "gas meat" consisting of NH_3 and H_2S. The traditional method for assessing gas production was to determine whether or not meat floated on water. Sensory tests, such as cooking tests, have also been conducted. Measuring the pH of the whale meat might provide information on conditions related to the slaughter of a particular whale. A study by Flisnes (1994) showed that most of the pH values were about 5.5 to 5.9 after slaughter. There were, however, individual animals with pH values from 6.0 to 7.0. It is believed that the latter values are related to the slaughter period duration and nutritional state of the whale. The muscle glycogen resources have been emptied and as a result there is little lactic acid production, which results in a higher pH in the meat. In muscles from four-legged domestic animals, a pH value higher than 6 is considered to indicate an animal welfare problem, and such meat is named Dark-Firm-Dry (DFD) meat. In a hygienic context, DFD meat is more susceptible to bacterial deterioration and is of lower quality and provides possibilities for growth of cold-tolerant pathogens as well.

4.5 Removal of skin and blubber, and evisceration

A specific regulation (Sjøpattedyrforskriften) describes the hygienic and control measures for seal and whale meat (Anon. 2003) and a revised regulation is under way .

Removal of skin and blubber should be carried out in such a manner that contact between the outside of the skin and the carcass is avoided. In order to avoid transfer of pathogenic bacteria, hands and equipment that touch the outside of the skin should not come into contact with carcass meat. To carry out procedures such as skinning and evisceration in particular, it is important that the operators are skilled and experienced. During the seasonal hunt, staffing is an important issue due to a lack of skilled personnel. Accordingly, relevant and adequate training plans and training programmes for slaughtering and dressing are essential.

During evisceration there is a particular risk that pathogens may be spread to the carcass meat from the oral cavity, oesophagus, stomach content, and intestines. During regular slaughter practices, the risk is particularly high during the circum-anal incision of the rectum and skinning, and during these processes hygienic procedures are particularly important. One important and compulsory prerequisite regarding hygienic slaughtering and dressing of four-legged animals in abattoirs is the so called two-knife method. The two-knife method involves the installation in the slaughter hall of knife decontaminators, with running water at a temperature of approximately 82 ºC. When an unclean working operation has been performed, for example, in the region around the rectum or during skinning, the knife is rinsed before being placed in the decontaminator. The operator should then wash his hands before the other knife is used for clean working operations.

During sealing and whaling, the slaughtering and dressing are performed on deck, and equipment for the two-knife method is not installed on the Norwegian boats hunting seals and whales. Even facilities for washing hands, knives, and equipment may largely be absent from the decks of these boats.

One of the most important hygienic arrangements on the deck, are wooden plates, usually new, that are often washed just before the whales or the seals are lifted on board. However, often the working space on the deck is limited and the crew must physically scramble over the slaughtered animals in order to work. Another aspect is the risk that the faeces from seabirds might represent during slaughtering and dressing and when handling meat on deck in the open air. Both *Salmonella* and *Campylobacter*, as well as other pathogens, are relevant in this context (Kapperud & Rosef 1983; Refsum *et al.,* 2002).

4.6 Whale meat: deboning and processing

After slaughtering and dressing, the whale carcass is deboned and the meat is divided into round pieces (luns), each with a weight from about 50 kg to about 100 kg. These huge meat pieces are stored on wooden plates on the deck until the core temperature has reached the ambient temperature, which may vary, depending on weather conditions and if the hunt is conducted in the North Sea or at the northern tip of Spitsbergen. During this process, the meat pieces are usually covered by plastic or tarpaulins. After the storage period on the deck, the meat pieces are stored on ice, with plastic separating the meat from the ice, until the boat reaches the processing plant. The previous maximum onboard storage time of 3 weeks has been rescinded. In the processing plant, the meat undergoes an organoleptic control by a veterinarian, who can discard meat with unfavourable colour, smell, or taste, or meat that is suspected of being contaminated with *Clostridium* spp. (gas production). The surfaces of the meat luns are trimmed with a knife, and then divided into smaller pieces, that are wrapped and put into consumer packages and are sold as a fresh (season) or frozen product.

The very few investigations of meat from minke whales that have been reported, indicates that the hygienic quality of these products were acceptable (see Annex 2).

4.7 Seal meat: deboning and processing

Seals are killed following the regulated protocol; shot, clubbed (hakapik), and bled on the ice. Pups may be killed just by using the hakapik and bleeding on the ice. The seals are then taken onboard for further processing (Picture 1).

The working conditions on board are not optimal for a hygienic treatment of seal meat, and some common challenges are:

a) Time from killing to obtaining the meat may vary from a few minutes to several hours.
b) The meat is cut while the animal is on-deck, which may also be contaminated by blood, urine, and faeces. This may contaminate the equipment (knives etc.), hands, and the meat itself.
c) It may be difficult to remove contamination, and this is often attempted using sea water.
d) There is often no specific room for trimming and packing the meat.

The very few investigations of meat from seals that have been reported, indicates that the hygienic quality of these products in general was acceptable (see Annex 2).

A veterinary inspector is compulsory if salted meat is prepared, due to the fact that this is classified as processing (Picture 2). The veterinary inspector on board conducts a general evaluation of the animal (condition, wounds, signs of disease etc.) before meat for human consumption is processed. After removing the skin and blubber, meat from the back is removed and further processed for vacuum packing in plastic (consumer packages). The fore-flippers and the ribs are removed, without accompanying skin and fur, and salted on board.

Bacteria used in bacteriological meat control as indicators of fecal contamination (indicator organisms):

Several groups of microorganisms have been used as indicators of faecal contamination in foods. The most common ones are *Enterobacteriaceae*, coliforms, *Escherichia coli*, cocci of faecal origin (enterococci), clostridia, and faecal bacteriophages. The microbiota normaly found in the faeces of marine mammals have been shown to contain high numbers of bacteria including *Enterococcus* sp. *Enterobacter* sp., *E. coli,* and *Clostridium* sp. (Ogawa *et al.,* 2010), These bacteria would be detected as members of one or several of the of the groups of indicators organisms mentioned. When indicator organisms are detected in marine mammal meat, it could either originate from the animal itself or from faeces from other homoeothermic ("warm blooded") organisms, including birds or humans.

5 Hazard characterisation

5.1 Human illness

Marine mammals can be infected with zoonotic pathogens and show clinical signs of disease, or can be asymptomatic carriers of such disease agents. While isolated cases of human disease from contact with marine mammals have been reported internationally, to our knowledge, only one survey was designed to estimate the risk of work-related injuries and illnesses in marine mammal workers and volunteers. The 17-question survey asked respondents to describe their contact with marine mammals, injuries sustained, and/or illnesses acquired during their period of marine mammal exposure. Most respondents were researchers and rehabilitators. Marine mammal work-related illnesses commonly reported included: 'seal finger' (assumed to be *Mycoplasma* spp.), conjunctivitis, viral dermatitis, bacterial dermatitis, and non-specific contact dermatitis. Although specific diagnoses could not be confirmed by a physician through this study, severe illnesses were reported and included tuberculosis, leptospirosis, brucellosis, and serious sequelae to seal finger. Risk factors associated with increased odds of injury and illness included prolonged and frequent exposure to marine mammals, such as direct contact with live marine mammals and contact with tissue, blood, and excreta (Hunt *et al.,* 2008).

Except for reported cases of seal finger, the incidence of zoonotic infections in Norway acquired from marine mammals is basically unknown. This includes both marine mammal workers, like whalers and sealers who have considerable exposure to marine mammals on a seasonal basis, and consumers of marine mammal products. The most important source of information on zoonoses in Norway is The Norwegian Surveillance System for Communicable Diseases (MSIS). As an official monitoring system for infectious disease it collates notifications from microbiological laboratories, hospitals and physicians of new cases of a number of infectious diseases. For diseases that are notifiable to MSIS, the degree of under-reporting varies considerably with the severity of each disease, the sensitivity of the diagnostic methods used, and which agent medical laboratories actually were looking for. Therefore, numbers will normaly only represent a fraction of the actual prevalence in the population. In addition, it is difficult to identify the sources of infection, particularly for sporadic cases. In addition, many illnesses caused by the microorganisms relevant to this assessment are not notifiable to MSIS, and may, to a greater extent, remain undiagnosed and non-reported.

No connection between consumption of marine mammal meat and human illness has been reported in MSIS.

Botulism

A total of 47 cases of botulism were reported to MSIS in the period 1977-2006. Of these, 35 were foodborne and 4 of these were infant botulism. The remaining cases were wound botulism among intravenous drug users. One death caused by botulism (foodborne) was reported to MSIS in the period 1975-2006.

None of the Norwegian foodborne cases could be linked to consumption of marine mammals. Botulism associated with marine mammal meat and products is reported to be connected to food habits, such as storage and preparation techniques, including fermentation, which is common in Inuit communities in Alaska, Canada, and Greenland.

Brucellosis

Brucellosis has been notifiable to MSIS since 1975. In the period 1977-2006, 18 cases of brucellosis were reported to MSIS. One case of a laboratory infection was acquired in Norway, the remaining cases were all infected abroad. There are no indications that these infections were caused by marine mammal *Brucella* bacteria, i.e. *B. ceti* (whales) or *B. pinnipedialis* (seals), and no link to consumption of marine mammal meat or products are reported. The three naturally acquired human cases of *B. pinnipedialis* infections reported so far have been CNS infections, which also might occur but is uncommon for classical brucellosis as it is known in humans, which is caused by other bacteria of this genus, i.e. *B. melitensis*, *B. suis* and *B. abortus*.

Campylobacteriosis

Campylobacteriosis has been notifiable to MSIS since 1977. In the period 2002 to 2006, more than 5000 domestic cases were reported.

Cryptosporidiosis

Whilst currently non-notifiable to MSIS, the status of this infection (notifiable/non-notifiable) is due to be altered. This is due to a number of outbreaks of cryptosporidiosis within Norway (with probable association with water/food in 2 of these). More extensive outbreaks in Sweden (both foodborne and waterborne) are also likely to be drivers for this change.

Giardiasis

Giardiasis has been the notifiable to MSIS since 1975. In the period 1999-2003, an average of 300-400 cases were reported annually. In 2004, 1548 cases were reported, an increase due to a large waterborne outbreak in Bergen.

Salmonellosis

In the period 2002-2003, as average of 1500 cases were reported annually. Of these, 80-90% were acquired abroad.

In MSIS there is no evidence to indicate that microorganisms from marine mammals pose a significant risk to Norwegian consumers or marine mammal workers. But the situation is uncertain as the degree of under-reporting varies considerably with the severity of each disease, the sensitivity of the diagnostic methods used, and which agent medical laboratories actually are looking for. In many cases it can also be a great challenge to trace source of infection back to consumption of specific foods, such as from marine mammals. The situation is even more uncertain for illnesses caused by the microorganisms relevant to this assessment that are not notifiable to the MSIS.

5.2 Infectious dose/dose response information:

***Cryptosporidium* spp.**

Theoretically a single viable oocyst is sufficient to cause infection in a susceptible host, but, in general, it is considered that the infectious dose depends on both host factors (age, immunity etc.) and parasite factors (species, genotype). In a comparison of 3 different isolates among healthy volunteers without any specific immunity against *Cryptosporidium*, it was estimated that for the most virulent isolate a dose of 9 oocysts resulted in infection in 50 % of the patients ($ID_{50} = 9$), compared with ID_{50} of 87 oocysts and 1042 oocysts obtained with the other two isolates. Exposure to *Cryptosporidium* results in the development of immunity, and therefore resistance to infection, and therefore children are more likely to be susceptible to infection than adults. An infection study has demonstrated that people with antibodies to *Cryptosporidium* are 20 times more resistant to infection with this parasite than people without antibodies, and this resistance is significantly greater if the specific IgG level is above 1.4 units (Teunis *et al.,* 2002a; Teunis *et al.,* 2002b). The species/genotype specificity of this immunity is unresolved.

Giardia duodenalis

In Rendtorff's classic infection study (Rendtorff 1954), doses ranging from 1 to 106 were ingested by volunteers, and at a dose of 10 cysts was reported to result in infection in 2 out of 2 volunteers. However, it is worth noting that although most of the volunteers became infected, and changes in bowel motions were observed, none of the volunteers in this study developed symptoms of giardiasis. Thus, although the individuals were infected, they did not have classical clinical giardiasis. The infection-to-illness ratio varies between isolates, as shown by the different response of volunteers subjects to two different isolates from symptomatic human infections in a study by Nash et al. (1987). An ID_{50} of 35 cysts has been recommended for modelling, with increased doses giving an increased risk of illness following infection (Teunis & Havelaar 2002). The effect of genotype (A or B) on infectious dose is currently unresolved.

Toxoplasma gondii

The infectious dose for humans is not clearly defined. Humans can be infected by ingestion of oocysts, by ingestion of tissue cysts in meat, or transplacentally. The infectious dose of oocysts has been suggested to be low; a single oocyst has been shown to cause infection in 13 of 14 pigs (Dubey *et al.,* 1996), and 2 out of 5 mice (Dubey 2006). Cats (the definitive host), however, are apparently more resistant to infection with oocysts and whilst 1 out of 4 cats fed 100 oocysts seroconverted, no infection was achieved at lower doses.

However, with respect to this risk assessment, infection by ingestion of tissue cysts is of more interest. A tissue cyst may contain a variable number of bradyzoites, from only a couple to several hundred. This is dependent on a number of factors including age of the cysts, the host cell parasitized, and host immunological status. A number of trials on the infectivity of free bradyzoites and tissue cysts to mice have been performed (see (Dubey 2006) for results of 2 trials, and summary of results of previous trials), and these suggest that as few as 10 bradyzoites administered *per os* may cause infection, although the infective dose for mice tends to be generally considered to be 100 bradyzoites/tissue cysts. Infectivity is apparently 100-fold lower by the oral route compared with the parenteral route of infection.

Trichinella spp.

The infectious dose for humans is not clearly defined. Dupouy-Camet and Bruschi (2007) suggest that ingestion of between 100 and 300 larvae of *T. spiralis* are sufficient to cause disease, and that an intake of 1000-3000 or more larvae causes severe disease. However Gottstein et al (2009) suggest that as these estimates are not based on scientific data they are of little practical value.

Leptospira spp. and *Nocardia* spp.

Little information is available on the infectious dose for *Leptospira* spp.and *Nocardia* spp. Transmission of these agents is via skin or mucous membranes, and not directly via food.

Clostridium botulinum

Botulin is characterized by an extraordinary potency as a neurotoxin in animals and humans. The estimated lethal intravenous or oral dose of botulin in humans is reported to be between 0.1 and 1.0 ng pr kg body weight (Johnson, 2010). Thus, if the environment is favourable for germination of spores and growth of the bacterium during processing of any food product, there is a potential risk of toxin production that can compromise food safety. The majority of registered cases of botulism among humans have been connected to consumption of homemade products, although several outbreaks have been traced to commercially available food items (Johnson 2007). Marine mammal products have also been involved in outbreaks of botulism. The risk of contracting botulism after eating meat from marine mammals in a raw or under-processed state has been documented among the native population of Alaska, Canada and Greenland, (Hauschild & Gauvreau 1985; Shaffer *et al.,* 1990; Sorensen *et al.,* 1993; Tryland 2000). In these studies it has been reported that up to 60 % of the botulism cases were caused by meat from marine mammals handled and stored under improper conditions, and the use (introduction) of plastic may have contributed to anaerobic conditions during storage, which is favourable for survival and growth of *C. botulinum.*

Seal finger (blubber finger) agent: *Mycoplasma* spp.

From reported human cases of seal finger, it seems that to be able to establish itself in the host the infectious agent is dependent on a breach of the skin, but that a high load of bacteria is probably unnecessary to establish infection. The bacteria are usually transferred from seals to the hands of the person handling the animal or animal products, such as skin and blubber. This disease in man has been described in the medical literature for about a century (Bidenknap 1907) and is most common among professional sealers.

***Campylobacter* sp.**

In one experiment, a dose of 500 cells ingested with milk caused illness in one volunteer (Robinson 1981). In a study involving 111 young adults from Baltimore, a dose ranging from 800 to 20 x 10^6 cells caused diarrhoeal illness (Black *et al.,* 1988).

***Salmonella* sp.**

Different serovars vary in their pathogencity. Accordingly it is difficult to determine the infective dose. Depending on the food and *Salmonella* serovar the infectious dose ranges from 10^0 to 10^{11} according to D'Aoust et al. (1994). In human volunteers, 10^7 *Salmonella* cells were required to have a significant likelihood of causing diarrhoeal illness (ICMFS 1996).

***Brucella* sp.**

From the few human cases reported with *Brucella pinnipedialis*, one was a laboratory infection in a person working with isolates from seals and whales in the laboratory. The three other cases were naturally acquired CNS infections (brain and spinal cord), with no registered link to marine mammals, in terms of contact or consumption of meat or products. Thus, from these cases, no information has been generated about infectious dose for *B. pinnipedialis* in humans. Bacteria of the genus *Brucella* are included in biological warfare programs, and it has been estimated that the inhalation of 50-100 bacteria is enough to cause disease in humans (Woods 2005).

Mycobacteria

M. tuberculosis, together with *M. bovis, M. pinnipedii* and other species form the 'M. tuberculosis complex', which is a group within the genus Mycobacterium. This genus also includes many different nontuberculous mycobacteria (NTM), of which *M. leprae* and *M. avium* are best known.

The infectious dose for different *Mycobacteria* has been investigated in different studies. The early studies with *M. tuberculosis* on guinea-pigs conducted by Riley (1995) and O'Grady and Riley (1963) suggest that the infectious dose is very low.

Dean et al. (2005) have attempted to determine the minimum infective dose of *M. bovis* necessary to stimulate specific immune responses and generate pathology in cattle. One-half of the animals infected with 1 CFU of *M. bovis* developed pulmonary pathology typical of bovine tuberculosis. No differences in the severity of pathology were observed for the different *M. bovis* doses.

M. marinum grows at an optimal temperature of 33 °C, far lower than that for *M. tuberculosis*. Consequently, *M. marinum* infection of mammals, called aquarium tank granuloma, resembles that of *M. tuberculosis,* is restricted largely to the cooler surfaces of the body, such as the extremities. In warm-blooded animals, including humans, dissemination to systemic organs occurs extremely rarely, even in the immunocompromised population. An intraperitoneal inoculum as low as 2,3 x 10 organisms was found sufficient to sustain a persistent infection in in the animal model study conducted by Ramakrishnan et al. (1997).

The minimal infectious dose of *M. leprae* in mouse foot pads was found to be in the order of 10 solidly staining bacilli in the study by Shepard and McRae (1965).

Influenza virus

Influenza virus is transmitted by direct contact with infected individuals, by contact with infected objects, and by inhalation of virus-containing aerosols. It appears that influenza A virus may be shared between avian and marine mammal hosts (Mandler *et al.,* 1990).

The minimum infectious dose (human infectious dose; HID_{50}) of influenza A virus by aerosol inoculation in human volunteers lacking detectable antibodies was 0.6-3.0 $TCID_{50}$ (median tissue cell culture infective dose for 50 % of inoculated cell cultures) (Alford *et al*., 1966), whereas the HID50 was 127-320 $TCID_{50}$ when virus was inoculated by intranasal drops (Douglas, 1975), which indicates aerosols to be the most efficient mode of transmission (Tellier, 2006).

During the epizootic among harbour seals (USA), influenza A virus was transferred to man, causing conjunctivitis among persons handling diseased and dead seals. Infected persons recovered within 4-5 days without complications and without producing detectable specific antibodies (Webster *et al.,* 1981). In a subsequent experimental trial, monkeys were infected with influenza A virus isolated from the seals, in which one monkey died of pneumonia, indicating that the virus was capable of systemic spread in primates (Webster *et al.,* 1992).

Transmission to man from infected seals and whales in captivity seems likely, either through close contact (nasal secretion) or via aerosol transmission. It is not very likely that influenza virus is transferred from marine mammals to humans through hunting activity (sealing and whaling) or through marine mammal meat and products.

Poxvirus

Poxvirus (*Parapoxvirus*) is transferred from seals through bite or contact with saliva or skin, or by handling seal products, particularly the skin. It is believed that a breach of the dermis is needed for the virus to be able to establish an infection. Transmission from seals to humans has been documented in several cases (Clark *et al.,* 2005; Hicks & Worthy 1987). There is no specific information available on the infectious dose with regard to poxvirus transmission to humans.

Calicivirus

No specific information is available on the infectious dose with regard to calicivirus transmission from marine mammals to humans. Also in the case of Norwalk virus, a common human pathogen in the *Caliciviridae* family, such data are lacking; about the infectious dose, actual dose levels associated with gastrointestinal outbreaks, concentrations of the viruses in ambient and drinking waters, and ability of caliciviruses to survive environmental settings and drinking water treatment processes (Reynolds 2003). Close contact with infected seals is probably necessary to be infected, and thus seal handlers, hunters and researchers are higher risk groups.

Rotavirus

No human rotavirus cases that could be associated with a marine mammal source have been reported. Theoretically, rotavirus can be transferred to seal, and maybe also whale meat and products, through faecal contamination, the source being infected and virus-shedding animals or possibly also humans. The oral dose needed to establish an infection in humans has been estimated to be small and similar to the minimum amount detectable in cultures of monkey kidney cells (Ward *et al.,* 1986). It has also been shown that relatively large amounts of rotavirus could be recovered from the hands of people in an experimental setting, 57 %, 43 % and 7 % after 20, 60, and 260 minutes, respectively, indicating that transmission of virus via contaminated hands may play an important role in the epidemiology of rotavirus (Ansari *et al.,* 1988).

6 Exposure assessment

Export of whale meat or whale products from Norway is prohibited. An overview of volume of meat and blubber and commercial value of the minke whale hunt for the period 2006 – 2009 is given in Table 2.

Table 2. Weight and first-hand commercial value of whale (minke whale) meat processed for human consumption in Norway during the period 2006-2009 (Norges Råfisklag)

	2006	2007	2008	2009
Meat weight (kg)	629 477	621 949	556 839	474 105

Commercial value (NOK)	18 832 250	19 789 545	17 548 024	15 312 260

An overview of frozen and salted seal meat and products (flippers and ribs) during the period 2006 – 2009 is given in Table 3.

Table 3. Weight of seal meat (frozen and salted) processed for human consumption in Norway in the period 2006-2009 (Mattilsynet)

	2006	2007	2008	2009
Frozen meat (kg)	9 967	1 200	1 100	3 242
Salted meat (kg)	9 360	11 300	2 430	6 570
Total	**19 327**	**12 500**	**3 530**	**9 812**

Generally, whale meat is distributed throughout the country and is available in stores, as fresh meat (season) or frozen (all year around), as well as in restaurants, while seal meat is consumed more locally, and is sold as more seasonal products (salted) or as vacuum packed consumer packages (frozen). Both whale and seal meat are to some extent prepared without heat treatment, such as raw, salted, dried and smoked, which seems to become more popular than previously. The panel has not been able to find exact data about the consumption of marine mammal meat in Norway (kg/person) but compared to general meat consumption 309 mill kg 2007 which leads to an uncertainty in the risk characterisation.

7 Risk characterisation

The panel concludes that seal and whale meat represent a minor risk to consumers under Norwegian conditions, and that the occurrence of specific diseases in humans cannot be directly associated with consumption of such foods.

However, the available data are scarce, therefore the risk may be greater than currently assumed because a) the hygienic control on marine mammal meat is *ad hoc* and mainly spot test based, and will not identify the whole range of potential human pathogens, b) many potential human pathogens found in marine mammal meat generally do not produce specific clinical signs of disease, and it seems unlikely that such symptoms would be reported in such a way that they could be associated with consumption of marine mammal meat.

Reports have shown that a wide range of human pathogens can be present in marine mammals, either present in the animals themselves or in the meat due to contamination from other sources during killing, dressing, storing and distribution. Some of these infectious agents exist as specific species in marine mammals as compared with other mammals, such as *B. pinnipedialis*, for which the pathogenic potential for humans is basically unknown.

The microbiological control (spot tests) address total bacterial count and bacteria that are indicators of faecal contamination. This indicates the general hygienic quality of the meat, as well as the possibility of the meat being exposed to faecal contents, which again may increase the risks of being exposed to enteric pathogens such as *Salmonella*. Few reports from these spot tests indicate the presence of such pathogens, although there are reasons to believe that the number of animals/samples investigated usually has been very low. Thus, it can be questioned if these control measures have the power to detect potential human pathogens in marine mammal meat.

Based on existing reports, there is no reason to believe that marine mammals are exposed to potential human pathogens to a larger extent than other mammals. However, contamination of marine mammal meat may be considered more likely than for domestic animals that are routinely slaughtered in slaughterhouses. This may be more likely for whale meat than for seal meat due to the on-deck cooling and long-term storage on ice, as compared with freezing of seal meat on board. This seems to be compensated to a certain degree by accepting more waste during the dressing of the prime quality beef of whale meat. On-board freezing of whale meat could maintain the hygienic quality better, although this may have other implications, such as less maturation of the meat. If meat is not frozen, an unbroken cold-chain should be documented through the production line from the slaughter to the retail level.

Many of the potential human pathogens in marine mammals result in non-specific clinical signs in humans, and thus a definitive diagnosis and consequent registration of disease are unlikely. Therefore, there is no documentation that marine mammals represent a risk for consumers, compared with other sources of meat that are commercially distributed to the public.

8 Lack of data

There is an obvious lack of data regarding presence and possible impact of human pathogens in marine mammal meat and products. A few investigations have included a reasonable number of individuals, several animal species, and different sampling years (Handeland *et al.,* 1995; Oksanen *et al.,* 1998; Tryland *et al.,* 1999), but usually, scientific reports cover only one infectious agent in one species, with a restricted number of individuals. These reports are also usually separated in time, giving no information on possible trends.

Also, results and information from the hygienic control of marine mammal meat (spot tests) are scarce, difficult to obtain, and have restricted value in terms of number of animals tested, and due to lack of consistency, these data are hard to compare. No systematic meat control investigations have been reported recently. Also, the range of infectious organisms that has been addressed is restricted, traditionally focusing on *Trichinella* sp. (Handeland *et al.,* 1995; Thorshaug & Rosted 1956) and indicator organisms for faecal contamination.

Regarding infectious dose/dose response information, no specific information is available for many of the infectious agents specifically found in marine mammals and with zoonotic potential, such as *Brucella pinnipedialis*/*B. ceti*, seal parapoxvirus, marine mammal caliciviruses etc. Thus, such evaluations have to be conducted on the basis of general knowledge for the actual group/genus of agents, thereby introducing uncertainty.

Since several other parasites, bacteria, and viruses are potential human pathogens in seals and whales, there is a need for systematic epidemiological studies in these animal populations to acquire knowledge about the incidence and burden of diseases caused by microorganisms from marine mammals.

The most important source of information on zoonoses in Norway is The Norwegian Surveillance System for Communicable Diseases (MSIS). As an official monitoring system for infectious disease it collates notifications from microbiological laboratories, hospitals and physicians of new cases of a number of infectious diseases. For diseases that are notifiable to MSIS, the degree of under-reporting varies considerably with the severity of each disease, the sensitivity of the diagnostic methods used, and which agents are actually considered by medical laboratories. Therefore, numbers will normaly only represent a fraction of the actual prevalence in the population. In addition, it is difficult to identify the sources of infection, particularly for sporadic cases. Furthermore, many illnesses caused by the microorganisms relevant to this assessment are not notifiable to MSIS, and may, to a greater extent, remain undiagnosed and non-reported.

9 Answers to the questions

1. Which human pathogens can be present in whale and seal meat?

a. Pathogens present in seals and whales

Based on the screenings and controls that have been reported on seal and whale meat from the species commercially hunted in Norway, no obvious threats from human pathogens have been documented.

The controls have generally been *ad hoc* and have focused mainly on bacteria, total counts (CFU) and bacteria that indicate faecal contamination. Also some analyses have been conducted for sulphite-reducing *Clostridium* spp. and, in some instances, *Salmonella* and *Listeria monocytogenes*. A wide range of human pathogens can theoretically be present in seal and whale meat, including the commercial species in Norway (Table 1). The most important of these are *Trichinella* spp., *Toxoplasma gondii*, *Salmonella*, and *Leptospira* spp. Other potential pathogens, such as *Brucella pinnipedialis*, must be regarded as very common in the hooded seal population, but their zoonotic potential is uncertain. Some human pathogens found in marine mammals may be looked upon as minor threats only, since they are generally not transmitted through consumption of meat and meat products, especially if these products are heat-treated (e.g. *Cryptosporidium* spp. and *Giardia duodenalis*). Some human pathogens are also of more occupational character, such as *Mycoplasma* spp., influenza A virus and poxvirus.

b. Contamination of meat during hunt, handling and storage

Based on the meat hygiene controls that have been reported for seal and whale meat from species commercially hunted in Norway, no obvious threats from human pathogens have been documented

Contamination of seal and whale meat may occur during shooting (penetration of stomach and intestines), through contact between meat and the environment (deck and equipment such as water hose, hooks etc.), by sea water for cleaning on board and fresh water used for ice (cooling of whale meat), from handling by personnel, and from other animals if infected, such as seabirds. It is common to look for indicator organisms, such as coliforms, *Escherichia coli*, and cocci of faecal origin. If these organisms are absent, it is less likely that other faecally-transmitted agents and zoonotic bacteria, such as *Salmonella* and *Campylobacter* are present. A standard microbiological control of seal and whale meat could therefore include these indicator organisms. With the existing meat control regimes, conducted *ad hoc* and on very few samples, it is unlikely that the real picture of the presence of indicator organisms, and thus potential human pathogens, is currently known.

2. Which factors during seal and whale hunts can impact on the contamination of meat, the survival of infectious agents, and transmission to humans?

Many factors, such as the killing, bleeding, evisceration, handling, processing and storage have impact on the contamination and survival/growth of potential human pathogens in marine mammal meat. Professional training of personnel on hygiene is crucial for developing good hygiene practices throughout all these processes.

Slaughtering and dressing of seals and whales are performed under relatively basic conditions on deck and in the open air, and contamination with pathogens from the skin and the alimentary tract of the slaughtered animal, the environment (in particular birds and water), equipment, and personnel is possible and likely.

Meat from seals, given that the animal is healthy, that the meat is not contaminated during the killing (intestinal content), and that the animal has been bled properly within a reasonable timeframe, is assumed to have a good microbiological status. Since meat from seals is usually consumer-packed and frozen onboard, this product should be comparable with other and slaughterhouse-produced meat. However, it is important that the personnel are sufficiently trained in hygiene, and that this has a high priority during all stages of the hunt and processing.

Meat from whales is cooled on deck until the inside of the luns has reached the ambient temperature of the outside air, which may take 1-2 days. This, and the fact that these pieces of meat may be exposed to birds, are handled with invasive tools (hooks) and may be stored for several weeks on ice before processing on land, make whale meat more susceptible to contamination than seal meat. It is also possible that some bacteria may be active and multiply during storage on ice, such as *Clostridia* spp., which is the reason for checking for gas production (percussion) during the organoleptic whale meat control.

3. To what extent do the regulations address these issues and which measures can be implemented to limit the risk of transmission of pathogens from marine mammal meat to humans?

Almost none of the comparable hygienic procedures that are compulsory when slaughtering four-legged domestic animals are addressed in the regulations covering the slaughter of marine mammals, but these regulations nevertheless address the most important issues for meat quality and hygiene. Increased training of personnel and increased and systematic meat control and screening are necessary to obtain knowledge on the presence of human pathogens in marine mammals, contamination of meat and the risk of transmission of human pathogens from marine mammals.

Regarding human pathogens that can be present in the animal (seals and whales; Table 1) it is generally difficult to address such infections in the field. It is important that animals that show signs of being unhealthy or are otherwise regarded as unsuitable for human consumption, such as being emaciated, moribund, having abscesses, open lesions and wounds etc., are not processed for human consumption. The bacteriological meat control, as conducted today, is too limited to address both human pathogens in the animals, and also faecal contamination, i.e. indicator organisms.

Due to the cooling procedures (open air and on ice) and the long-term storage (several weeks) without freezing, good hygiene on the meat surfaces is even more important for whale meat than for seal meat. Meat of poor microbiological quality from slaughter may be unsuitable for human consumption after storage. Freezing of minke whale meat on board would improve the microbiological quality of the meat (less contamination and less bacterial growth) and also lead to less wastage when the high quality beef is prepared, which could increase the net output from the hunt and also provide better use of natural resources. Freezing the meat directly on board may, however, affect the maturation of the beef, and this issue should be further addressed.

Personnel conducting seal and whale hunts are not professional slaughterhouse workers. It is thus important that they receive professional training in killing, bleeding, and processing meat from these animals, since all these steps are closely linked to the meat quality, especially regarding microbiological aspects. Currently, this training comprises part of a one-day course arranged by Directorate of Fisheries (Fiskeridirektoratet), providing only limited time for focussing on these issues.

10 Conclusions

Based on existing reports, it may be reasonable to conclude that seal and whale meat represent a minor risk to consumers under Norwegian conditions, and that known disease occurrence is not associated with consumption of such foods. The very few investigations of meat from minke whales and seals available, report that the hygienic quality of these products was acceptable. However, since these products are not monitored thoroughly and regularly, it is not possible to conclude whether or not they represent a risk to the consumers. The main risk aspects are probably associated with the fact that slaughtering of marine mammals is performed under relatively basic conditions, on deck and in the open air, and almost none of the comparable hygienic procedures, which are compulsory in slaughtering four-legged domestic animals, are addressed in the regulations covering the slaughter of marine mammals.

It is also of concern that no systematic, large-scale investigations on the quality of seal and whale meat have been conducted, with focus on potential pathogens and faecal indicators. The information available is generally based on *ad hoc* approaches, on few animals, and with no time series. This has created a data gap, and the lack of reference knowledge makes it impossible to assess whether the meat quality changes over time.

The available data are scarce, therefore the risk may be greater than currently assumed as many of the potential human pathogens found in marine mammal meat generally do not produce specific clinical signs, and it seems unlikely that such symptoms would be reported, particularly in such a way that they could be associated with consumption of marine mammal meat. Indeed, most of these potential infections and diseases (Table 1) are not reported through the national surveillance system (MSIS). The general trend of increased eating raw or lightly cooked food may increase the risk for transmission of pathogens to humans.

In general, proper management of slaughter and dressing procedures uses Hazard Analysis and Critical Control Point (HACCP) and Good Hygienic Practice (GHP) systems and focuses on limiting the spread of human pathogenic bacteria. A proper hazard analysis is the basis for the identification of Critical Control Points (CCPs) during processing, for the specification of critical limits to be used when monitoring the process, for corrective actions when the process is not properly controlled, and finally for verification of the effectiveness of the HACCP plan. Such tools are not implemented for hunt and processing proceedures of seals and whales. Increased dissemination of knowledge on meat hygiene to hunting personnel, a more systematic meat control practice (routine control), and broad-scale research projects that focus on human pathogens that may be present in seals and whales, as well as pathogenic agents that may contaminate marine mammal products, will increase our knowledge on the risks that transmission of these human pathogens via marine mammal meat may represent.

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12 Annex1

Pathogens in marine mammals – importance for public health

Parasites

***Cryptosporidium* spp.**

Cryptosporidium spp. are intestinal protozoan parasites in the phylum Apicomplexa, with a direct lifecycle. Infections with *Cryptosporidium* have been reported from a wide range of vertebrate hosts including mammals, birds, reptiles, and fish. To date over 20 species have been described, and many more genotypes. Some species, such as *C. parvum*, appear to have little, if any, host specificity, whereas other species, such as *C. hominis*, are associated with infection in a particular host. Particular characteristics of *Cryptosporidium,* including their small size, high excretion rate, low infectious dose, and the robustness of the transmission stage (the oocyst) to environmental pressures, including some disinfectants commonly used by the water industry, mean that they are particularly associated with waterborne transmission. Indeed, communitywide outbreaks of waterborne cryptosporidiosis, involving hundreds or thousands of individuals, are widely reported in the literature. Foodborne outbreaks have also been reported.

Cryptosporidiosis in humans is largely manifest as a diarrhoeal disease, with the possibility of other abdominal symptoms such as nausea and vomiting. *Cryptosporidium* infection may also be asymptomatic. In an immunocompetent host, cryptosporidiosis usually resolves within a matter of days, although supportive therapy due to fluid loss may be necessary in severe cases. As a satisfactory treatment for cryptosporidiosis has, to date, been elusive, cryptosporidiosis in the immunocompromised host may develop into an intractable infection, which may be life-threatening.

Giardia duodenalis

Giardia are flagellated intestinal protozoan parasites in the phylum Sarcomastigophora, order Diplomonadida, with a direct lifecycle. Of the 6 accepted species, *Giardia duodenalis* infects a wide-range of mammals, including humans. *G. duodenalis* is currently considered as a species-complex in which different genotypes, or Assemblages, are associated with particular hosts. Currently 6 such assemblages are recognised, or which 2, A and B, are considered to be zoonotic. *Giardia* is the most common intestinal parasite worldwide.

Infection is often asymptomatic and can result in long-term carrier status. In Norway, most reported infections are considered to be imported, but contaminated drinking water has been known to be a source, with one extensive waterborne outbreak in 2004. Protozoa may also be transmitted via contaminated food. The infectious dose is low (theoretically one cyst). Patients are infectious as long as cysts are present in the faeces, usually up to six months.

Incubation lasts 5-25 days, usually 7-10 days. Acute disease is characterised by fatty diarrhoea and symptoms of upper gastrointestinal tract with abdominal pain and regurgitation of air. Of those infected, 5-10 % may still present with symptoms after treatment, even though *Giardia* cannot be detected in the stool sample, due to alterations in gut physiology.

Toxoplasma gondii

Toxoplasma gondii is a widespread protozoan parasite in the phylum Apicomplexa, with an indirect lifecycle, in which cats and other felines are the definitive hosts, and the intermediate stages occur in a variety of species of mammals and birds. Transmission to humans may occur by ingestion of oocysts excreted from cats, following sporulation in the environment which occurs approximately 3 days after excretion, or by consumption of tissue cysts encysted in the muscles of infected intermediate hosts. Transplacental transmission from mother to foetus is also a clinically important route of transmission, as, whilst adult infection is asymptomatic or has only mild symptoms in the immunocompetent, congenital toxoplasmosis may result in severe symptoms including learning and visual disabilities. Immunocompromised patients may also experience severe symptoms including ocular problems, CNS involvement, and encephalitis, which is frequently fatal.

Trichinella spp.

Trichinella spp. are nematode parasites in the order Trichurida. *Trichinella* spp have an unusual lifecycle, in that all stages (two generations) are completed within the same individual host, with two phases of infection; an enteral (gastrointestinal) phase and a parenteral (systemic) phase. Transmission between hosts is by ingestion of muscle tissue from the first host that is infected with the encysted larvae of the parasite. Digestive enzymes release these larvae and in the mucosa of the small intestine they mature into adults worms which mate and produce new larvae. These are carried from the lymphatic vessels to the striated muscle tissue via the circulatory system. Ingestion of the muscle tissue with these encysted larvae by another potential host continues the transmission cycle. Although light infections may be asymptomatic, clinical trichinellosis/trichinosis, that is known to occur only in humans, is associated with each stage of the infection, from adult females penetrating the intestinal mucosa and producing larvae, to the larval migration into the muscle tissues, to larval encystment. In extreme cases, trichinosis can be fatal.

The systematics of *Trichinella* spp. have been revised in recent years, due to the development of new molecular tools, and the genus is currently considered to be composed of two clades, an encapsulated group (five species and three genotypes) and a non-encapsulated group (three species). Renewed research on the host range has revealed that *Trichinella* spp. not only have a broad mammalian host range, but that some species can also infect reptiles and birds (Pozio 2005). Another important point is that the larvae of different species are very resistant to various different environmental pressures to which meat may be exposed, including those associated with muscle putrefaction, and low and high temperatures.

Bacteria

Salmonella

Infection is acquired usually through contaminated food. The most common sources are meat - especially pork and poultry meat - but also eggs, egg products, milk, shellfish, contaminated vegetables and spices. Infection via non-disinfected drinking water may occur. Person to person transmission via the faecal-oral route, or from domestic animals including pets (dogs, cats, birds and reptiles) and wild animals (birds, hedgehogs) to humans, can occur.

Salmonella infections (excluding *S. typhi*) usually cause only a short-term carrier status. In a few cases the carrier status can last longer than three months, and, in extremely rare cases it may last longer than a year. In infants and young children, carrier status occurs more often and lasts longer than in adults. Antibiotic treatment appears to prolong the carrier status.

Incubation period is 6-72 hours, usually about 48 hours. There are many asymptomatic infections. The symptoms are usually self-limiting and include diarrhoea, headache, abdominal pain, nausea, and possibly fever. Diarrhoea can, in rare cases, be prolonged and severe. Salmonella infections can cause septicaemia with focal lesions in internal organs. Dehydration, especially in children, may occur. Salmonellosis may rarely cause reactive arthritis.

***Brucella* sp.**

Brucellosis is an infectious disease caused by Gram-negative non-spore forming coccobacilli of the genus *Brucella*. Brucellosis primarily affects cattle, sheep, goats, and swine, but also horses and dogs (Metcalf *et al.,* 1994). In general, brucellosis is characterized by abortion and also infertility in males (orchitis).

Of the terrestrial bacterial species within the genus *Brucella*, *Brucella melitensis*, *B. abortus* and *Brucella suis* (biovars 1, 3 and 4) are also well-known pathogens in humans (zoonotic). People are infected through consumption of contaminated milk or dairy products, or through occupational contact with infected animals (veterinarians, agricultural workers, laboratory workers, meat industry workers and hunters). Infection from person to person is unknown. Incubation is very variable but usually 5-60 days. Some *Brucella*-infections are asymptomatic. When clinical symptoms occur, they are generally not disease-specific. Symptoms of brucellosis in humans are usually associated with a fluctuating (undulant) fever and sweating, sometimes associated with headache, poor appetite, backache, weakness, and depression, which may last for weeks or months. In rare cases, (undetected/untreated) brucellosis can give severe, and even fatal, complications such as pneumonia, meningitis, and abortion, and in chronic cases also cause osteomyelitis and arthritis.

Mycobacteria

Tuberculosis is a chronic infectious disease caused by acid-fast bacteria of the genus *Mycobacterium*. The most common form of the disease is tuberculosis of the lungs (pulmonary consumption, or phthisis), but the intestines, bones and joints, the skin and the genito-urinary, lymphatic, and nervous systems may also be affected.

***Campylobacter* spp.**

Campylobacteriosis is usually acquired through contaminated food, especially non-disinfected drinking water, poultry meat, and unpasteurised milk. The microorganism can also be transmitted through contact with faeces of contaminated animals. Flies can transfer the bacteria from faeces to food. In rare cases, infection can occur from person to person through poor hand hygiene. The infectious dose is low and incubation lasts 1-10 days, usually up to 2 days. Human illness includes moderate fever and flu-like symptoms, diarrhoea, which is often bloody, and abdominal pain. Approximately 20% of the cases will have symptoms lasting for over a week. Rarely, cases can develop reactive arthritis and Guillain-Barré disease.

***Leptospira* sp.**

Bacteria in the genus *Leptospira* are motile, helical bacteria 6 to 20 µm long and 0.1 µm in diameter (Levett 2001). Currently there are 20 species and over 200 recognised serovars in the genus. Leptospirosis is a worldwide disease among wild and domesticated animals, as well as humans. It is assumed that leptospirosis is greatly underreported, in particular in tropical regions (Levett & Haake 2010). The most significant pathogenic species is *L. interrogans*. The proximal convoluted tubuli of the kidney is the natural habitat of *L. interrogans*, and the microbe is excreted to the environment in the urine of chronically infected animals (Levett & Haake 2010). Humans are accidental hosts after contact with soil or water contaminated by urine from infected animals, or after close contact between humans and diseased animals (Johnson & Faine 1984; Levett & Haake 2010)). Leptospires enter the body through small cuts or abrasions, via mucous membranes or through the conjunctiva (Adler & de la Pena 2010). The clinical manifestations of leptospirosis in humans range from mild and self-limiting infections, seen in approximately 90 % of recognised cases, to severe and potentially fatal cases involving renal or liver failure and pulmonary infections (Bharti *et al.,* 2003; Levett & Haake 2010). There are no indications of transmission of leptospirosis among humans (Adler & de la Pena 2010; Bharti *et al.,* 2003).

***Nocardia* sp.**

Nocardia spp. are weakly-staining Gram-positive, and filamentous bacteria. At present more than 85 *Nocardia* species have been recognized. Bacteria belonging to the genus *Nocardia*, grow by branching filamentous colonies, and are acid fast by the Ziehl-Neelsen stain. *Nocardia* are found worldwide in soil that is rich in organic matter, among the oral microflora in healthy gingiva as well as periodontal pockets. The genus comprises both pathogenic, as *N. asteroides*, and non-pathogenic species. *N. asteroides* is considered to be an opportunistic pathogen infecting animals and humans after inhalation or by direct inoculation of the skin (Pier & Fichtner 1981; Sorrell *et al.,* 2010). Among terrestrial animals, infection most often occurs in dogs and cattle, as well as in humans (Pier & Fichtner 1981).

Clostridium botulinum

Clostridium botulinum is a Gram-positive, rod-shaped and anaerobic spore former of great importance for feed and food safety. This bacterium is naturally found in soil, sediments, and water on a worldwide basis (Fach *et al.,* 2002; Gram 2001; Hielm *et al.,* 1998; Huss & Pedersen 1979). Most strains of *C. botulinum* are able to produce potent proteinaceous neurotoxins, collectively known as botulin, during growth.

Botulism is a neuroparalytic disease caused by toxins produced by *Clostridium botulinum*, usually acquired through foods containing toxin. Infants can become infected via ingestion of bacterial spores in food, particularly honey. Due to the immature intestinal environment in infants, the spores can germinate and produce toxin causing illness. This often occurs in the weaning period. Botulism may also occur by growth in infected wounds (Johnson 2007). Incubation is up to three days, usually 12-36 hours. The symptoms of botulism in humans are caused by the inhibiting effect of botulin on the normal neuromuscular activity. Typical symptoms include blurred or double vision, nausea, vomiting, and constipation, dry or sore throat, and muscular paralysis. Mortality is approximately 10 %. In serious, untreated cases botulism may result in respiratory failure within 3-7 days. *C. botulinum* can be divided into seven types (A to G) based on the serology of the toxins produced. These toxins are thermally unstable, and will generally be inactivated at temperatures above 85°C for more than 5 minutes. Human botulism, i.e. infections or intoxications associated with *C. botulinum*, are, in the vast majority of cases, associated with the types A, B, E, and rarely F and C (Johnson 2007).

Viruses

Influenza virus

Influenza virus (family *Orthomyxoviridae*) exists in three serotypes, A, B and C. Influenza A virus is an enveloped virus with a diameter of 80-120 nm and a genome consisting of single-stranded RNA in eight segments. Influenza A virus causes a highly contagious and acute respiratory disease with high morbidity and mostly low mortality among humans, horses, swine and different avian species, as well as occasionally in other animals.

Influenza B- and C virus infects only humans. Influenza B virus may also change genetically and may cause human epidemics, but the changes are not as rapid and profound as in influenza A virus, and epidemics are usually not widespread as influenza A virus epidemics.

Influenza C virus rarely causes disease, and no epidemics caused by this virus are reported.

Poxvirus

Poxviruses are generally large (200 x 300 nm), oval to brick shaped, enveloped DNA viruses with a cytoplasmic replication in infected cells (unlike other DNA viruses). Members of the the *Poxviridae* family can infect both vertebrate and invertebrate animals. Viral representatives of four genera can infect humans; orthopox (variola, vaccinia, cowpox, monkeypox), parapox (orf virus, pseudocowpox, bovine popular stomatitis virus), yatapox (tanapox, yaba monkey tumor virus) and molluscipox (molluscum contagiosum). Of these humans pathogens, cowpox (rodents, cats, humans), orf (sheep, goat, reindeer, muskox, humans), pseudocowpox (cattle, humans), bovine popular stomatitis virus (cattle, humans) and molluscipox (humans only) occur in Norway. Of poxviruses that are not pathogenic to humans, members of the genus *Avipoxvirus* are represented in wild birds in Norway.

Calicivirus

Caliciviruses (*Caliciviridae* family) are relatively simple, non-enveloped and small (35-39 nm), with a genome consisting of non-segmented, single-stranded, positive-sense RNA. Caliciviruses may infect humans, pigs, cattle, cats, chickens, reptiles, amphibians, as well as dolphins. The most common caliciviruses in Norway are Norwalk virus (genus Norovirus), which infects humans through drinking water, and feline calicivirus (FCV) that infects domestic cats and causes respiratory disease (rhinitis, tracheitis), conjunctivitis, and lesions in the oral mucosa.

Rotavirus

Rotavirus is a genus of double-stranded RNA viruses of the *Reoviridae* family. Rotavirus is generally the most common cause of severe diarrhoea in infants and young children (< 5 years old), whereas adults, due to immunity, are rarely affected. Rotavirus A (one of five species) causes more than 90 % of infections in humans. Rotavirus is transmitted via the fecal-oral route, and infects the cell lining in the intestines, causing gastroenteritis (“omgangssyke”), with diarrhoea and vomiting. Approximately 200 cases are reported annually in Norway, but the disease is probably underreported. Rotavirus can also cause diarrhoea in young animals, such as monkeys, cattle, pigs, sheep, cats, dogs, and others, and represents economic losses for farmers, due to the high morbidity and sometimes also high mortality (dehydration) of such infections. Rotavirus in animals may be a potential reservoir for genetic exchange with human rotaviruses.

13 Annex 2

13.1 Experiences from meat inspection and bacteriological control in Norway

Minke whales

Bacteriological investigation of minke whales by the Norwegian Food Safety Authority in Nordmøre during the summer 2002 (Mork 2002)

During summer 2002, three series of samples from minke whales were investigated. The samples were collected 12 June, 19 July, and 27 August from one processing plant in Nordmøre.

At the processing plant, the round pieces (luns) of whale meat, each with a weight from about 50kg to about 100kg are received. In the processing plant the surfaces of these pieces (luns) are trimmed by knife. The trimmed pieces are then divided into pieces suitable for consumer packages.

Each of the sample series consisted of ten single samples:

- five samples from surfaces of untrimmed luns

- five consumer packages from the same trimmed luns

Bacteriological guidelines from the Norwegian Food Safety Authority for the analysis of food (Mattilsynet, 2004) were followed in this study. *Salmonella* spp., *Listeria monocytogenes* or *Clostridium* spp**.** were not isolated from the samples. Staphylococci were isolated from one luns, but not from the consumer package from the same luns. *Vibrio* spp. were isolated from five samples. However, further identification of the *Vibrio* isolates was not performed.

Presence of *Aeromonas* spp. was tested by a method which does not distinguish between *Aeromonas hydrophila* and other *Aeromonas* spp. without further characterisation. *Aeromonas* spp. were isolated from ten of the samples. Four isolates were identified as *Aeromonas caviae*. The isolates were aerolysin-positive and moderately cytotoxic. *Aeromonas hydrophila* was not detected.

The occurrence of coliform bacteria on the surfaces of the luns was compared with the occurrence in consumer packages of whale meat from the same luns. The microbiological quality was acceptable, even on the surfaces of the luns. However, trimming the luns seemed to reduce the bacterial flora so efficiently that the products in the consumer packages were characterized as good quality whale meat (Table 3).

Table 4. Comparative investigations of coliform bacteria (number of bacteria; colony forming units; CFU) in untrimmed round pieces of minke whale meat (luns; 50-100 kg) and from the corresponding consumer packages, according to Nordic Committee on Food Analysis[1]

Sample no.	Surface of untrimmed round pieces (lunser): CFU per g	Surface of meat in consumer package from the corresponding luns: CFU) per g
1	220	<10
2	90	<10

3	50	<10
4	90	<10
5	280	<10
6	2,000	20
7	60	30
8	6,000	<10
9	200	20
10	3,000	<10
11	100	10

[1] The guidelines of Norwegian Food Safety Authority (Mattilsynet 2004) are as follow: The lower limit that preferably should not be exceeded (m): 1,000 CFU per g, and the upper limit that is unacceptable (M): 100,000 CFU per g

Bacteriological investigation of minke whales by the Norwegian Food Safety Authority in Sunnmøre during summer 1983 (Flisnes 1994)

The load examined consisted of 68 whales caught near West Greenland. A total of 88 samples of whale meat were included. Less than 100 coliform bacteria and clostridia per gram were detected in all samples. In 51 of the samples, the total numbers of bacteria were less than 1000 per gram. In the remaining 37 samples, the total numbers ranged from 1000 to 40000, with an average of 5000 per gram. pH was measured in one sample from each of the 68 whales, with an average of 5.66 (range: 5.40 to 6.05).

Seals

Seal-hunting boats have an inspector on board, usually a veterinarian (compulsory if salted meat is prepared on board), who evaluates the general health status of the animal before meat and other products are obtained for consumption. In 2004, 74 of 5000 seals were condemned on board due to emaciation (n=20), lesions, abscesses, and abnormal smell, colour or general appearance (personal communication, Mattilsynet, Tromsø). The bacteriological meat control itself is based on spot tests conducted by Mattilsynet when the meat is landed. This control normaly focuses on a few groups of bacteria, such as coliform bacteria, the commonly used bacterial indicator of the sanitary quality of foods and water (*Enterobacteriacea* family), *Staphylococcus* spp., sulphate-reducing *Clostridium* spp., and *Enterococcus* spp. (personal communication, Mattilsynet, Tromsø).

"Enteric pathogens in seals" – a research project

A special investigation on enteric pathogens in seals was conducted on colon samples obtained from 174 animals caught by four different vessels during the season of 1990 (Øisund 1990). The samples were frozen on board (- 20 ◦C) and kept frozen until investigation (some weeks later). The samples were investigated for presence of *Salmonella* spp., *Yersinia enterocolitica* and *Listeria monocytogenes*, which were chosen since they are important during regular meat control on terrestrial mammals. 1 g faeces were investigated for each of the bacteria by cultivation, and all results were negative.

Results from spot controls, Tromsø

During a spot control of a consumer package of frozen seal meat (beef) obtained from the hunting season of 1993 the following results were obtained:

a). Coliform bacteria: <10/g

b). Total number of bacteria: 200 000/g

During a spot control of seal meat (beef) from 13 animals, caught during the commercial seal hunt in 1994, the following results were obtained:

a). Colifom bacteria: <100/g: n=1; <1000/g: n=12,.

b). Total number of bacteria: <100 000/g: n=8; 100 000/g: n=2; 200 000/g: n=2; 1 mill/g: n=1.

c). *Aeromonas hydrophila*: <100/g: n=13.

d). *Salmonella* spp.: Not detected.

e). *Listeria monocytogenes*: Not detected.

Bacterial counts of 200 000 or more are beyond the acceptable limit for meat. Aside from these, the results from these investigations were acceptable.

13.2 Experiences from marine mammal meat inspections in other countries

Faroe Islands

The main marine mammal of interest in the Faroes is the Pilot whale. The catch volume is closely monitored, and statistics are available for several hundred years. These publically available statistics, represents the longest continuous catch monitoring on any marine mammal. Little information is available on microbiological analyses of seal and whale products from The Faroe Islands.

Iceland

<u>Samples for bacteriology</u>
A total of 135 bacteriological samples from 26 pilot whales caught in 2003, 12 caught in 2004, and a single one in 2005 were collected and analysed. Preliminary results of cultures from blood and major organs of these animals were negative with respect to pathogenic bacteria. The samples were cultured at 37°C, aerobically on Columbia Blood agar and/or Sheep blood agar, and anaerobically on Wilkins-Chalgren agar and/or Sheep blood agar. Positive cultures were investigated further by microscopy and biochemical methods. Four samples were analysed for *Dermatophylus congolensis*.

<u>Results</u>
Bacteria were isolated from 38 samples from 20 animals. No bacteria were isolated from 5 animals. The bacteria isolated belonged mainly to the groups *Aeromonas*, *Pseudomonas*, *Edwardsiella*, *Streptococcus*, *Moraxella*, *Staphylococcus* and *Vibrio*. *Dermatophylus congolensis* cultures were all negative.

Discussion
All the samples came from healthy animals that had been recently shot and samples taken aseptically. Many of the bacteria groups isolated are known to be common in seawater, so it is questionable whether the methods used for sampling were adequate.
Little is known about the normal bacterial flora of Cetaceans and it is unknown whether the bacteria isolated are a part of the normal flora or if they are opportunistic pathogens.
The bacteria cultures have been stored at -80°C. Final interpretation and further diagnostic work remains to be completed.

14 Pictures

Sealing

Picture 1. Seals are shot, clubbed (hakapik), and bled on ice before they are taken onboard for processing. On deck, the skin is removed and pieces of meat are cut from the back (Photo: Michael Polterman, Institute of Marine research, Tromsø, Norway.

Picture 2. Foreflippers from seals are prepared for salting in barrels. Seawater is used for cleaning. (Photo: Ingebjørg H. Nymo, Norwegian School of Veterinary Science, Tromsø, Norway.

Whaling

Picture 3. Whale meat is cut into pieces (luns) of 50-100 kg and cooled on deck until the ambient temperature is reached. Hooks used to handle the meat are a potential source of contamination (deep inoculation), especially if they are also used to handle intestines etc.

Picture 4. When several animals are caught within short time, the whole deck area can be covered with meat. This may impact on the hygienic quality of the meat.

Picture 5. Organoleptic meat control takes place when landing the whale meat at certified land stations for processing.