APHIS Risk Analysis on Importation of Exotic Newcastle Disease (END) Virus from Denmark

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Veterinary Services
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Executive Summary

Prior to July 16, 2002, APHIS recognized Denmark as being free from Exotic Newcastle Disease (END), allowing Denmark to export poultry products to the United States [1]. On July 16, 2002, the Danish Veterinary and Food Administration (DVFA) reported to the World Organization for Animal Health (OIE) a suspected outbreak of Newcastle disease (ND), which APHIS refers to as Exotic Newcastle disease (END) [2].[1] Over the next seven weeks, a total of 135 END outbreaks were confirmed in eight counties of Denmark. Since August 2002, there have been no further reported outbreaks of END in Denmark [4].

In response to the END outbreaks in Denmark in an effort to help prevent the introduction of END into the United States, APHIS amended its regulations by removing Denmark from the list of regions considered free of Exotic Newcastle Disease and banning trade in Danish poultry products. The trade restriction did not prohibit importation of live birds since the legal entry of live birds into the United States is satisfactorily controlled through existing quarantine measures (9 CFR Part 93) [5]. The interim rule, published in the Federal Register on September 20, 2002 effective retroactively to July 16, 2002, restricts the importation of poultry carcasses, parts or products of poultry carcasses, and eggs (other than hatching eggs) of poultry, game birds or other birds from Denmark [6].

In this document, APHIS presents the results of its re-evaluation of the END status of Denmark. Because of the long history of trade between the United States and Denmark, APHIS did not require a site visit. APHIS is basing this review on the evaluation of documentation submitted by the European Commission (EC) on behalf of the Danish Veterinary and Food Administration (DVFA) [7-9], information available on DVFA's website [10], European Commission (EC) Food and Veterinary Office report [11], EC legislation [12-14], and reports to OIE [2, 4].

As a result of this evaluation, APHIS concludes that DVFA was able to effectively control and to eradicate END in its domestic poultry population. The DVFA was able to eradicate END despite the initial delay in detection due to concurrent Marek's disease infection in a commercial flock from which END spread. The effectiveness of the eradication program was attributed to prompt actions taken by DVFA and the cooperation of backyard and commercial flock owners. Since the 2002 outbreaks, Denmark has conducted extensive serological surveillance for END, with no new END outbreak detected.

[1] Newcastle Disease (ND), as defined in the OIE Manual of Diagnostic Tests and Vaccines for Terrestrial Animals, and Exotic Newcastle Disease (END) are synonymous and refer to the highly pathogenic, velogenic and mesogenic strains of avian paramyxovirus, type 1 ND, (APMV-1 ND) for which its virulence can be characterized as either having (a) an intracerebral pathogenicity index (ICPI) in day-old chicks of 0.7 or greater, or (b) having a specified pattern of amino acid residues as described in the Manual [3].

Since the 2002 outbreaks, Denmark has strengthened record-keeping and reporting requirements related to trade of live poultry, implemented a mandatory vaccination policy for commercial flocks and poultry markets, and increased testing by its national reference laboratory of poultry submissions for END to enhance early detection.

However, Denmark trades with countries or regions that the United States does not recognize as free of END, including some European Union (EU) Member States. As a safeguard, APHIS will require certification to ensure that poultry and poultry products from Denmark originate in Denmark or in any other region recognized by APHIS as END-free and that, prior to export to the United States, such poultry and poultry products are not commingled with poultry and poultry products from regions where END exists. Such certification is consistent with APHIS policy regarding the risk presented by commingling when a country recognized as disease-free supplements its supply with animals or products from regions not recognized as disease-free.

Based on the results of the release assessment, APHIS could identify no additional risk factors currently applicable to Denmark that would justify keeping Denmark from the list of regions APHIS considers as END-free.

Regarding the likelihood of exposure, historical experience indicates that the risk of introducing END via importation of live birds is considerably higher than via poultry products. Disease introduction via legal entry of live birds is satisfactorily prevented through existing quarantine measures in the United States and is not currently prohibited under the current import ban of poultry products from Denmark. Therefore, given the results of the release assessment, APHIS considers the likelihood of introduction of END-infected birds and products from Denmark to be extremely low.

The consequence assessment addresses potential effects of an END outbreak on animal and public health, as well as associated environmental and economic considerations. Consequences of human exposure from END are low. While consequences on poultry health are high, effective disease surveillance and control measures should reduce the consequences by reducing the extent of spread. Consequences to the environment should be within the scope of APHIS resources and authority to manage adequately.

The economic portion of the consequence assessment was based on available information regarding the economic consequences of END introductions into the United States since 1950. This assessment, while demonstrating that the consequences can be significant under certain conditions, also demonstrated that an END introduction does not necessarily result in extensive consequences. If the disease is diagnosed prior to extensive spread, appropriate biosecurity measures are implemented, and the public is educated to look for clinical signs, the consequences can be minimized. Furthermore, because of the outbreak in the western United States in 2002-2003, APHIS has enhanced its END surveillance program in such a way as to increase the likelihood of future detection prior to spread.

In summary, APHIS concludes that the risk of introducing END into the United States with the resumption of trade in poultry carcasses, parts or products of poultry carcasses, and eggs (other than hatching eggs) of poultry, game birds or other birds from Denmark is low. Although consequences of an END outbreak are potentially substantial, the likelihood of an outbreak occurring from exposure of the domestic poultry population to poultry products imported from Denmark is low.

Introduction

On July 16, 2002, the Danish Veterinary and Food Administration (DVFA) reported to the OIE a suspected outbreak of Newcastle Disease (ND), which APHIS refers to as Exotic Newcastle disease (END) [2].[2] Over the next seven weeks, a total of 135 END outbreaks were confirmed in eight counties of Denmark. Since August 2002, there has been no further reported outbreak of END in Denmark [4].

In response to these END outbreaks in an effort to help prevent the introduction of END into the United States, APHIS amended its regulations, 9 CFR Part 94.6 (a)(2), by removing Denmark from the list of regions considered free of Exotic Newcastle Disease.[3] The interim rule, published in the Federal Register on September 20, 2002, and effective retroactively from July 16, 2002, restricted the importation of poultry carcasses, parts or products of poultry carcasses, and eggs (other than hatching eggs) of poultry, game birds or other birds from Denmark [6].

Under § 94.6, poultry carcasses, and parts and products of poultry carcasses may be imported into the United States from regions where END exists only if they have been cooked or are consigned directly to an approved establishment in the United States. Eggs (other than hatching eggs) of poultry, game birds, or other birds from regions where END exists may be imported into the United States only if: (1) They are accompanied by a health certificate regarding the flock of origin and meet certain other conditions; (2) they are consigned directly to an approved establishment for breaking and pasteurization; (3) they are imported under permit for scientific, educational, or research purposes; or (4) they are imported under permit and have been cooked or processed and will be handled in a manner that prevents the introduction of END into the United States.

It is important to note that the trade restriction did not prohibit importation of live birds. Legal entry of live birds into the United States is controlled through existing quarantine measures (9 CFR Part 93) [5]. These regulations require the quarantine of imported live birds in facilities operated or approved by APHIS.

In the preamble to the interim rule, APHIS stated its intention to reassess Denmark's END status at a future date. This document provides that reassessment. The results of this assessment will be used as a decision-making tool to determine whether safe trade with Denmark in poultry products can be resumed.

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[2] Newcastle Disease (ND), as defined in the OIE Manual of Diagnostic Tests and Vaccines for Terrestrial Animals, and Exotic Newcastle Disease (END) are synonymous and refer to the highly pathogenic, velogenic and mesogenic strains of avian paramyxovirus, type 1 ND, (APMV-1 ND) for which its virulence can be characterized as either having (a) an intracerebral pathogenicity index (ICPI) in day-old chicks of 0.7 or greater, or (b) having a specified pattern of amino acid residues as described in the Manual [3].

[3] Denmark was recognized by APHIS as END-free through a rulemaking action published in the Federal Register on November, 8, 1974 [1].

Objective

The objective of this review is to evaluate the risk associated with the resumption of import of poultry carcasses, parts or products of poultry carcasses, and eggs (other than hatching eggs) of poultry, game birds, or other birds from Denmark.[4] The results will provide the basis for APHIS to decide whether to recognize Denmark as free from END.

The risk analysis was based on information from several sources. The European Commission (EC), on behalf of Danish Veterinary and Food Administration (DVFA), provided information to APHIS regarding the 2002 outbreaks of exotic END in Denmark. DVFA's *Newcastle Disease Outbreaks in Denmark 2002 Final Report* [7], correspondence provided by DVFA [8, 9], information available on DVFA's website [10], European Commission (EC) Food and Veterinary Office report [11], EU legislation [12-14], and reports to OIE [2, 4] constitute the supporting documentation for this evaluation.

Denmark, as a Member State of the European Union (EU), is obligated to comply with the provisions of Council Directive 92/66/EEC which describes the measures for the control and eradication of Newcastle disease [14] and Council Directive 90/539/EEC which proscribes the conditions under which live birds and hatching eggs may be imported into Member States from third countries [12]. These measures are harmonized and binding throughout the EU serving as an important means to prevent the introduction and spread of ND within the EU as well as to prevent the spread of ND to other countries through its export market. The Commission has the authority to conduct periodic evaluations to verify Member State compliance.

Some important provisions required by Council Directive 92/66/EEC are: the compulsory notification of suspected cases of ND; depopulation of poultry on holdings where ND is confirmed; cleaning and disinfection of affected premises; establishment of protection and surveillance zones around affected holdings to enforce movement controls; epidemiological investigations; a national laboratory in each Member State and a Community reference laboratory for ND diagnosis; and standards to be followed when implementing a ND vaccination program. The evidence listed above provided the means for APHIS to evaluate the effectiveness of Denmark's implementation of Council Directive 92/66/EEC in response to the series of END outbreaks in 2002.

APHIS did not conduct a site visit as part of this evaluation. Prior to the outbreaks in 2002, the United States had a long history of trade of poultry and poultry products with Denmark. Denmark, as a country and as a Member State of the European Union, has

[4] Although the purpose of this assessment is to evaluate the risk of resuming trade of poultry products rather than live birds from Denmark, the exposure and consequence assessments discuss risks associated with importation of live birds. This is necessary because historically END introductions into the United States have been associated with the importation of live birds rather than with importation of poultry products.

previously been evaluated for END and other animal diseases. The EU system for animal disease control for classical swine fever has been extensively evaluated by APHIS and provides an basis for understanding the EU system for control of END. APHIS has maintained contact with Danish veterinary authorities who kept APHIS advised of animal disease conditions in their country. Therefore, APHIS concludes that a document review is sufficient to meet the needs of this risk analysis.[5]

Hazard Identification

The Animal and Plant Health Inspection Service identified several animal diseases listed by OIE [16] that pose primary hazards associated with initiating trade in animals and animal products from foreign regions. The listed foreign animal diseases of primary concern are addressed specifically in APHIS regulations [17]. One of these diseases, Exotic Newcastle Disease, is recognized by APHIS as a hazard of primary concern. In this regard, before opening or, as in this case, resuming trade in poultry and poultry products with a region or country considered by APHIS to have been affected with END, APHIS is obligated to conduct an import risk analysis to support rulemaking [18].

The viruses which cause END belong to the avian paramyxovirus (APMV) family, for which nine serotypes have been identified (APMV-1 to APMV-9). Strains of APMV-1 virus vary widely in the severity of the disease they may produce in birds, and are generally characterized by their pathologic symptoms into three groups: lentogenic, mesogenic, and velogenic, reflecting increasing levels of virulence [3].

Newcastle Disease (ND), as defined in the OIE Manual of Diagnostic Tests and Vaccines for Terrestrial Animals, and Exotic Newcastle Disease (END) are synonymous and refer to the velogenic or mesogenic forms of the disease caused by highly pathogenic strains of avian paramyxovirus type 1 (APMV-1 ND) for which its virulence can be characterized as either having (a) an intracerebral pathogenicity index (ICPI) in day-old chicks of 0.7 or greater, or (b) having a specified pattern of amino acid residues as described in the Manual [3]. APMV-1 ND viruses are considered exotic to the United States [19].

Epidemiological characteristics of APMV-1 ND relevant to the import risk it may pose [3, 19, 20], described in more detail in Appendix 1, include the following:

- END is a highly contagious viral disease known to infect chickens, turkeys and many other domestic and wild bird species.
- END has been reported throughout the world and is endemic in many countries of Asia, the Middle East, Africa, and Central and South America.

[5] A document, titled *Process for Foreign Animal Disease Status Evaluations, Regionalization, Risk Analysis, and Rulemaking*, describes the approach APHIS uses to evaluate regions previously considered free of a disease and that subsequently experienced an outbreak of the disease and then eradicated it, The document also describes circumstances when a site visit may not be deemed necessary for an evaluation [15].

- Clinical symptoms of END vary depending on viral strain, host, age and environment. END is a systemic disease most notably involving the respiratory, digestive or nervous systems.
- The disease is spread primarily through direct contact between healthy birds and the bodily discharges of infected birds, such as droppings and secretions from the nares, mouth and eyes.
- END incubation ranges from 2 to 15 days.

Risk Analysis

This analysis is composed of four components: the release assessment, the exposure assessment, the consequence assessment, and the risk estimation. These components are defined in OIE guidelines and represent the internationally recommended components for animal health import risk analysis [21]. Although the primary focus for this analysis is the evaluation of risks associated with poultry products import from Denmark, the exposure and consequence assessments include discussion of live bird factors because of their historical significance to END outbreaks in the United States.

Release Assessment

For the purpose of this report, release assessment refers to the likelihood that END exists in Denmark and, if so, how likely it would be for the disease to be introduced into the United States through imports of poultry carcasses, parts or products of poultry carcasses, and eggs (other than hatching eggs) of poultry, game birds, or other birds from Denmark The likelihood will depend on the effectiveness of the eradication and control measures undertaken by Denmark in response to the 2002 outbreaks of END.

Status of disease in the region

In recent years, Denmark reported outbreaks of END in 1995, 1996, and 1998, for which there was limited spread of disease [4, 7]. In 1995 outbreaks occurred in 14 backyard flocks; in 1996, 1 commercial flock, 2 backyard flocks and 1 game-bird flock were involved; and in 1998, outbreaks were reported in 2 commercial flocks. However in 2002 the spread of infection was more extensive. In July and August, 2002, Denmark experienced a total of 135 END outbreaks which lead to the current ban by APHIS. The following information describes the 2002 outbreaks.

Overview of 2002 outbreaks [4, 7]

DVFA initially reported suspicion of END on July 16, 2002. By the time the last affected flock was stamped out on August 29, 2002, Denmark had reported to OIE a total of 135 outbreaks. Each reported outbreak involved a single affected premises. Most of the

outbreaks occurred in the central and southern areas of the Jutland Peninsula, but a single outbreak occurred on one of Denmark's smaller islands in the Baltic Sea.

Based on the results of epidemiological investigations, DVFA characterized four of the 135 outbreaks as primary outbreaks and 131 as secondary outbreaks.[6] The source of infection could not be determined for the four primary outbreaks (identified by DVFA as outbreaks no. 1, 28, 29 and 127). However, DVFA determined that all 131 secondary outbreaks were the result of disease spread from a single commercial flock (outbreak no. 1).

A relatively small number of birds were involved in these outbreaks; a total of 175,455 were destroyed as a result of the 135 outbreaks. While only nine commercial flocks were affected (two breeder, five layer and two dealer flocks), the disease spread to 126 backyard flocks. Summary statistics for the 2002 outbreaks are presented in Table 1. All 4 primary outbreaks occurred in commercial flocks. Secondary outbreaks occurred in 5 commercial flocks and all (126) of the affected backyard flocks. Information on the 9 commercial flocks affected with END is summarized in Table 2. The outbreaks and epidemiological investigation are subsequently discussed in more detail later in this document.

Table 1: Affected poultry, confirmed holdings, eradicated holdings and holdings with clinically affected poultry and number of clinically affected poultry in the Newcastle Disease outbreaks in Denmark in 2002.

	Commercial holdings	Back-yard flocks
Affected poultry with ND	169,497	5,958
Holdings with ND	9	126
Eradicated holdings	9	126
Holdings with clinically affected poultry	7	6
Clinically affected poultry	164,780	804

Source: DVFA [22]

[6] An outbreak is characterized as being primary when it cannot be epidemiologically linked to another outbreak, often the source of infection cannot be identified or the outbreak results from introduction of the disease into a region where that disease was previously not known to exist. An outbreak is characterized as being secondary when an epidemiological link indicates that the disease spread from another outbreak.

Table 2. Information on END in commercial flocks

Outbreak serial no.	*Type of flock*	*Outbreak confirmed**	*Diagnostic aspects*	*Source of infection*
1	Pullets	July 26, 2002	Clinical: Ataxia, lameness, torticollis Serology: July 19, 2002	Primary introduction of unknown origin**
2	Layers	July 26, 2002	Clinical: Egg drop, lameness, torticollis Serology: July 20, 2002 Virology: July 26, 2002, ICPI = 1.75	Pullets from outbreak no. 1 June 15, 2002
3	Layers	July 26, 2002	Clinical: Ataxia, lameness, torticollis Serology: July 20, 2002	Pullets from outbreak no. 1 June 18, 2002
4	Layers	July 26, 2002	Clinical: Ataxia, torticollis Serology: July 20, 2002	Pullets from outbreak no. 1 June 15, 2002
6	Dealer flock, mixed poultry	July 26, 2002	Clinical: Lameness Serology: July 20, 2002	Pullets from outbreak no. 1 May 28, 2002
7	Dealer flock, mixed poultry	July 26, 2002	No clinical symptoms Serology: July 20, 2002	Pullets from outbreak no. 1 June 13, 2002
28	Layer	Aug. 2, 2002	Clinical: Paralysis, egg drop Serology: July 15, 2002 Virology: Aug. 2, 2002 ICPI = 1.71	Primary introduction of unknown origin**
29	Breeders	July 29, 2002	No clinical symptoms Serology: July 27 and 29, 2002 with a difference in titers	Primary introduction of unknown origin**
127	Layers	Aug. 19, 2002	Clinical: Torticollis, egg drop Serology: Aug. 20, 2002 Virology: Sept. 4, 2002 ICPI = 1.75	Primary introduction of unknown origin**

* Outbreaks no. 1, 2, 3, 4, 6, 7, and 28 were depopulated before the outbreaks were confirmed.
** Outbreaks no. 1, 28, 29, and 127 were all located less than 2 km from a coastline.

Source: DVFA [7]

Suspicion of END [4, 7-9]

First suspect case (outbreak no. 28)

On July 13, 2002, Denmark began an investigation of a suspected case of END in a poultry layer farm exhibiting high mortality and reduced egg production. Danish veterinary authorities took immediate action to place the suspect farm under quarantine. DVFA carried out sampling for serology, virology, and other diagnostic laboratory investigations which were initiated at the Danish Veterinary Institute (DVI).

Two days later, the DVI obtained positive serological evidence of END when all 30 samples initially taken from the flock reacted positively. The titers measured from these samples ranged from 16 to 4096. The finding of positive titers supported suspicion of an active END infection. Based on clinical symptoms and serological results, on July 16, 2002, DVFA established 3-km protection and 10-km surveillance zones around the suspect farm. The DVFA destroyed the flock on July 19, 2002. These actions were taken as precautionary measures pending laboratory confirmation of END. Virus isolation from samples taken from this flock proved difficult due to the very slow in-vitro growth of the viral strain involved, but END was eventually confirmed on August 2, 2002, nearly a week after virus isolation confirmed the diagnosis of END infection in another flock.

Epidemiological investigations would eventually conclude that the outbreak (now referred to as outbreak no. 28) on this farm was unrelated to other outbreaks which occurred during the summer of 2002. [7] There were no reported contacts between this farm and other farms which could explain either the introduction or the transmission of the infection. While the source of the infection could not be determined, the epidemiological investigation discovered a malfunctioning ventilator which breached the strict bio-security measures previously established on the farm. Birds nearest the defective ventilator were the first to exhibit clinical symptoms. Attempts to confirm a link with possible infected wild bird populations were inconclusive. As such, this outbreak (no. 28) would be classified by DVFA as one of the four primary END outbreaks which occurred in the summer of 2002.

Second suspect case (outbreak no. 1)

A second flock suspected of being END infected (subsequently classified as outbreak no. 1) was placed under official surveillance on July 18, 2002. [7] This was a commercial breeding flock located approximately 150 km north of the first suspect flock. An epidemiological link could not be made between the first suspect case (outbreak no. 28) and this second suspect case (outbreak no. 1). Furthermore, both of these cases were classified as primary outbreaks since their source of infection could not be determined. The second suspect case (outbreak no. 1) was significant because it was determined to be the source of secondary spread of END for 131 additional outbreaks.

Initially, lameness was the clinical symptom first observed in this flock (outbreak no. 1) which was thought to be suggestive of Marek's disease. In June, 2002, samples were submitted to DVI for virological and histological testing for Marek's disease; but the results of these investigations were inconclusive. Serological testing for ND was not conducted during this initial diagnostic investigation. In their report, DVFA concedes that apparently the clinical symptoms of Marek's disease in outbreak no. 1 shifted focus away from clinical suspicion of ND thus contributing to the delay of detection of the ND outbreak.

However, the owner of this farm independently submitted samples to a laboratory in Germany. In addition to testing for Marek's disease, the German laboratory routinely tested samples for ND and thus, on July 18, 2002, advised the owner that the serology samples tested positive for ND. The owner promptly reported the positive ND results to Danish veterinary authorities.

Again, Danish veterinary authorities acted immediately by implementing control measures while the laboratory investigation ensued. The following day, July 19, 2002, DVI reported serological results similar to the first suspicion (all samples tested produced high titers). Clinical examinations also revealed birds exhibiting torticollis. Based on clinical presentation and positive serology, this flock was destroyed on July 27, 2002.

It is important to note that the German laboratory reported positive results for Marek's disease on July 22, 2002 and DVI reported a positive RT-PCR test for Marek's disease on August 7, 2002. DVFA cites that an unclear medical history report and co-infection with Marek's disease "blurred suspicion of ND" [9].

Spread of END [4, 7-9]

Prior to suspicion of END, pullets were sold from the outbreak no. 1 flock (the flock co-infected with END and Marek's disease). Investigators identified six contact flocks (outbreaks no. 2, 3, 4, 5, 6, 7) that had received pullets from the outbreak no. 1 flock during the period from May 28, 2002, to July 18, 2002, before restrictions were placed on the flock. Of these six contact flocks, three were commercial flocks, two were dealer flocks and one was a backyard flock. By the time of the epidemiological investigation, poultry in outbreaks no. 2, 3, 4, 5 and 6 had shown varying degrees of clinical symptoms.

END virus was never isolated from the outbreak no. 1 flock; however, it was isolated from one of the contact farms receiving pullets directly from it. DVI reported a positive viral isolation result on July 26, 2002 from samples taken from one of these contact flocks, a commercial layer flock (outbreak no. 2). In its final report DVFA concluded that, by the time that END was suspected in July, the infection in outbreak no. 1 had already passed the acute phase, which was the reason why the virus could not be isolated from poultry in this outbreak [7].

The two dealer contact flocks (outbreaks no. 6 and 7) received pullets from the outbreak no. 1 flock on May 28, 2002, and June 13, 2002. The poultry dealers later resold these birds to owners of backyard flocks, often through live bird markets or fairs. This resulted in the spread of infected pullets to backyard flocks primarily in the southern part of the country. According to DVFA, "Tracing of these backyard flocks was complicated, as one of the dealers did not keep the compulsory records of sales. A large effort had to be made to trace these contact flocks by using phone number records from the dealer, in addition to advertisements in local mass media in order to contact the backyard flock keepers" [7].

Epidemiological investigations concluded that the pullets from the second suspect case (outbreak no. 1) had been infected at the time of delivery and subsequently spread the infection to the receiving farms. Movement of infected birds by two poultry dealers, prior to disease detection, eventually spread END to 5 commercial flocks and 126 backyard flocks. As such, this primary outbreak (outbreak no. 1) and the related contacts comprised one large epidemiological cluster of infected flocks.

Control Measures [7, 9, 11, 14]

Once END was suspected on July 16, 2002, DVFA responded quickly. It implemented a crisis management structure to coordinate the government's response to the outbreaks. The Central Coordination Centre set up three task force groups, Epidemiology and Eradication, Information and Contacts, and Transport and Movements.

The Epidemiology and Eradication group worked closely with the local crisis centers and the Regional Veterinary Centers to coordinate the epidemiological investigations, diagnostic sampling and surveillance, eradication, and cleaning and disinfection. This group was responsible for enforcing the protection and surveillance zones around each infected premises.

The Information and Contacts group acted as a liaison, providing information and updates to the European Commission, OIE and veterinary authorities of other countries. They were also responsible for distributing END response information within the Danish government and to the Danish poultry industry, veterinary profession, and the media.

The Transport and Movement task force handled issues related to movement control, issuing the necessary documents for internal movement of birds and products, movement within the European Union, and export to third countries.

As mentioned previously, DVFA acted quickly upon suspicion of END to quarantine suspect flocks and to establish protection and surveillance zones around them. Protection and surveillance zones, typically a 3 km or 10 km radius respectfully, were set up and ultimately lifted according to EC regulation [14].

DVFA's statement that, "[t]he only transmission route documented for spread of infection between flocks during the outbreaks was trade with sub-clinically infected or sero-positive poultry, before the detection of the first outbreak" [7] provides evidence of the movement control measures' efficacy.

Poultry on outbreak farms were euthanized and disposed by rendering or burying, and the farm was cleaned and disinfected. These actions were taken under official supervision in accordance with EC regulation [14].

At the time of the outbreaks, commercial flocks were already registered and listed in a central database, thus simplifying identification of commercial flocks within the protection and surveillance zones. Furthermore, as a result of the 2002 outbreaks, a new regulation was issued by Denmark requiring owners of backyard flocks to register with DVFA if they are located within a designated "risk area" [7]. Registration could be made via the internet, by phone or mail. Announcements of the registration requirements were made on television and radio and in print media. This campaign resulted in registration of 22,829 backyard flocks, of which 11,500 were located within surveillance zones and 3,433 within protection zones.

Inspection and screening of all flocks within the protection and surveillance zones were carried out by the local crisis centers during August and early September, 2002. Within the protection zone, if veterinary officers detected clinical symptoms indicative of END, restrictions were imposed, and the flock was serologically tested. For all flocks located within 500 meters from an outbreak flock, serological sampling was required in addition to clinical examination. All flocks with positive serology were depopulated as a precautionary measure and samples collected for viral isolation.

In total, 604 flocks (including four flocks which exhibited non-specific clinical symptoms) were tested serologically. Of these, 39 flocks reported one or more positive samples. Virological testing was conducted on these 39 flocks, with all producing negative results.

Initially Danish authorities suspended all export of live poultry (effective July 26, 2002) and hatching eggs (effective Aug. 7, 2002) [7, 11]. These restrictions were sequentially lifted in six regionalization steps, allowing unaffected portions of the country to resume trade as outbreaks were brought under control [7]. Beginning Aug. 19, 2002, restrictions on trade of poultry for slaughter and hatching eggs were lifted from Zealand, Funen and surrounding islands in eastern Denmark. On Aug. 29, 2002, those areas had additional restrictions removed to allow trade of all live poultry (not only that intended for slaughter), and at the same time, all restrictions were removed from North Jutland. All restrictions were lifted in Central Jutland on Sept. 12, 2002. By Nov. 2, 2002, restrictions on all but two surveillance zones, one in North Jutland and the other in West Zealand, were lifted. By January 1, 2003 all restrictions, including those on all surveillance zones, had been lifted. This gradual resumption of Denmark's poultry export market was in compliance with EC regulations regarding the control of Newcastle disease [14]. This

process was completed by March 1, 2003 when Denmark, in accordance with OIE standards, reclaimed its END-free status.

Source of END [2, 7]

In this epidemic, DVFA concluded there were four primary outbreaks – outbreak no. 1 (from which secondary spread occurred), outbreak no. 28 (the first suspect case), outbreak no. 29 (a clinically asymptomatic breeder flock which demonstrated infection during routine serological surveillance), and outbreak no. 127 (a layer flock on an isolated island, which presented with clinical symptoms consistent with END, and later confirmed END positive by serology and virology).

In total, out of the 135 outbreaks, END virus was isolated from three of the infected flocks (outbreak no. 2, 28, and 127). Isolates from outbreak no. 2 and 28 were submitted by DVFA to the EU Reference Laboratory in Weybridge, UK for typing and antigenic characterization. Both isolates were classified as antigenic group C1 viruses and showed identical amino acid sequencing. This finding led DVFA to conclude that only one viral strain was involved in the 2002 epidemic, even though no epidemiological link could be established between the three flocks from which END virus was isolated. This evidence suggests that a common source of infection, such as infected wild birds, may have been involved.

Furthermore, the 2002 virus strain was the same one implicated in Denmark's 1995, 1996 and 1998 outbreaks, as well as the same strain isolated in 2000, 2001, and 2002 from wild birds in Denmark. However, the 2002 strain differed from the C1 isolates previously identified in that DVI found the former to be exceedingly difficult to isolate, growing very slowly. The Weybridge laboratory experienced the same difficulty. The appearance over time of the same END viral strain suggests that a viral reservoir may exist, although it is not clear whether such a reservoir is located within Denmark or elsewhere, perhaps along a wild bird migratory path. The slow growing characteristic of this particular END viral strain complicates early disease detection.

Although sources of infection for these outbreaks were never identified, the epidemiological investigation observed that all four primary infected flocks were located less than 2 km from the coastline, raising the question whether waterfowl could have potentially been an infection source. DVFA collected fecal samples from nearby waterfowl for virological examination. Although two isolates of low-pathogenic Newcastle Disease virus (APMV-1 ND) were recovered from goose droppings in the vicinity of an infected farm, no isolates similar to the APMV-1 ND strains causing the 2002 outbreaks were detected. The result of the investigation to identify waterfowl as a source of infection was inconclusive.

From this evidence, APHIS concludes that there exists a risk of reintroduction of END into Denmark's poultry population. Furthermore, if the same, slow growing strain that caused the 2002 outbreaks is reintroduced, detection may be delayed, increasing the risk

of disease spread within Denmark's poultry population. However, in consideration of the quick and decisive action undertaken by Danish authorities upon suspicion of END during the 2002 outbreaks, the measures implemented in Denmark as a result of lessons learned in 2002, and the high level of awareness and cooperation of Danish poultry keepers, APHIS concludes that, if reintroduced, spread of END in Denmark would be limited.

Surveillance [7-9]

Since 1996, all parent and grandparent poultry flocks were serologically tested once a year for ND, prior to production of hatching eggs. As a result of the 2002 epidemic, Denmark issued a new regulation requiring that all pullets from commercial flocks be serologically tested prior to movement. Serology is also performed on all bird species imported into zoos and pet shops prior to release from quarantine and in cases where there is clinical suspicion of ND.

From July 14 to December 20, 2002, DVI processed 37,794 serological samples related to the epidemiological investigations of outbreaks or suspect cases, screening of contact flocks or flocks within restricted zones, and as part of routine surveillance. In 2002, Denmark did not allow vaccination for ND. Consequently once ND had been confirmed by virus isolation, DVFA relied on positive serology to identify secondary outbreaks.[7]

In 2003, DVI tested 18,566 serological samples for ND. Primarily these samples were collected as part of the ongoing commercial poultry surveillance programs (breeding flock testing and the newly established compulsory testing of pullets). All samples from these two programs in 2003 tested negative. Approximately 500 of the 18,566 samples collected in 2003 were collected as a result of quarantines and clinical suspicions. Private veterinary practitioners or local veterinary authorities raised 8 suspicions based on clinical presentations, and 7 suspicions were raised by DVI due to either laboratory results, findings at autopsy or the history of disease. These 15 suspected cases involved 4 commercial flocks, 10 back yard flocks, and 1 quarantine station for imported birds. Restrictions were imposed on all 15 flocks when suspicions were raised and lifted when the results of either serological or virological testing were found to be negative.

At the time this report was being prepared, DVFA projected that a total of 16,156 serological samples would be tested during 2004. No cases of END in Denmark have been reported since August, 2002.

[7] According to Council Directive 92/66/EEC, ND is confirmed when a APMV-1 virus with a intracerebral pathogenicity index (ICPI) of 0.7 or above is isolated, however, once confirmed, clinical symptom and positive serology can be used to identify secondary outbreaks [14].

Vaccination [8, 9]

As previously mentioned, in 2002 Denmark prohibited vaccination for ND, except for racing pigeons. However, effective October 15, 2004, Denmark changed its policy to initiate a ND vaccination program.[8] This program was developed by DVFA in close contact with the Danish poultry industry which will share in its cost and management.

Under this new policy, ND vaccination is now required for all commercial flocks except for broilers kept inside and slaughtered before they reach 8 weeks of age. A serological test will now be required of all layer and parent stocks at the 23-25 weeks of age to verify that the birds have been vaccinated.

For non-commercial flocks, vaccination will be compulsory only for poultry going to any kind of gathering (e.g. exhibitions, markets, show, etc.). Most backyard flocks will not be vaccinated. Therefore if ND is reintroduced into Denmark, mortality would likely be observed in these flocks.

DVFA acknowledges that there is not a currently available ND vaccine that can elicit a serological response distinguishable from the serological response elicited by exposure to disease-causing ND virus. In other words, a marker vaccine for ND does not exist. Therefore in countries that vaccinate for ND, preliminary confirmation of a suspect ND case cannot be based on serology. Instead, DVFA intends to confirm ND using PCR or virological testing and will suspend the serological surveillance programs. APHIS recognizes these as preferred methods of investigating END in regions where END vaccination is conducted.

Risk factors applicable to Denmark

Occurrence of Outbreaks

The occurrence of END outbreaks in Denmark posed a risk to the United States from export of poultry carcasses, parts or products of poultry carcasses, and eggs (other than hatching eggs) of poultry, game birds or other birds exported to the United States [6]. APHIS implemented a ban to address that risk.

While eradication of disease should mitigate immediate risk from the outbreaks that occurred, reintroduction of diseases is always a concern. The response to the 2002 END outbreaks demonstrates that Danish authorities have adequate control measures in place.

[8] Vaccination for Newcastle Disease (ND) utilizes vaccines made from killed or modified live versions of the lentogenic or mesogenic strains of APMV-1 ND virus [3]. ND vaccination offers protection against milder strains of ND and provides some protection against the highly pathogenic strains mostly by reducing the more serious consequences of the disease. Virus replication and shedding may still occur at a reduced rate [23].

APHIS cites the prompt actions by Danish veterinary authorities, often implementing precautionary measures while laboratory confirmation was pending, and the high level of awareness and the cooperation of poultry keepers, both commercial and backyard flock owners, as contributing to detection in the presence of confounding factors and the success of the eradication campaign. However, if reintroduction is not detected early then disease could spread before control measures would have an effect.

Delay in Detection

Detection of disease was delayed by approximately six weeks. Several factors were cited by DVFA as contributing to the delayed suspicion of END. These factors include concurrent infection with Marek's disease, an unclear initial medical history report, and non-specific clinical presentations. However, once suspicion of END was raised, DVFA acted quickly to implement precautionary control measures.

Laboratory confirmation of END was also delayed due to the slow growth of the virus in the laboratory, thus making virus isolation difficult. Unfortunately this was characteristic of the particular END viral strain implicated as causing these outbreaks. This factor underscores, again, the importance of the decisions by Danish authorities to act immediately upon suspicion of END rather than waiting for laboratory confirmation.

In response to this experience, DVI diagnostic procedures now requires laboratory personnel to contact the sender to obtain sufficient information on the background for the diagnostic request in cases where samples are received without a clear medical history. In addition, most poultry material submitted from any source to DVI is now automatically examined for END. In cases where the laboratory suspects END, DVFA is contacted so that local authorities may go to the farm to perform clinical examinations.

During the 2002 outbreaks, Denmark increased its surveillance level to require serological testing of all commercial flock pullets prior to moving. This requirement was in addition to the required annual serological testing of parent and grandparent flocks for END. The routine serological testing program was responsible for detecting one of the 2002 outbreaks (outbreak no. 29) in a flock which did not exhibit clinical symptoms.

As of October 15, 2004 with the introduction of Denmark's END vaccination program, the serological surveillance program could no longer be relied upon as a means of preliminarily confirming suspect END cases. Instead, a serological test will now be required of all layer and parent stocks at the 23-25 weeks of age to verify that the birds have been vaccinated.

APHIS recognizes that delayed disease detection was a significant factor leading to secondary spread of END during the 2002 outbreaks in Denmark. Movement of birds from a flock, in which a poultry disease other than END was suspected, resulted in secondary disease spread, accounting for 97% of the 2002 outbreaks. APHIS is encouraged that Denmark plans to increase routine END screening of poultry samples submitted to DVI. Routine END testing of poultry laboratory submissions increases the

likelihood of disease detection prior to spread. However considering that Denmark has implemented a vaccination program, PCR or virological testing is needed for both END surveillance and investigation of suspicious cases. APHIS recognizes these as preferred methods of investigating END in regions where END vaccination is conducted. DVFA has indicated its intention to use these diagnostic technologies [9].

Dealer Record-keeping

The extensive END spread during the 2002 outbreaks in Denmark was primarily due to significant internal marketing by poultry dealers of infected pullets from commercial farms to backyard flocks prior to disease detection. Once END was detected and epidemiological investigation began, it was discovered that one of the dealers failed to maintain required records of sales, making it difficult to accurately trace contacts. Fortunately, DVFA was able to overcome this obstacle by using media resources to raise awareness among backyard flock owners and to foster their cooperation in the eradication efforts.

As a result of this experience and to mitigate this risk, Danish authorities strengthened regulations regarding the record-keeping and reporting requirements related to the movement of poultry. The Danish Order no. 43 of 29 January 2004 requires registration of poultry dealers with regional veterinary authorities and specifies the information required to be recorded for all poultry sales [8]. In addition, organizers of live bird markets and gatherings are also required to maintain records of participants and to verify that dealers are registered. Compliance with this order is monitored by the regional veterinary authorities who are required to submit periodic reports to DVFA.

Reintroduction of END

The source of END virus which caused the 2002 outbreaks in Denmark was never identified. However, evidence suggests that infected wild bird populations may be involved.

The virus strain isolated from the 2002 outbreaks was identified as being the same strain connected with Denmark's 1995, 1996 and 1998 outbreaks. It is also the same strain isolated in 2000, 2001, and 2002 from wild birds in Denmark.

During the 2002 epidemiological investigation, it was observed that all four primary infected flocks were located less than 2 km from the coastline, areas where waterfowl normally congregate. It was also observed that while the commercial farm involved in the first suspicion (outbreak no. 28) adhered to strict bio-security standards, these standards were breached due to a malfunctioning ventilator. Although the investigation could not confirm the source of infection, the pattern of disease spread on the farm suggested that the defective ventilator allowed an environmental exposure to occur resulting in that outbreak.

As the only practical mitigation against reintroduction from END-infected wild bird populations, DVFA continues to stress the need for adherence to strict bio-security standards [9].

END is endemic in many countries of Asia, the Middle East, Africa, and Central and South America [19]. As such the potential for END introduction to European countries via the migration of infected wild birds from endemic areas deserves further investigation. However, this potential exists world-wide. It is not unique to either Denmark or the EU, and APHIS is not aware that it is a particular concern in the region. Therefore, APHIS does not consider it a critical issue for this evaluation.

Reintroduction of END into Denmark may also occur through legal trade of poultry or poultry products if imported commodities were infected with END. This is a potential risk because Denmark trades with countries or regions that the United States does not recognize as free of END, including all EU Member States other than Finland, France, Great Britain (England, Scotland, Wales and the Isle of Man), Greece, Luxembourg, Republic of Ireland, Spain, and Sweden.

In keeping with APHIS policy regarding the risk presented by commingling when a country recognized as disease-free supplements its supply with animals or products from regions not recognized as disease-free, as a safeguard APHIS will require certain certifications by the exporting country. Such provisions will be incorporated into the rules addressing specific regions.

APHIS will require certification to ensure that poultry and poultry products from Denmark originate in Denmark or in any other region recognized by APHIS as END-free and that, prior to export to the United States, such poultry and poultry products are not commingled with poultry and poultry products from regions where END exists.

Release Summary

APHIS cites the following factors as relevant to the situation in Denmark:

- DVFA was able to effectively control and eradicate END in its domestic flock, despite the atypical clinical manifestation of the viral strain and the initial delay in detection due to concurrent Marek's disease infection. The effectiveness of the eradication program was mainly due to the prompt actions taken by DVFA and the cooperation of backyard and commercial flock owners.

- From the time of the 2002 outbreaks until implementation of the vaccination program (October 15, 2004), Denmark has conducted an extensive serological surveillance program.

- No new END outbreak has been detected since 2002 after the last END infected flock was depopulated in August 2002.

- As a result of the lessons learned from the 2002 outbreaks, Denmark has strengthened record-keeping and reporting requirements related to trade of live poultry. DVI has increased testing of poultry submissions for END.

- Denmark has implemented a mandatory vaccination policy for commercial flocks and poultry markets.

- Denmark conducts trade of poultry or poultry products with countries or regions that the United States does not recognize as free of END.

Release Assessment Conclusion

With the successful eradication of END following the 2002 outbreaks in Denmark and the subsequent measures implemented in response to those outbreaks, APHIS could identify no additional risk factors currently applicable to Denmark that would justify keeping Denmark from the list of regions APHIS considers as END-free.

Exposure Assessment

This exposure assessment is based in large part on an analysis of historical information regarding END outbreaks in the United States, particularly outbreaks that occurred in 2002 and 2003 in several western States. Earlier outbreaks were also examined to the extent that relevant information was available. In this regard, we consider data reflecting real events occurring during outbreaks in the United States to be the most legitimate model for this exposure assessment. Historical information provides valuable insight into the past and potential pathways of entry, exposure, and mechanisms of disease spread in the United States. This exposure assessment therefore uses such historical information to prioritize potential risk pathways for END introduction and spread.

Pathways of END introduction and spread

Historical information from END outbreaks in the United States is presented here in order to identify the most likely pathways of disease introduction, as well as risk factors influencing the spread of END once introduced. Possibilities for mitigation of identified risk factors are also considered. The historical information is further used to provide a basis for the economic section of the consequence analysis, which is based on the actual costs incurred during at least some of these outbreaks.

Pathways of introduction

The United States has experienced multiple END outbreaks over the last 50 years (Table 3) [24-28]. Of note is the fact that disease was most likely introduced through live birds in all cases except for one incident in 1973 involving hatching eggs from Hungary. Live birds implicated in END outbreaks entered the United States through either legal or illegal channels. Introductions through legal pathways declined substantially after regulations requiring quarantine of imported live birds in facilities operated or approved by APHIS were implemented in 1972, and were essentially eliminated after the requirements for approval of private quarantine facilities were strengthened in 1979.

The most extensive outbreaks involving commercial poultry occurred in 1971-1973 and 2002-2003. END was introduced into the United States in November 1971 via a shipment of Mexican double yellow-headed parrots from South America to a pet bird importer located in the city of Fontana, California. There were no quarantine requirements for imported birds at the time. Some of the infected birds escaped and exposed the dense population of backyard flocks and commercial poultry flocks in the area to the END virus. The outbreaks subsequently spread to involve most of southern California before containment in 1973.

Table 3. History of END introductions into the United States

Date	Place of Outbreaks	Exposure Pathway
1950 (Apr)	Contra Cost County, CA	Chukars and pheasants imported from Hong Kong
1970 (Aug)	Bronx, NY	Quaker parrots from Paraguay
1970 (Aug)	Clint, TX	Domestic chickens
1970 (Sept)	Blackstone, MA	Domestic chickens
1971 (Apr)	Las Cruces, NM; El Paso, TX	Domestic chickens
1971 (Apr)	Largo, FL	Mynah bird from Thailand
1971 (Sept)	Dade County, FL; Sonoma County, CA	Domestic game chickens
1971 (Oct)	Miami, FL	Commercial and game birds
1971 (Nov)	Manchester, CT	Parrot from Paraguay
1971 (Nov)	Fontana, CA	Parrots imported from South America
1971 (Dec)	Puerto Rico	Commercial and game chickens
1972 (Feb)	Chicago, IL	Parrot of unknown origin
1972 (Apr)	Parker, AZ	Game chickens
1972 (Apr)	Atlanta, GA	Parrot from Mexico
1972 (May)	Kingman, AZ	Fancy chickens
1972 (May)	Dade and Broward Counties, FL	Commercial and game chickens
1972 (June)	Los Angeles, CA	Exotic birds from Thailand
1972 (July)	Los Angeles, CA	Exotic birds from Thailand and Columbia
1972 (July)	Denver, CO	Parrot from Mexico
1973 (Jan)	Los Ebanos, TX	Game chickens
1973 (Sept)	Somerset, KY	Hatching eggs from Hungary
1974 (Feb)	El Paso, TX	Domestic and game chickens
1974 (May)	Hidalgo, TX	Domestic chickens
1974 (May)	Bulverde, TX	Parrots from Mexico
1975 (Mar)	Long Island, NY	Pet bird dealer
1975 (June)	Pharr, TX	Domestic chickens
1977 (Feb)	Charlotte Courthouse, VA; San Diego, CA	Pet birds
1977 (July)	Kaneohe, HI	Pet birds
1980	Florida and 22 other States	Pet birds
1991 (April)	Michigan, Indiana, Illinois, Texas	Double yellow-headed Amazon parrots
1992 (Aug)	North Dakota	Migratory cormorants
1998 (May)	Fresno, CA	Game fowl
2002 (Oct)	California, Arizona, Nevada	Game fowl
2003 (April)	El Paso county, Texas	Game fowl

The October 2002 introduction into California game fowl presumably occurred through illegal importation of infected game birds into the United States from Mexico. Phylogenetic analysis indicated that the California END virus was closely related to an END virus isolated in Mexico in early 2000 and was distinct from the strain isolated from a backyard flock in the 1998 California outbreak. The outbreaks in Arizona and Nevada were most likely seeded from the California outbreaks, based on the timeline of detection and the strain of virus isolated. Spread of disease was contained in all States by September 2003.

Although overlapping chronologically, the 2003 outbreak in Texas is thought to have resulted from a separate introduction of END, possibly through unauthorized movement of game fowl. This hypothesis is based on the observation that the type of virus isolated in Texas differed from that found in the other States, although it was similar to a strain isolated previously in Mexico.

In summary, the majority of introductions of END into the United States are thought to have been associated with live birds, although one was apparently associated with hatching eggs. None of the introductions have been known to be associated with other poultry products, such as meat. Historical experience in the United States therefore suggests that importation of live birds represents a far more likely initial exposure pathway than poultry meat or products. With regard to this assessment of the END status of Denmark, the primary interest is importation of poultry meat rather than live birds.

Commodity factors

Commodity factors that are relevant to an exposure assessment include the type and quantity of the commodity to be imported, the intended commodity use, disposition of the products in the region, and waste disposal procedures [21]. The potential amount of poultry meat imported from Denmark is expected to be relatively low.

Although the precise disposition of the imported poultry product is as yet unknown, it is reasonable to assume that it will enter common wholesale channels for distribution to restaurants, retail markets, and other institutions. Usage patterns and waste disposal procedures would be expected to follow common practices in the United States. In this regard, exposure of domestic poultry populations through waste feeding to backyard flocks or other channels cannot be precluded. However, APHIS considers this to be a far less likely exposure pathway than introduction via live birds, based on historical data.

Pathways of spread

Historical accounts of END outbreaks in the United States also provide significant information regarding likely pathways and extent of disease spread after introduction. In this regard, the 1971-1973 and 2002-2003 outbreaks are examined here in greater detail.

As mentioned above, END was introduced into the United States in November 1971 via a shipment of Mexican double yellow-headed parrots from South America, some of which

subsequently escaped and exposed domestic flocks. Once the disease was introduced into commercial poultry, it spread rapidly by various means throughout southern California. The disease threatened not only the California poultry industry but the entire U.S. poultry and egg supply.

The 2002 introduction of END into California is thought to have occurred through illegal importation of game fowl. Outbreaks were initially limited primarily to backyard flocks, which were defined as flocks raised in small numbers on private premises for hobby, exhibition and personal consumption in a predominantly immigrant community [27-29]. The types of birds involved included game fowl, pet birds, ostriches, and waterfowl. However, the END virus ultimately spread from backyard flocks to commercial facilities for laying hens as well.

The disease also spread from California to Arizona and Nevada, most likely through unauthorized movement of infected game fowl. In both States, the primary facilities involved were backyard flocks of game fowl or poultry. No commercial poultry were affected in either State, possibly due to a lack of interaction between backyard flocks and the small number of commercial facilities in the area. Similarly, there was no significant spread as a result of the 2003 outbreak in a backyard flock of game fowl in Texas, and no commercial facilities were affected.

The epidemiological investigations of both the 1971-1973 and the 2002-2003 END outbreaks identified four primary pathways of disease spread: (1) movement of infected birds, (2) movement of infected products (eggs), (3) movement of contaminated equipment, and (4) movement of people. In the 1971-1973 outbreaks, there was strong epidemiological evidence that an organized effort to vaccinate all birds in southern California contributed as much to disease spread as any other factor. This occurred as personnel who were untrained in disease prevention methods traveled rapidly between premises, often carrying the virus with them and exposing other premises in the area.

In the 2002-2003 outbreaks, strict biosecurity measures were implemented so that task force personnel would not act as vectors for disease spread. In addition, vaccination was not a component of the control and eradication plan. Despite extensive outreach and public education efforts, movement of birds and eggs, equipment sharing among farms, and employee contact with off-farm poultry were subsequently identified as significant factors in disease spread. The extent of disease spread was further influenced by proximity of neighboring infected backyard flocks and the presence of a commercial poultry industry in the area. A risk factor influencing the likelihood of exposure in a backyard flock was having game fowl on a premises with a large flock size. Presence of feral chicken on the premises may also have contributed to disease spread.

In summary, historical experience in the United States indicates that, once END is introduced into a live bird population, the most significant pathways of disease spread involve movement of equipment, birds, products, and people. The extent of disease spread depends in large part on biosecurity practices and the density of susceptible

populations. In addition, backyard flocks and non-commercial birds may play an important role in disease introduction and spread.

Risk mitigation measures

Mitigation measures affecting END introduction

As previously discussed, the most likely pathway of END introduction into the United States is through legal or illegal importation of live birds. Several outbreaks prior to 1972 resulted from legal entry of imported pet and game birds. These introductions occurred at a time when the United States had no quarantine requirements in place for birds from END-affected regions, so infected birds were released without a period of observation for clinical signs.

In March 1972, APHIS published a regulation to enhance its import control measures by requiring live birds to be imported under permit through designated ports and subjected to a 30-day quarantine in facilities operated or approved by APHIS (9 CFR 93.106) [5]. The quarantine requirement was further strengthened in 1979 by additional requirements for approval of private quarantine facilities. Of note is that legal introduction by infected birds declined significantly after 1972 and has not been documented since the 1979 quarantine requirement was instituted. Although not confirmed, the 1998 exposure was hypothesized to have resulted from illegal entry of an infected bird.

Except for special provisions for birds from Canada and U.S. returning birds gone for less than 60 days, all live birds must go through a quarantine period when they enter the United States. Birds are kept for a minimum of 30 days in a USDA quarantine facility or a private USDA-approved quarantine facility or home quarantine for U.S.-origin birds gone greater than 60 days. Poultry are brought directly to the quarantine facility in a sealed truck. USDA personnel perform inspections and testing of birds in the private facilities. Cloacal swabs are taken from the birds to test for END and highly-pathogenic avian influenza via virus isolation. If the tests are positive, a re-test is performed. The quarantine period may be extended at the discretion of the USDA management. If the birds test negative, they can be released after the end of the quarantine period. If positive, they may be destroyed. The birds are held for a sufficient period of time that exceeds the incubation period of END. The likelihood that infected birds could remain undetected throughout the quarantine process is very low.

APHIS considers the risk of END introduction through legal importation of live birds to be effectively mitigated by the quarantine measures currently in place in the United States. The risk of illegal importation of live birds would logically be highest where land borders are shared. Illegal importation of live birds from Denmark would be technically difficult because of the travel distance between the two countries and inspection procedures at airports and seaports. APHIS therefore considers the likelihood of illegal introduction of live poultry from Denmark to be low.

Detection of END in Denmark prior to exportation of poultry or poultry products is facilitated by the close interaction between DVFA veterinary authorities and producers, and by the effective census, movement control, and ongoing surveillance programs implemented by DVFA. While END virus can be transmitted in poultry meat, APHIS considers the likelihood that disease would be detected clinically in Denmark prior to arrival of the product in the United States to be relatively high. While most commercial poultry in Denmark will now be routinely vaccinated for END, most backyard birds will not and, therefore, backyard flocks will serve as sentinel animals for detecting END outbreaks in the poultry population.

Mitigation measures affecting END spread

Epidemiological investigations of the U.S. outbreaks have identified several potential and confirmed pathways of disease spread, most notably movement of people, live birds, products, and equipment [27, 28]. However, the U.S. outbreaks varied significantly in the extent of spread. Epidemiological investigations have suggested that the likelihood of spread after END introduction is increased if the following factors are present:

1. A large commercial poultry industry exists in the region.
2. Backyard flock sizes are relatively large.
3. Backyard flocks are commonly present.
4. Feral chickens (or other wildlife that could serve as vectors) exist in the region.
5. Areas of concentration are common and interrelated.
6. Cockfighting is practiced in the region.
7. Reporting of clinical or suspect cases is slow or delayed.
8. Poultry and poultry products can be introduced illegally from affected regions.
9. Biosecurity measures are ineffective.
10. Movement control measures are insufficient.
11. Surveillance is inadequate.

Specific mitigations have been developed in the United States that address some, but not all, of these risk factors. For example, factors 1-5 have not been subjected to direct risk mitigation measures. Specifically, direct measures such as controlled location and size of commercial poultry flocks, prohibition of backyard flocks, eradication/control of feral chickens, and restriction of movement among interrelated areas (e.g., slaughter operations, backyard poultry, live bird markets, high concentrations of commercial poultry) have not been taken.

Rather, mitigation measures have been indirect and have included implementation of biosecurity measures by producers to reduce the probability of contact with infected birds, conduct of public awareness campaigns to facilitate biosecurity and disease reporting, and cleaning and disinfection of vehicles, equipment, and people moving among facilities. Such procedures, which are routine for commercial poultry facilities, are enhanced significantly under outbreak conditions (for examples, see the U.S. END website at http://www.aphis.usda.gov/lpa/issues/enc/exoticnc.html).

In contrast, factors 6-11 have been subjected to direct risk mitigation measures. For example, cockfighting is now banned in most States in the United States. The Animal Welfare Act as modified by the Farm and Security Rural Investment Act of 2002 prohibits, with certain exceptions, sponsorship or exhibition of animal in an animal fighting venture, if the animal was moved in interstate or foreign commerce. APHIS highlighted this law by publication of a Federal Register notice in 2003 (FR vol. 68, no. 91, Monday, May 12, 2003). However, although this may have some risk mitigating effect, it is likely that cockfighting and the associated movement of game birds continues illegally at an unknown level.

Regarding disease reporting, APHIS has maintained the standard practices and requirements in place for reporting suspect cases of disease at the federal level, and taken actions to increase the willingness and awareness of the need to report among the general public. Under outbreak conditions, APHIS cooperates in outreach programs in affected areas to educate the public in order to facilitate disease recognition and reporting, as well as to emphasize appropriate biosecurity measures (for examples, see notices and summaries available at http://www.aphis.usda/gov/lpa/issues/enc/moreinit03.html).

In addition, APHIS plays a major role in implementing movement controls when disease outbreaks occur. Some of these focus on reducing the interaction level in areas of concentration. APHIS also increases its routine surveillance activities during outbreak periods. All of these activities are taken to mitigate the risk of disease spread and represent aspects of the contingency plans APHIS has in place to facilitate allocation of resources to risk areas during outbreak periods.

In summary, epidemiological investigations of past END outbreaks have identified a number of factors that influence the extent of disease spread. Some of these risk factors have been addressed by direct mitigation measures, whereas other factors (such as the existence of a large commercial poultry industry, the presence of backyard flocks, and interrelated areas of concentration with significant amounts of interchange) have only been addressed indirectly. While the events in 2002 and 2003 demonstrate that these risk mitigation activities do not eliminate disease spread once introduction has occurred, it is highly likely that they mitigate the extent of spread.

Exposure summary

Given the results of the release assessment, APHIS considers the likelihood of introduction of END-infected birds and products from Denmark to be extremely low. Historical experience indicates that the likelihood of END introduction is substantially higher for live birds than for other commodities, including poultry meat. APHIS considers that the quarantine requirements currently in place are sufficient to mitigate the risk posed by legal importation of live birds. The likelihood of illegal importation of live birds is quite low based on travel distance and current inspection practices. Furthermore, a change in the END status of Denmark is unlikely to substantially impact the risk of illegal importation of live birds.

Significant direct and indirect mitigation measures are currently in place in the United States to address the risk of END spread should introduction occur. Major pathways of disease spread include movement of people, birds, products, and equipment; however, the extent of spread is influenced by a number of other factors. Based on current conditions, and depending on the local circumstances, substantial disease spread could occur if END were introduced to a concentrated susceptible population.

Consequence Assessment

The *Terrestrial Animal Health Code* recommends that a consequence assessment include an evaluation of the consequences of importing a foreign animal disease with regard to animal and public health, and also consider relevant environmental and economic factors.

Animal health consequences

END is one of the most severe diseases of poultry throughout the world and its consequences in terms of animal health are significant [19]. Morbidity and mortality rates vary according to the strain of virus, but morbidity may approach 100% and mortality may approach 90% in susceptible chickens. Lesions in chickens primarily occur in the brain and respiratory tract. Neurological signs or severe depression are the most common clinical signs. Egg production in infected laying hens drops dramatically, followed within 24-48 hours by high death losses. Ten to fifteen percent of a flock may die within the first 24 hours of an outbreak. The reproductive system of surviving birds may be permanently impaired and egg production may not return to previous levels.

Public health consequences

In contrast to the severe animal health consequences, direct human health consequences of END are minor and END is not considered to be a significant human pathogen [19]. Disease manifestations in humans are limited to conjunctivitis and recovery is usually rapid.

Environmental consequences

Environmental consequences resulting from END introduction occur primarily when there is a need to dispose of large numbers of carcasses due to death from disease or depopulation of flocks. Disposal of large amounts of litter and manure can also be problematic. The environmental consequences in relation to poultry and poultry product imports from Denmark were considered negligible as the proposed action would not result in significant adverse impacts, including no extraordinary circumstances which might affect the significance of any potential impacts and no cumulative impacts with other related projects that might result in significant adverse impacts. This action is excluded under APHIS' National Environmental Policy Act Implementing Procedures [30].

Economic consequences

This assessment of economic consequences is largely based on historical experience in the United States relative to END outbreaks. The economic data from previous outbreaks in the United States provides the most legitimate approximation of consequences of future outbreaks. Although estimates of the costs of foreign animal disease eradication from other countries are available, information from other countries may not be a good model for the United States. This is because other countries have different production practices and approaches to disease eradication and control [31].

The outbreaks that have occurred in the United States for which economic information is available can be categorized as relatively limited or relatively extensive. This section examines in more detail the 1950 outbreaks in California and the 2002-2003 outbreaks in Arizona, Nevada and Texas as examples of relatively limited disease spread, and the 1971-1973 and 2002-2003 outbreaks in California as examples of relatively extensive disease spread. The distinction was made to provide comparative information on economic consequences under conditions of extensive and more limited disease incidence. The discussion of economic consequences of relatively limited outbreaks is restricted to control and eradication costs, whereas the discussion of relatively extensive outbreaks is expanded to include effects on trade and indirect effects on the poultry industry in affected areas.

Relatively limited disease incidence (1950 and 2002-2003 in Arizona, Nevada, Texas)

The 1950 END outbreaks were limited to five poultry farms in Contra Costa County, California. The infection was quickly eliminated through depopulation of the infected chickens. The control and eradication efforts cost approximately $30,000 in 1950, which is equivalent to approximately $229,000 in 2003 [24].

The outbreaks in 2002-2003 in Arizona, Nevada and Texas could each be considered representative of a limited incidence. In this regard, only a single premises was detected in each of the States of Arizona and Texas, and only ten premises were confirmed as infected in Nevada. By September 28, 2003, approximately $3.5 million dollars had been spent toward eradication efforts in Arizona; $6.2 million in Nevada; and $4.2 million in Texas [32].

Relatively extensive disease incidence (1971-1973, 2002-2003)

Control and eradication costs

The introduction of END into southern California between 1971 and 1973 resulted in major occurrence of disease [24]. A reported 1,341 infected flocks were identified and 12 million infected and exposed birds were destroyed. Most of these were laying hens. Eradication activities severely disrupted the operations of many producers and increased the prices of poultry and poultry products to consumers.

The eradication effort was coordinated through a State-Federal Newcastle Disease Task Force. Eradication efforts, which continued throughout 1972 and into 1973, cost approximately $56 million [24-26]. This amount is equivalent to approximately $232 million in 2003. A total of 3,102 personnel participated in the task force between March 14, 1972, and June 30, 1974. An additional 74 individuals participated as "miscellaneous personnel."

Eradication efforts for the 2002-2003 END outbreaks in California, Arizona, Nevada and Texas were also labor intensive and expensive. Spread within the state of California was the most extensive among the four states affected. Ultimately, birds from 920 premises in California tested positive for the disease, and nearly 4 million birds were depopulated in California alone. As of October 28, 2003, approximately $168 million dollars had been spent on the eradication efforts in all four states [32]. The cost estimates in this sum included expenses for long-term goals and measures such as (1) surveillance and diagnosis; (2) euthanasia, carcass disposal, cleaning and disinfection; (3) administrative and logistical costs; (4) compensation or indemnification; and (5) personnel costs. Personnel were recruited from various federal, state, county, and metropolitan agencies to participate in the effort. Approximately 2,780 personnel contributed from the federal sector alone.

Effects of the 2002-2003 END outbreaks on trade

The effects of an extensive END incidence on U.S. trade can be characterized using information from the 2002-2003 outbreaks. Immediately following the confirmation of END in the United States in 2002, trading partners imposed trade restrictions on poultry products that were perceived as posing a risk of exporting END from the United States. Live birds, fresh, frozen or chilled poultry meat, and hatching eggs from the United States were commonly banned. At the peak of the incident, 46 countries had imposed restrictions [31].

Direct trade impacts of END were calculated for the period between October 2002 and September 2003 for five categories of product: live poultry, ducks and geese, poultry meat and offal, hatching eggs, and table eggs [31]. The total estimated value of all poultry restrictions over the roughly 12 months of the END eradication period was $121 million, or 7% of the trade recorded during that period.

This relatively low percent reduction in trade probably reflects the effects of a regionalization approach taken by most countries for imposing restrictions, in which live birds and products were only banned from areas adjacent to affected areas and/or affected areas alone. The effect of regionalization was most likely to reduce the trade consequences at the national level. However, the economic impact at the local level was significant in terms of trade dollars. The effects of trade restrictions on individual involved States were estimated from February 7, 2003, through September 17, 2003, as follows [31]:

State	$ million
California	34.18
Arizona	2.01
Colorado (unaffected but adjacent to an affected State)	0.69
New Mexico	0.02
Texas	57.12

These estimates do not account for trade shifting or the movement of production within the United States to avoid export restrictions. In this regard, companies operating in multiple States could have shifted production or processing to States on which there were no restrictions. Products that were restricted from one export country could also have been shifted to alternate export markets or sold at new outlets within the United States. It is possible that the true impact of the trade restrictions is significantly less than the calculated values presented [31].

Larger scale restrictions logically have greater economic consequences. For example, in 2001, which was the last full year before END trade restrictions were imposed, total poultry and poultry product exports were $2.38 billion. In 2002, that total fell to $1.84 billion, an actual decrease of 22%. This decrease was attributed to significant restrictions on poultry exports imposed by Japan and Russia because of avian influenza (AI) controls. Both of these countries restricted exports of poultry and poultry products from the entire United States. In comparison, END restrictions were regionalized to the involved States (and in some cases, contact States like Colorado), so the total impact was relatively minor compared to the AI restrictions.

While the 22% decrease was not necessarily attributable to the END outbreaks, it was caused by restrictions placed because of a disease in poultry and therefore represents a potential outcome of extensive disease spread. Consequently, this value can also be viewed as a maximized consequence estimate with regard to END.

Indirect effects of the 2002-2003 END outbreaks on the poultry industry

Since END does not have a significant human health impact and consumers do not raise a significant concern about consuming products from the quarantine zone, the losses from trade restrictions are generally the most significant cost to the U.S. poultry and allied industries. Within southern California in the 2002-2003 outbreaks, the cost to the commercial poultry industry was mitigated by indemnity payments for depopulated birds, equipment and inputs. These costs were reflected in the previously reported eradication and control costs to the federal government.

However, the federal government did not indemnify losses to the allied industries that supported poultry production in the area. Affected allied industries included feed mills, egg retailers, replacement hen producers, manure haulers, farmers who used manure for fertilizer, and the trucking concerns that moved feed, manure and eggs in the area.

Potential indirect losses to some of the allied industries in southern California were estimated [31]. The information was gathered from various resources including epidemiological survey information, information gathered from industry experts, and estimates of inputs and outputs for the production of table eggs in southern California. Some of the estimates provide examples of the types of indirect consequences that occur during outbreaks and are described below.

Table eggs

Approximately 52 million table eggs, which normally would have been sold into the local southern California retail market place, were not available because of depopulations. Based on the January-April 2003 average unprocessed table egg price, the value of the 52 million eggs that did not enter the supply chain was $27 million [31].

Feed impact

During the course of cleaning and disinfection of premises inside the quarantine zone in California, some feed was destroyed because it could not be disinfected and remain safe for feeding. Feed destroyed was valued at $340,000 [31].

The average amount of feed that would have been needed to produce a dozen table eggs by each of the 52 million depopulated hens was estimated as approximately 3.7 lbs. Using the number of eggs not produced (as estimated previously), the amount of lost feed sales in southern California resulting from the outbreaks was approximately 4.9 million pounds. The reduced feed demand resulted in a lost value of feed sales of $17 million [31].

Labor wage impacts

Total labor wages were estimated separately for modern facilities in which eggs were collected on conveyer belts and those in which eggs were collected by hand. The analysis of labor wages lost reflected only those associated with the 3 million hens depopulated that could be matched with egg gathering method. Total wages lost for the automatic hen houses were $6500, and total wages lost for the hand-gathered hen flocks were $3.5 million. These values reflect wages lost from the day of depopulation until July 3, 2003 [31].

Consequence summary

This consequence assessment provides general information regarding the type and magnitude of the effects of END introduction into the United States from an historical perspective. The major consequences of the END outbreaks concerned animal health and economic costs of control, indemnity, and lost trade. The consequences of a poultry disease outbreak in a State with a small commercial poultry industry are likely to be relatively minor. However, the economic and animal health consequences of a disease outbreak in a State with a large concentration of poultry are likely to be substantial.

Risk Estimation

APHIS concludes from its release assessment that the eradication and control measures undertaken by Denmark in response to the 2002 outbreaks were effective and that additional risk factors were not identified. Therefore APHIS considers the risk of introducing END into the United States with the resumption of import of poultry carcasses, parts or products of poultry carcasses, and eggs (other than hatching eggs) of poultry, game birds or other birds from Denmark to be low.

According to OIE guidelines, if the release assessment indicates that there is no significant risk of introduction, the risk assessment may conclude. However, APHIS continued its analysis in the interest of completeness and conducted exposure and consequence assessments based on information available on the history and economic effects of past END introductions into the United States.

Regarding the likelihood of exposure, historical experience indicates that the risk of introducing END via importation of live birds is considerably higher than via poultry products. Legal entry of live birds is satisfactorily controlled through existing quarantine measures in the United States and is not currently prohibited under the current import ban of poultry product from Denmark. Likewise, resumption of poultry product trade with Denmark would not likely impact illegal bird movement from Denmark. Poultry product imports historically have not been implicated in END introductions into the United States. Therefore, taken together with the low risk assessed by the release assessment, APHIS considers the likelihood of exposure from poultry imports from Denmark to be low.

APHIS continued its assessment further and conducted a consequence assessment that addressed the potential effects of an END outbreak on animal and public health, as well as associated environmental and economic considerations. Consequences of human exposure from END are low. While consequences on poultry health are high, effective disease surveillance and control measures should reduce the consequences by reducing the extent of spread. Consequences to the environment should be within the scope of APHIS resources and authority to manage adequately.

The economic portion of the consequence assessment was based on available information regarding the economic consequences of END introductions into the United States since 1950. This assessment, while demonstrating that the consequences can be significant under certain conditions, also demonstrated that an END introduction does not necessarily result in extensive consequences. If the disease is diagnosed prior to extensive spread, appropriate biosecurity measures are implemented, and the public is educated to look for clinical signs, the consequences can be minimized. Furthermore, because of the outbreak in the western United States in 2002-2003, APHIS has enhanced its END surveillance program in such a way as to increase the likelihood of future detection prior to spread.

In summary, APHIS concludes that the risk of introducing END into the United States with the resumption of trade in poultry carcasses, parts or products of poultry carcasses, and eggs (other than hatching eggs) of poultry, game birds or other birds from Denmark is low. Although consequences of an END outbreak are potentially substantial, the likelihood of an outbreak occurring from exposure of the domestic poultry population to poultry products imported from Denmark is low.

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APPENDIX

CHARACTERISTICS OF NEWCASTLE DISEASE VIRUS

(Used by permission from the Canadian Food Inspection Agency)

Newcastle disease (ND) is an infectious, highly contagious and pathogenic viral disease which affects chickens, turkeys and many other domestic and wild bird species. Occasionally humans are affected. ND virus (NDV) is an enveloped RNA virus, a member of the *Paramixoviridae* family, *Paramyxovirinae* subfamily and *Rubulavirus* genus (Alexander 1997). Exotic Newcastle Disease is the velogenic form of the disease, and the virus is of the serotype PMV-1.

Clinical Disease

Newcastle disease manifests a great variability in signs depending on viral strain, host, age and environment.

Viscerotropic velogenic: highly pathogenic with hemorrhagic enteritis

- VVND is the most severe form, with morbidity approaching 100% and mortality of up to 100% in chickens.
- In chickens signs may consist of a fall in egg production, listlessness, increased respiration depression, diarrhea, prostration, edema of the head and wattles, nervous signs such as muscular tremors, paralysis and torticollis, and respiratory signs (Alexander 1997).
- The younger the chicken the more severe the signs including sudden death (McFerran and McCracken 1988).
- Signs are generally less severe in turkeys (Alexander 1997).
- Some species (e.g., finches, canaries) may not show clinical signs (USAHA 1992).

Neurotropic velogenic: high mortality, respiratory and nervous signs

- Neurotropic velogenic form (NVND) has been reported mainly from the USA with dramatic drops in egg production, up to 100% morbidity, nervous signs of tremors, torticollis, opisthotonos and paralysis of the legs and occasionally the wings; mortality of up to 50% in older birds and up to 90% in younger birds (Alexander 1997).

Mesogenic: respiratory and occasional nervous signs but low mortality.

Lentogenic: mild or subclinical respiratory signs.

Asymptomatic: subclinical enteric infection (Alexander 1990).

Incubation Period

- The incubation period of ND after natural exposure has been reported to vary from 2 to 15 days (average of 5-6 days) (Alexander 1997).
- Incubation in natural infections is 4-6 days (Fenner 1993).
- Neurotropic velogenic Newcastle disease (NVND) virus isolated from racing pigeons in Sweden caused high mortality and a incubation period of 5-11 days in chickens (Engstrom 1985).
- The mean death time for inoculated pigeons was 9.5 days (range 4-25) and virus was shed for up to 20 days (Pearson 1987).

Pathogenesis

In chickens, the virus enters the body via the respiratory and the intestinal tract. Particles greater than 5 microns are caught in the conjunctivae, nose and trachea down to the bifurcation. In the trachea the virus is spread by ciliary action and by cell-to-cell infection. Highest titers are found for 24-96 hours post-infection in the turbinates; titers decrease thereafter, most likely by antibody formation from day 5, but virus is still present by day 12. Virulent virus can be found within 22-44 hours in practically all tissues, with highest titers in the thymus and lowest in muscles and brain. After initial multiplication at the introduction site, virulent virus is carried by viremia to spleen, liver, kidney and lung. There multiplication is usually interrupted for 12-24 hours, from the 36th hour post-infection and virus titers drop. Virus invades the brain after multiplication in non-nervous tissue has ceased (from 60 hours post-infection) whereupon birds start dying. During the second multiplication following the arrest period, virus is once again released into the blood stream (Kouwenhoven 1993).

A persistent carrier state has been demonstrated in psittacine and certain other wild birds for more than a year, while virus can be recovered from most other species for a shorter period of usually 2-4 weeks or less, until antibody is developed (Alexander 1991). Susceptible turkey poults that survived experimental infection with a viscerotropic velogenic strain of NDV shed the virus from the intestinal tract for up to 46 days. NDV was recovered up to 53 days postchallenge from the cloaca of turkey poults that were vaccinated once at 4 days of age and challenged at 1 month of age. Persistent infection was detected as long as 88 days postchallenge in organ cultures of cecal tonsil (Gillette and others 1975).

Fowls of 7 to 20 weeks of age were divided into 3 groups according to their antibody status (high, low, absent) and were infected with a velogenic viscerotropic Newcastle disease virus. To follow patterns of viral replication, birds were killed at regular intervals up to 22 days later and organs were sampled from each bird. In non-immune birds, virus could be isolated from all organs examined. In birds with antibody, virus was isolated most frequently from the proventriculus, cecal tonsil, bursa, and brain. In immune birds,

although clinical signs were either mild or absent, widespread virus replication occurred up to 19 days after challenge (Pared and Yound 1990).

Host Range

- Natural or experimental infection with NDV has been demonstrated in at least 236 species from 27 of the 50 orders of birds (Alexander 1997).
- Chickens, turkeys, pigeons, guinea fowl, peacock, pheasants, quail, partridges (Kouwenhoven 1993).
- Geese and ducks are usually regarded as resistant even to NDV strains most virulent for chickens (Alexander 1997).
- Ostriches can become infected (Samberg and others 1988; Huchzermeyer and Gerdes 1993).
- Wild birds represent a potentially important but unknown reservoir.
- Although people may become infected with velogenic viscerotropic Newcastle disease (VVND) virus, the resulting disease is usually limited to conjunctivitis. Recovery is usually rapid and the virus no longer present in eye fluids after 4 to 7 days; infections have occurred mostly in laboratory workers and vaccinating crews; no instance of transmission to humans through handling or consumption of poultry products is known (Alexander 1991).
- 1971-1973 California outbreak involved 391 flocks (86% chickens, 6% exotic birds, 3% pigeons, 2% game birds, 2% turkeys, 1% ducks and geese (Burridge 1975).
- An added complication in the epidemiology of VVND was experienced in outbreaks in Great Britain during 1984 when virulence of the virus from pigeons increased with respect to chickens, only after passage through chickens (Alexander 1985).

Global Distribution

- ND has been reported world wide: Europe, Asia, Americas, Africa, Japan, Australia
- In most countries with developed poultry industries, lentogenic and some mesogenic forms are common, the velogenic forms (viscerotropic (VVND) or neurotropic (NVND)) are less common.
- Alexander (1997) considered three panzootics of ND: 1) slow, worldwide spread from Southeast Asia to Europe in poultry from 1926 to the 1960s, 2) rapid spread from the Middle East to worldwide in the late 1960s to 1973, believed to have originated from imported caged psittacine birds which continued to be an important factor in the spread of the disease, and 3) rapid spread from the Middle East in the late 1970s to the early 1980s, originating from pigeons and doves, including the spread to chickens in Great Britain in 1984 through feed that had been contaminated by infected pigeons.

Examples of specific outbreaks of VND include:

- Confirmed in backyard poultry in southern California in October 2002 and in commercial poultry in December 2002; later identified in Nevada and Arizona in January and February 2003, respectively; in April 2003, the disease was also diagnosed in Texas (USDA News Release, Aug. 4, 2003).
- Poultry in California 1971-1973, of which the source of infection was considered to have been illegally imported exotic birds (Burridge and others 1975).
- Poultry in England 1970-1072 and 1984 (Alexander and others 1984).
- Imported cockatoos and love birds appear to have been a source of VVND in Japan in 1980 (Hirai 1981).
- Exotic pet birds in five American states April-July 1991; eradicated without spread to domestic poultry; source: Amazon parrots suspected of being illegally imported into Texas (Brunning-Fann and others 1992).
- EU countries 1986-1990, 85 outbreaks, 75 in Italy including 45 in 1988, and trend of increasing EU numbers from 18 in 1991, to 83 in 1992, to 134 in 1993; about 40% of these EU outbreaks have been in hobby birds (Alexander 1995).
- Recently in Canada outbreaks of ND in wild cormorants, pelicans, gulls and terns have occurred in 1990 and 1992, with isolation of velogenic virus and neurologic clinical signs in wild birds, but no evidence of transmission to commercial poultry (Wobeser and others 1993, OIE 1990; 1992).
- VND was confirmed in a range flock of 26,000 turkeys in North Dakota in 1992, demonstrating neurological symptoms and located approximately three miles from where a “die-off” of cormorants had occurred (Grow 1992, Meteyer and others 1997).

Modes of Transmission

Transmission occurs by direct contact via ingestion of infective material or inhalation of excreted droplet particles; the success of the inhalation route of transmission will depend on many environmental factors such as temperature, humidity, and stocking density (Alexander 1995). Vertical transmission is controversial; its true significance is not clear. Transovarial transmission may be important especially with lentogenic strains, and virus infected chicks may hatch from virus-containing eggs, cracked or broken eggs, or eggs contaminated with feces can be a source of virus for newly-hatched chicks (Alexander 1997).

Spread

- Inapparently-infected carriers are the most likely source for introduction of VVND into ND free countries, including numerous species of exotic pet, game and exposition birds, racing pigeons, waterfowl and domestic poultry (Alexander 1995).

- Many species of caged birds harbor VVND without showing clinical signs, so the smuggling of captive birds poses a hazard (Alexander 1988).
- Wild cormorants may have been the source of infection for an outbreak of velogenic ND among range turkeys in North Dakota 1992 (Grow 1992), however, NDV isolates from migratory birds are usually of low virulence (Alexander 1995).
- The 1971-73 California outbreak experienced extensive spread between flocks by movement of live birds and mechanical transport of virus by vaccination and service crews on clothes and equipment; there was no evidence of significant wind-borne spread in that outbreak (Burridge and others 1975).
- 19 of 23 outbreaks in Great Britain between February and July 1984 occurred directly or indirectly as a result of spread from diseased pigeons infecting feed stores at port docks (Alexander 1985); the preparation of food for layer and broiler-breeder flocks involved no process which would adversely affect virus infectivity (Alexander 1985).
- Outbreaks in Great Britain in the early 1970's indicated windborne spread of up to 8 km; but other outbreaks (e.g., California 1971, England 1984) appeared not to involve windborne spread (Alexander 1991).

pH stability

The pH range of stability is broad. NDV tolerates pH 2 to 10 (Beard and Hanson 1984). The infectivity of the virus is not appreciably modified between pH 4 and 11. It loses some of its infectivity at pH 3 and almost all at pH 1 and pH 13 (Commission des Communautés européennes 1975).

Thermal stability

Thermal stability depends on the strain but all activity is destroyed at 100 degrees Celsius for one minute. At 56 degrees Celsius destruction of infectivity, hemagglutinating activity and immunogenicity occur within 5 minutes to 6 hours. At 37 degrees Celsius, hours and days may be required, and at lower temperatures (20 and 8 degrees Celsius) the virus can be stable for months and years (Beard and Hanson 1984).

In trials in which the survival of 4 NDV virus strains at differing times and temperatures was assessed it was found that: At 70C the virus was inactivated within 40 to 50 sec.; at 60 degrees Celsius, within 6 to 7 minutes; at 37.5, within 8 to 11 days; at 22 degrees Celsius, within 25 to 42 days. The authors concluded that all strains, whether virulent or avirulent, showed no difference in viability (Foster and Thompson 1957).

Ultraviolet ray sensitivity

Ultraviolet rays destroy NDV similarly to other myxoviruses (Beard and Hanson 1984). The virus is inactivated in 35-45 minutes by a wavelength of 2537 A (254 nm) and in 0.8-

1.08 seconds by a wavelength of 1600-1800 A (160-180 nm) (Brandly and others 1946). The sun emits a wide variety of electromagnetic radiation, including infrared, visible, ultraviolet A (UVA: 320 to 400 nm), ultraviolet B (UVB: 290 to 320 nm), and ultraviolet C (UVC: 10 to 290 nm). The only UVR wavelengths that reach the Earth's surface are UVA and UVB. UVA is the predominant ultraviolet light reaching the Earth's surface (tenfold to one hundred fold more than UVB) (National Institutes of Health 1989).

Environmental stability

Stability of the virus in the environment depends on the medium in which it is present: carcasses, feces, mucus, decaying materials, proteinaceous matter. Warm temperatures and solar radiation facilitate destruction of NDV (Alexander 1980). Infectious virus may survive for months at room temperature in eggs laid by infected hens, and for over a year at 4 degrees Celsius. Similar survival times have been observed for virus on feathers, and virus may remain infectious for long periods in contaminated premises (Fenner et al. 1987). In an examination of the ability of NDV to survive in fermented edible waste material, it was found the NDV survived the entire test period at temperatures of 5 to 30 C (Wooley et al 1981; Beard and Hanson 1984). In a further study of the antimicrobial effects of *Lactobacillus* fermentation survival of NDV in infected chicken carcasses was examined in waste material. In two trials NDV survived 4 days at 20 C, 2 days at 30 C and 1 day at 40 C (Shotts et al 1984).

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